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Riparian and Groundwater-Dependent Ecosystems of the Dixie and Fishlake National Forests: An Assessment of Resources and Current Conditions

D. Max Smith
Katelyn P. Driscoll
Steven D. Warren
Deborah M. Finch







Forest Service

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Abstract

This assessment provides information on the current conditions of riparian and groundwater-dependent ecosystems on the Dixie and Fishlake National Forests. We summarized dominant riparian community types and described riparian fish and wildlife habitat. We used peer-reviewed literature, data from the Forests and other partners, and site visits to inventory and map the distribution of riparian and groundwater-dependent ecosystems, as well as to evaluate the status of four key ecosystem characteristics: (1) surface water and groundwater fluctuations, (2) water quality, (3) channel and floodplain dynamics including the condition of spring runout channels, and (4) composition and structure of riparian and groundwater-dependent ecosystems. We determined that roads, recreation, livestock use, and climate change were primary stressors to riparian and groundwater-dependent ecosystems on the Forests. The relative pressure of these stressors, as well as resistance and resilience of riparian and groundwater-dependent ecosystems, differ across geographic units. Anthropogenic activities have especially impacted the limited riparian ecosystems in the low-elevation, arid Canyon Mountains. Alternatively, riparian and groundwater-dependent ecosystems located at higher elevations with abundant surface water appear more resilient to stressors and generally displayed greater ecological integrity. Our results support the ecosystem assessment completed during the forest plan revision process and can help inform decisionmaking related to restoration and maintenance of riparian and groundwater-dependent ecosystems on the Dixie and Fishlake National Forests.

Keywords: forest plan, key ecosystem characteristic, riparian vegetation, flow regime, channel morphology, floodplain, natural range of variation

Cover photos

Clockwise from the left: Cottonwood-dominated riparian community along City Creek in the Tushar Mountains, Fishlake National Forest. Photo by D. Max Smith, USDA Forest Service. Sedge-dominated riparian community on the Markagunt Plateau, Dixie National Forest. Photo by D. Max Smith. Willow-dominated riparian community along Sand Creek near the Thousand Lake Plateau, Fishlake National Forest. Photo by D. Max Smith.

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Authors

D. Max Smith is a Research Associate with the Rocky Mountain Research Station at the Forestry Science Laboratory in Albuquerque, New Mexico. He completed a B.S. degree in Wildlife Biology at the University of Montana and an M.S. degree in Zoology at the University of Oklahoma.

Katelyn P. Driscoll is a Research Ecologist with the Rocky Mountain Research Station at the Forestry Science Laboratory in Albuquerque, New Mexico. She completed a B.S. degree in Biology and minor in Spanish at Gonzaga University and an M.S. degree in Systems Ecology at the University of Montana.

Steven D. Warren is a Research Ecologist with the Rocky Mountain Research Station at the Shrub Sciences Laboratory in Provo, Utah. He completed a B.S. degree in Botany and Range Science, an M.S. degree in Wildlife and Range Resources at Brigham Young University, and a Ph.D. in Watershed Management at Texas A&M University.

Deborah M. Finch is a Biological Scientist and Program Manager with the Rocky Mountain Research Station at the Forestry Science Laboratory in Albuquerque, New Mexico. She completed a B.S. degree in Wildlife Management at Humboldt State University, an M.S. degree in Zoology at Arizona State University, and a Ph.D. in Zoology and Physiology at the University of Wyoming.

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List of Acronyms

ATV	All-Terrain Vehicle
CNHP	Colorado Natural History Program
DNF	Dixie National Forest
EF	East Fork
FNF	Fishlake National Forest
KEC	Key Ecosystem Characteristic
GDE	Groundwater-dependent ecosystem
GIS	Geographic Information System
NF	North Fork
NHD	National Hydrography Dataset
NRV	Natural Range of Variation
NWI	National Wetlands Inventory
PFC	Proper Functioning Condition
PNC	Potential Natural Community
R-CAT	Riparian Condition Assessment Tool
SF	South Fork
TCA	Terrestrial Condition Assessment
UDEQ	Utah Department of Environmental Quality
UDWR	Utah Division of Wildlife Resources
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VCMQ	Vegetation Classification, Mapping, and Quantitative Inventory
WCF	Watershed Condition Framework
WF	West Fork
WRU	Water Rights & Uses

Introduction

Background and Objectives

We completed an assessment of riparian, wetland, and groundwater-dependent ecosystems (GDEs) in partial fulfillment of an agreement between the Forest Service, U.S. Department of Agriculture Intermountain Region and the Rocky Mountain Research Station. Our aim was to provide support during the process of revising National Forest management plans under the 2012 Planning Rule (36 CFR Part 219). Our methods were designed to meet planning rule requirements for a rapid assessment of ecological integrity—"the quality or condition of an ecosystem when its dominant ecological characteristics occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence"—while only using information and data relevant to the plan area that already exists (appendix A). As specified in the planning rule, we addressed structure, function, composition, and connectivity of terrestrial and aquatic ecosystems, as well as drivers and stressors. The planning rule uses an "all-lands approach" because study systems cross administrative boundaries. Additionally, it requires consideration of how actions by the Forest impact resources beyond the boundary and how conditions outside the National Forest influence resources within the boundary.

We prepared the assessment to assist the Dixie (DNF) and Fishlake (FNF) National Forests in understanding ecological conditions under the current plan and identify needs-for-change to be addressed by the revised forest plan. The assessment includes descriptions of dynamics and distributions of riparian ecosystems and GDEs, identification of anthropogenic influences, and analysis of ecosystem structure, composition, and processes.

Scale of Assessment and Study Area

We completed our assessment of riparian ecosystems and GDEs at two spatial scales: the DNF and FNF (fig. 1a) and 11 geographic units within the two Forests: Boulder Mountain, Canyon Mountains, Escalante, Fishlake–Thousand Lake, Markagunt Plateau, Monroe Mountain, Paunsaugunt–Mt. Dutton, Pavant Range, Pine Valley, Tushar Mountains, and White Mountain (fig. 1b). We selected and named these geographic units, which align well with ranger districts and geological features, while meeting with National Forest staff in 2018. In this study, we evaluated key ecosystem characteristics (KECs) at the scale of the geographic units and summarized results for each Forest.

The 1.9 million-acre DNF is located in southern Utah and the FNF covers 1.5 million acres in south-central Utah. Ten ecoregions are present across the two Forests (fig. 2). These areas summarize ecosystems with different geologies, landforms, soils, vegetation, climate, land use, wildlife,

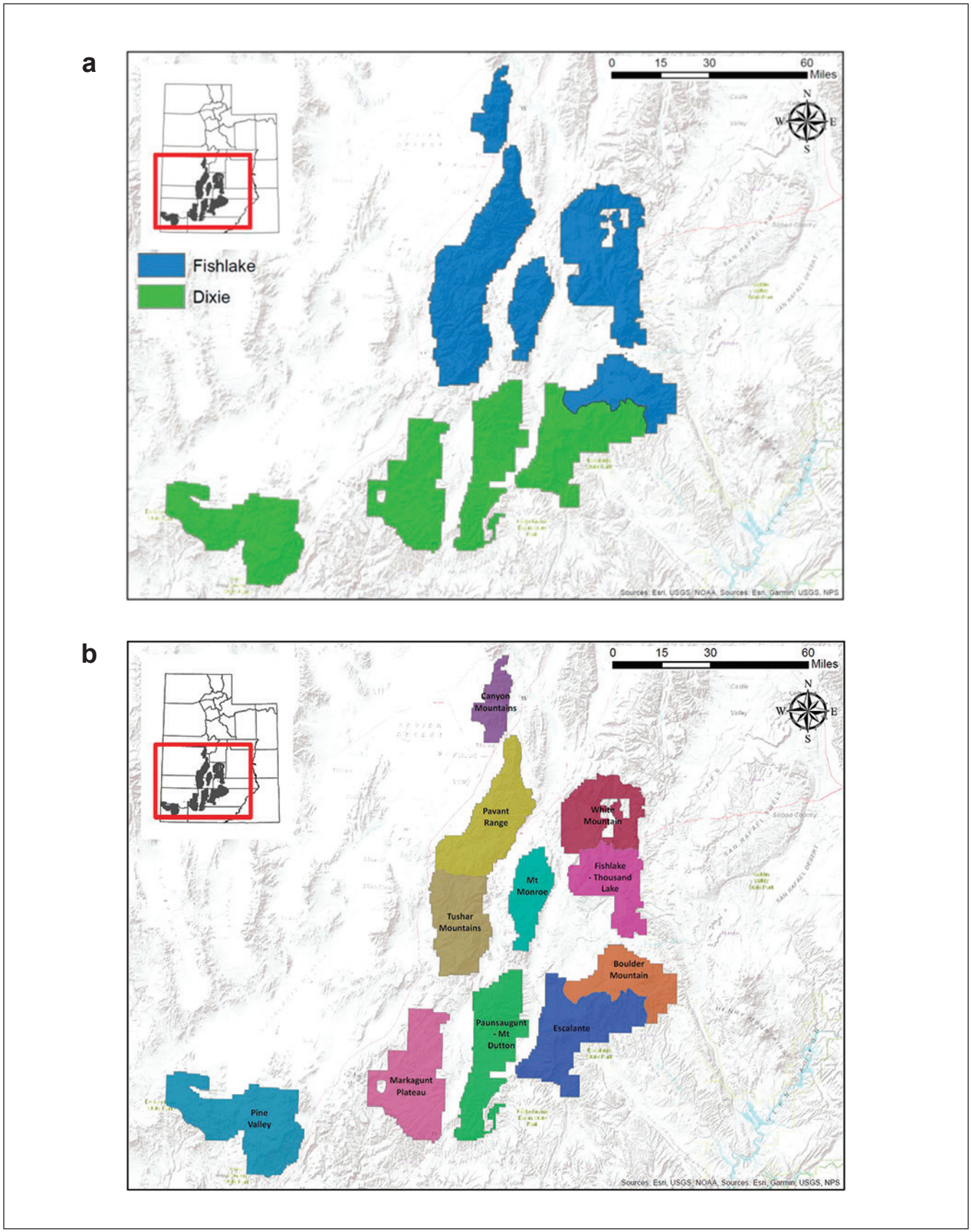


Figure 1—This assessment of riparian and groundwater-dependent ecosystems was completed at two spatial scales: (a) the Dixie and Fishlake National Forests and (b) 11 geographic units.

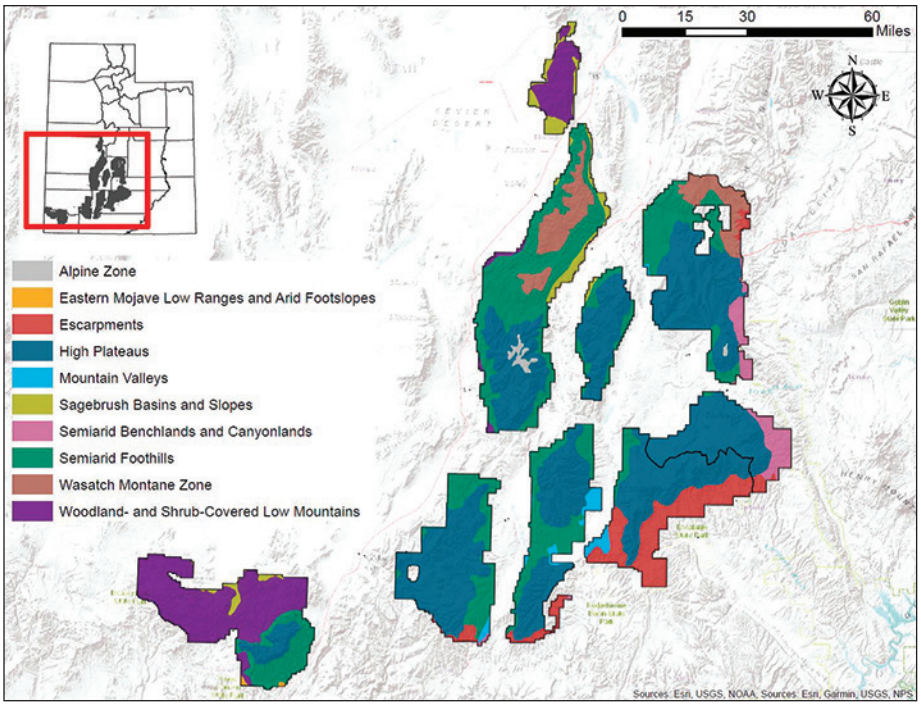


Figure 2—Level IV ecoregions present on the Dixie and Fishlake National Forests.

and hydrology, which ultimately influence the quality and integrity of both terrestrial and aquatic ecosystems (Omernik 1987). The largest ecoregion present in the assessment area is the High Plateaus, which cover 44 percent of the combined DNF and FNF (fig. 2). The High Plateaus are characterized by forests of Douglas-fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), white fir (*Abies concolor*), and limber pine (*Pinus flexis*) at elevations between 8,000 and 11,000 feet (fig. 3; Woods et al. 2001). Some of the High Plateaus were partially glaciated, leaving a legacy of colluvium, alluvium, glacial drift, and basalt geologies. The temperature regime is classified as cryic, with long cold



Figure 3—The Aquarius Plateau, part of the Boulder Mountain and Escalante geographic units, is the tallest of the High Plateaus, with a summit exceeding 11,300 feet. Photo by D. Max Smith, Forest Service.

winters common. Mean annual precipitation is highly variable, ranging from 16 to over 40 inches, with much captured in a deep winter snowpack (Woods et al. 2001). The High Plateaus provide wildlife habitat and forage for grazing, with seasonal heavy grazing occurring in high meadows, and logging occurring outside protected areas (Woods et al. 2001). This ecoregion is prevalent in the Escalante, Paunsaugunt–Mt. Dutton, Markagunt, Fishlake–Thousand Lake, Tushar Mountains, Boulder Mountain, and Monroe Mountain units (table 1).

The next largest ecoregion in the assessment area is the Semiarid Foothills, which cover 25 percent of the combined DNF and FNF (fig. 4). This system was also partially glaciated. Consequently, the geology includes colluvium, alluvium, and glacial drift with frequent outcrops of bedrock (Woods et al. 2001). The Semiarid Foothills occur between 5,000 and 8,000 feet in elevation and are characterized by gambel oak (*Quercus gambelii*), maples (*Acer* spp.), juniper (*Juniperus* spp.), sagebrush (*Artemisia* spp.), pinyon (*Pinus edulis*), serviceberry (*Amelanchier alinfolia*), mountain mahogany (*Cercocarpus ledifolius*), snowberry (*Symphoricarpos* spp.), and associated grasses. These areas experience long, cold winters with mesic and frigid temperature regimes and 12 to 16 inches of mean annual precipitation (Woods et al. 2001). Some perennial streams exist within the Semiarid Foothills ecoregion, but they tend to originate at higher elevations. This system provides wildlife habitat, forage for grazing, recreational opportunities, and water supply (Woods et al. 2001). The majority of the Pavant Range is classified as Semiarid Foothills, with large amounts of this ecoregion present in the White Mountain, Paunsaugant–Mt. Dutton and Tushar Mountain units as well (table 1).



Figure 4—The northern end of the Pavant Range contains the Semiarid Foothills ecoregion at lower elevations and the Wasatch Montane Zone ecoregion at the upper elevations. Photo by D. Max Smith, Forest Service.

Table 1—Percentages of level IV ecoregion represented within 11 geographic units of the Dixie and Fishlake National Forests.

Geological unit	Forest	Total acres	Alpine	Eastern Mojave low ranges and arid footslopes	Escarpments	High plateaus	Mountain valleys	Sagebrush basins and slopes	Semiarid benchlands and canyonlands	Semiarid foothills	Wasatch montane zone	Woodland and shrub-covered low mountains
Escalante	Dixie	436,680	--	--	41	51	3	--	--	5	--	--
Markagunt Plateau	Dixie	404,293	--	--	3	68	1	< 1	< 1	27	--	--
Paunsaugunt–Mt. Dutton	Dixie	388,704	--	--	5	55	6	--	< 1	33	--	--
Pine Valley	Dixie	481,135	--	1	--	9	--	3	--	20	--	68
Boulder Mountain	Fishlake	253,752	--	--	4	76	--	--	19	1	--	--
Canyon Mountains	Fishlake	119,909	--	--	--	--	--	27	--	--	--	73
Fishlake–Thousand Lake	Fishlake	266,984	1	--	--	78	< 1	--	13	8	--	--
Pavant Range	Fishlake	373,267	--	--	--	--	--	9	--	62	28	2
Tushar Mountains	Fishlake	313,098	4	--	--	58	< 1	--	--	36	--	2
White Mountain	Fishlake	284,466	--	--	3	27	< 1	< 1	1	44	25	--
Monroe Mountain	Fishlake	175,651	--	--	--	77	--	2	--	21	--	--

Twelve percent of the assessment area is classified as Woodland- and Shrub-Covered Low Mountains (fig. 5). These areas consist of pinyon-juniper woodlands, mountain brush, and sagebrush vegetative communities on fault-block mountains with rocky ridges, mountain slopes, foothills, terraces, and alluvial fans ranging from 5,000 to 9,000 feet in elevation (Woods et al. 2001). These systems have mesic to frigid temperature regimes and receive 10 to 22 inches of mean annual precipitation. Streamflow in these areas tends to be ephemeral. The primary land uses in the Woodland- and Shrub-Covered Low Mountains are grazing, wildlife habitat, and logging. In some locations, livestock grazing has reduced the cover of grasses in the understory, which has altered the fire regime and allowed invasion of sagebrush (Woods et al. 2001). This ecosystem makes up large portions of the Pine Valley and Canyon Mountain units, 68 and 73 percent respectively (table 1).

The Escarpments ecoregion covers approximately 7 percent of the study area (fig. 6). This system is characterized by high elevation cliffs, mesas, and breaks dissected by streams (Woods et al. 2001). The elevations of the Escarpments range from 5,000 to 10,000 feet with variable temperature regimes including mesic, frigid, and cryic. These areas receive 8 to 30 inches of mean annual precipitation. The vegetation of this system is highly influenced by aspect and soil moisture. Douglas-fir, shrublands, and woodlands are the most common, but subalpine fir and Engelmann spruce occur at high elevations and on north-facing slopes (Woods et al. 2001). The Escarpments are used for recreation and wildlife habitat, with small amounts of grazing. Coal mining and gas production occur in some local areas, but



Figure 5—The majority of the Canyon Mountains are within the Woodland- and Shrub-Covered Low Mountains ecoregion. Photo by D. Max Smith, Forest Service.



Figure 6—The southern edge of the Escalante unit is within the Escarpments ecoregion. Photo by D. Max Smith, Forest Service.

generally steep slopes and unstable soil limits human development (Woods et al. 2001). The Escarpments make up a high percentage of the Escalante unit but are rare throughout the rest of the study area.

Approximately 5 percent of the combined DNF and FNF is classified as the Wasatch Montane Zone (fig. 4). These areas occur between 8,000 and 10,000 feet in elevation and were partially glaciated, leaving behind glacial till, colluvial, and alluvial geologic settings (Woods et al. 2001). The vegetation consists of mountain slopes, tops, and ridges covered with aspen parkland, scattered Douglas-fir, and big sagebrush understories (Woods et al. 2001). Moraines and lakes are located throughout and several perennial streams occur in the Wasatch Montane ecoregion. These are fed by deep winter snowpacks, with the system receiving 16 to over 50 inches of mean annual precipitation (Woods et al. 2001), with local FNF staff estimating the area receives about 33 to 34 inches of snow each year (Adam Solt, USDA Forest Service, Richfield, UT, personal communication, May 20, 2020). The winters are long and cold and the temperature regime is classified as cryic. The primary land uses in this system include logging, seasonal grazing, recreation, wildlife habitat, and water supply (Woods et al. 2001). Within the study area, the Wasatch Montane Zone is only found in the Pavant and White Mountain units, making up about one quarter of the landscape in both.

The remaining five ecoregions all occupy relatively small landscapes within the study area. The Semiarid Benchlands and Canyonlands make up 2.5 percent of the collective DNF and FNF; the Sagebrush Basins and Slopes cover 2.4 percent of the study area; Mountain Valleys occupy 1.2 percent; and the Alpine Zone and Eastern Mojave Low Ranges and Arid Footslopes

both cover less than 1 percent of the Forests. Most of these areas are arid and have limited freshwater systems, but the Alpine Zone and the Mountain Valleys are disproportionately important for consideration in this assessment of GDEs, riparian, and wetland systems. The Alpine Zone was extensively glaciated, leaving behind deposits of glacial till, alluvium, colluvium, and rubble (Woods et al. 2001). These systems occur between 11,000 and 13,528 feet in elevation and are dominated by glacial features including moraines and u-shaped valleys with wet meadows. The Alpine Zone is a large and important water source for lower ecoregions, receiving an average annual snowfall exceeding 300 inches and having long, cold winters that maintain deep snowpacks (Woods et al. 2001). The largest area of Alpine Zone cover is located in the Tushar Mountain unit (table 1). Comparatively, the Mountain Valleys are not a large water source, but they include many of the riparian areas considered in our assessment. These areas consist of unforested alluvial fans, terraces, and floodplains that divide the high plateaus (Woods et al. 2001). They occur at lower elevations between 4,800 and 8,000 feet and receive between 5 and 24 inches of mean annual precipitation. While grasses and sagebrush are common, the riparian areas are characterized by cottonwoods (*Populus* spp.) and Russian olives (*Elaeagnus angustifolia*; Woods et al. 2001). The largest amount of Mountain Valley ecoregion occurs in the Paunsaugunt–Mt. Dutton unit (table 1).

Riparian and Groundwater-Dependent Ecosystems of the Dixie and Fishlake National Forests: Descriptions, Dynamics, and Distributions

In this section we provide an overview of riparian ecosystems and GDEs of the DNF and FNF. We first define these ecosystems and review the processes that create and maintain them. We then present a classification system for riparian ecosystems and GDEs and discuss their importance to fish and wildlife. Finally, we use several datasets to describe the distribution of riparian ecosystems, springs, and fens in the Forests.

Riparian Ecosystem Definitions

There are many definitions of riparian ecosystems, but three components are often included: (1) an interface of aquatic and terrestrial communities at a body of water, (2) landforms and organisms that are influenced by surface water and groundwater, and (3) plant communities differing in composition and/or structure from those in adjacent upland ecosystems (fig. 7) (Dall et al. 1997; Gregory et al. 1991). At streams, riparian ecosystems are three-dimensional zones of direct interaction between terrestrial and aquatic systems. The first dimension extends longitudinally from the headwaters of a stream to its mouth, the second extends vertically from the groundwater zone



Figure 7—Composition and structure of vegetation in Water Canyon of the Pine Valley geographic unit differ dramatically from adjacent upland vegetation. Photo by D. Max Smith, Forest Service.

to the canopy of vegetation, and the third extends laterally from the stream bed to the outer extent of the floodplain (Stanford and Ward 1988, 1993; Vannote et al. 1980). In the western United States, riparian ecosystems are also noted for supporting high levels of productivity and species richness, providing essential wildlife habitat, and covering a small percentage of the landscape (Hansen et al. 1995; Johnson et al. 2018).

Groundwater-Dependent Ecosystem Definitions

The emergence of groundwater to the surface or near surface creates unique ecosystems in the arid and semiarid regions of the western United States (Stevens and Meretsky 2008). GDEs are "communities of plants, animals, and other organisms whose extent and life processes are dependent on access to or discharge of groundwater" (USDA FS 2012a,b). For the purposes of forest planning, GDEs include wetlands fed by groundwater; terrestrial vegetation and fauna sustained by shallow groundwater; ecosystems in streams and lakes fed by groundwater; caves and karst aquifers; aquifer systems; hyporheic and hypolentic zones; and springs (from Forest Service Manual [FSM] 2880.5). Many aquatic systems, including some stream segments and riparian areas along gaining river reaches can therefore be considered GDEs as well. GDEs contribute to regional biodiversity by supporting specialized and endemic species, many of which are listed as threatened or endangered (Kreamer et al. 2015; Murray et al. 2006).

Springs are ecosystems entirely supported by groundwater. Various types of springs occur within Region 4 National Forests, each with features that promote regional biodiversity (Springer and Stevens 2009). Springs with surface pools provide lentic habitat for plants, vertebrates, and other biota. Spring runout channels provide unique lotic habitats due to relatively uniform water temperatures and low oxygen concentrations (Springer and Stevens 2009). These channels also increase connectivity across the landscape for organisms associated with surface water systems (fig. 8). Runout channels may connect with streams or may terminate to subsurface flow while still supporting aquatic and riparian species. Spring mounds, composed of calcareous minerals, peat, and other substrates, provide specialized habitat features as well. Vegetation communities sustained by springs often have greater structural diversity and therefore high value as wildlife habitat. Springs are also a critical source of drinking water for wildlife and livestock (Young 1994).

Aquifers are permeable rock or soil bodies that store and transmit groundwater in economic quantities (Heath 1983; USDA FS 2016). These extensive groundwater systems influence volume and temperatures of streams within the Forests and their larger landscapes. Alluvial aquifers typically occur in unconsolidated deposits of floodplains and valley bottoms. Bedrock aquifers occur in consolidated rocks with primary openings, such as lava tubes or intergranular pores, or secondary openings such as fractures and dissolution cavities (Heath 1983). Karst systems are specialized bedrock aquifers created by the chemical dissolution of carbonate bedrock, including



Figure 8— Spring channels support unique assemblages of aquatic and riparian species in the Sevenmile Creek Valley of the Fishlake–Thousand Lake geographic unit. Photo by D. Max Smith, Forest Service.

limestone and dolostone. These systems are characterized by disrupted surface drainage, abundant enclosed depressions, and well-developed underground drainage systems, which may include caves (USDA FS 2016). Karst systems facilitate movement and discharge of groundwater in many parts of the region, and they host unique floras and faunas (Humphreys 2006).

Fens are wetlands that are primarily supported by groundwater, have a minimum depth (30 to 40 cm) of accumulated peat, and support unique plant communities (Bedford and Godwin 2003; Chadde et al. 1998; USDA FS 2007, 2012a). Fens can occur in isolated conditions, surrounded by upland vegetation, or can be connected to streams and riparian ecosystems. Both connected and isolated GDEs provide critical habitats and ecosystem services such as carbon sequestration (Cohen et al. 2016). In crystalline bedrock geologies where karst systems and aquifers are absent, fens can play a similarly important role in modulating fluctuations in volume and temperature of streamflows by releasing water stored in thick organic soils throughout the growing season (Bedford and Godwin 2003; Schimelpfenig et al. 2014).

Dynamics of Riparian and Groundwater-Dependent Ecosystems

The Forests contain mountain ranges and plateaus that differ from one another in geological history, disturbance regimes, and effects of human use. The legacy of bedrock formation and subsequent geological events controls the dynamics of valley bottoms, streams, and groundwater in the Forests' watersheds. (Heath 1983; Waring 2011). Through processes of

erosion, deposition, and dissolution, streams and groundwater work with the geological material available to create and modify geomorphic features such as floodplains, gravel bars, terraces, and spring runout channels (Stanford et al. 2005).

These geomorphic features are occupied by plant communities that may change in structure and composition over several successional pathways (Gregory et al. 1991). The composition of communities and the nature of successional pathways is determined by a complex suite of factors that include geomorphic setting, surface and groundwater dynamics, disturbance regime, wildlife interactions, and human activities (Padgett et al. 1989; Youngblood et al. 1985). In general, hydroriparian pioneer species establish on newly deposited sediment or scoured floodplains. Hydroriparian pioneer trees and shrubs depend on flood disturbance and bare sediment for seedling establishment and require a connection with groundwater for survival and growth (Stromberg and Merritt 2016). As this vegetation stabilizes the sediment and streambanks, soil development proceeds, allowing establishment of late seral mesoriparian species (Winward et al. 2000; Youngblood et al. 1985). Late seral communities may persist on geomorphic features until a subsequent disturbance occurs, allowing reestablishment of pioneer species and communities. If surface water and groundwater are limited, deep-rooted xeroriparian trees, xeroriparian shrubs, or desert shrubs will establish and thrive in valley bottoms (Lytle et al. 2017; Stromberg and Merritt 2016).

Beavers (*Castor canadensis*) exert a particularly strong influence on these dynamics in meadows and unconfined valley bottoms. Beaver ponds and canals distribute surface water and groundwater across valley bottoms, helping to maintain hydroriparian plant communities (Gurnell 1998; Naiman et al. 1988). In some areas, beaver dam complexes maintain perennial streamflows and increase the extent of riparian and aquatic habitats (Grudzinski et al. 2020; Pollock et al. 2014). Beaver dam complexes also influence the ecology and geomorphology of valley bottoms by accumulating valley-fill sediment and promoting the multi-channel, biologically controlled stages of stream evolution processes (Castro and Thorne 2019; Powers et al. 2019; Westbrook et al. 2011).

The dynamics of GDEs are driven in part by underlying geology, terrain, and land formation processes. The geographic units of the Forests include mountain ranges in which sedimentary and crystalline rocks were folded and thrusted by Basin and Range formation. They also include high plateaus formed by uplift of sedimentary layers and subsequent volcanic activity. Following the building of mountains and plateaus, valley bottoms and floodplains were filled with unconsolidated colluvial and alluvial deposits. The greatest rates of groundwater movement occur in jointed and cavernous volcanic rocks, coarse unconsolidated deposits, and karst systems that form in carbonate bedrock. These geological units create extensive groundwater conduits that connect recharge and discharge areas in the landscape (Heath 1983). Bedrock aquifers consisting of consolidated or semi consolidated

rock, such as sandstone, serve as groundwater storage units in this landscape. Springs are located at the contacts, joints, and faults of disparate geologies, or where aquifers are exposed. In many cases, springs emerge at a fault line scarp (Whiting and Stamm 1995). Due to their location at faults, spring distribution in this region can be influenced by ongoing tectonic activity (Wood et al. 1985).

Fens often occur in historically glaciated features such as cirques and outwash channels (Chadde et al. 1998). Two major types have been identified in in the Rocky Mountains: valley peatlands and subalpine peatlands (Bursik 1990; Heidel et al. 2017). Valley fens form around lakes and ponds at relatively low elevations in major river valleys. Subalpine peatlands are more common and tend to occur along low-gradient subalpine streams (Chadde et al. 1998).

GDE dynamics are also influenced by regional climate and local weather patterns, particularly annual variation in snowpack and snow water equivalent. Their continued existence relies on discharge from groundwater and recharge to these systems depends on the distribution, amount and timing of precipitation, evapotranspirative losses, snow cover thickness, snowmelt characteristics, land use, and land cover (Klove et al. 2014). Areas with high precipitation, particularly areas that accumulate a slowly melting snowpack, are important sources of recharge and are influential to water table depth. Typical climate patterns that include low humidity and prolonged dry periods significantly limit the development of fens, which require specific hydrology for the accumulation of peat (Bedford and Godwin 2003; Chadde et al. 1998).

Community Type Classification

To describe the riparian ecosystems and GDEs in a region, classifications must be made based on biota, growth forms, associated landforms, hydrologic regimes, or other variables. In this assessment, we classified ecosystems using previously identified plant communities. We applied Padgett et al.'s (1989) description of Utah riparian community types for our classification systems. We chose this system because it is useful for describing composition and structure of riparian ecosystems and GDEs and for understanding their development and long-term trajectories. Manning and Padgett (1995), Padgett et al. (1989), and Youngblood et al. (1985) developed this system in which community types are determined by the dominant canopy and understory plants currently present, along with other associated species. Flow regime responses and successional statuses are not used for classification but are discussed in community type descriptions. For this assessment, we compiled dominance groups and community types that Padgett et al. (1989) described for the Utah Plateaus floristic section. To further describe the site characteristics associated with dominance groups and community types, we compiled information from subsequent descriptions of riparian communities sampled in and near Region 4 (Bowerman 1999; Crowe and Clausnitzer 1997; Hansen et al. 1995; Manning and Padgett 1995; Walford et al. 2001; Youngblood et al. 1985).

We grouped community types by their dominant growth forms, which are useful for describing vegetation structure and potential for wildlife habitat. The use of these dominance groups follows Padgett et al.'s (1989) classification for Utah and Manning and Padgett's (1995) classification for Nevada. Our dominance groups, described below, are (1) coniferous tree, (2) tall deciduous tree, (3) low deciduous tree, (4) tall willow, (5) low willow, (6) nonwillow shrub, and (7) herbaceous. A list of dominance groups and community types is included in appendix B.

Coniferous Tree Dominance Group

Coniferous tree-dominated community types often resemble adjacent upland forests in structure and composition (Gregory et al. 1991). Overstory species include *Abies lasiocarpa*, *Picea engelmannii*, *Picea pungens*, *Alnus incana*, *Populus tremuloides*, and *Populus angustifolia*. Dominant understory species include *Betula occidentalis*, *Cornus sericea*, *Dasiphora fruticosa*, and several mesic forbs and graminoids. These community types are found in narrow to broad valley bottoms with variable stream gradients. Elevations range from 6,000 to 10,500 feet. Geomorphic features are typically terraces adjacent to streams but also include benches, floodplains, streambanks, toe slopes, and meadows. Coniferous tree-dominated types have been identified at streams, springs, and fens. Water table depth fluctuates seasonally for most types but can remain 100 cm below the soil surface.

In some areas, these types may develop through invasion by conifers of sites previously dominated by graminoids, willows, cottonwoods, and other riparian plants (fig. 9). Soils are Entisols, Inceptisols, Mollisols, or Histosols. Composition of conifer-dominated types is stable in the absence of valley bottom disturbances. Fires, insect outbreaks, and floods from runoff or beaver dams may promote a shift to dominance by shrubs, deciduous trees, or herbaceous plants.

Tall Deciduous Tree Dominance Group

Dominant overstory trees in this group include cottonwoods (*Populus angustifolia* and *Populus fremontii*), aspens (*Populus tremuloides*), and boxelders (*Acer negundo*). Valley bottoms with tall deciduous tree-dominated types tend to be wider with lower gradients compared to those with coniferous-dominated groups. Elevations range from 3,840 to 9,000 feet. These community types are frequently located on terraces adjacent to or away from stream channels. They are also located on streambanks, benches, bars, and other portions of the floodplain where water tables fluctuate but remain in contact with the rooting zone of tall deciduous trees (fig. 10). Aspen-dominated riparian types occur along streams or springs.

Boxelder seedlings can establish under closed canopies and boxelder stands are persistent, barring major fluvial disturbance (Padgett et al. 1989). Cottonwood-dominated communities quickly colonize sediment deposits or scoured floodplains. Cottonwoods are maintained on the landscape by disturbances including flood and fire, which create bare substrate required for germination or induce sprouting (Kleindl 2015; Wilding et al. 2014). Stands



Figure 9—Conifer- and tall willow-dominated riparian community types are found along Merchant Creek in the Tushar Mountains. Composition and structure of willow stands have been affected by conifer encroachment, livestock use, and road construction. Photo by D. Max Smith, Forest Service.



Figure 10—Narrowleaf cottonwood, boxelder, and bigtooth maple are among the tall deciduous trees along Corn Creek in the Pavant Range. Photo by D. Max Smith, Forest Service.

will be replaced by late seral community types if disturbances are suppressed. Soils are often Entisols where cottonwoods develop on recently deposited sediments. Aspen-dominated types are more frequently found in Mollisols, where soil development has had more time to occur. Some aspen-dominated types are replaced by coniferous tree-dominated types in the absence of disturbances, such as fire, from which aspens can rapidly recover. In some settings, aspen types are persistent (Hansen et al. 1995).

Low Deciduous Tree Dominance Group

Stands of Alnus incana, Betula occidentalis, and other deciduous trees often occur on streambanks in valley bottoms of various widths and gradients. Elevations range from less than 5,600 to 9,200 feet. Given their proximity to active stream channels, these pioneering types establish following floods on newly deposited sediment or on scoured banks. The roots of Alnus incana and Betula occidentalis are therefore helpful in stabilizing streambanks. Soils typically remain wet throughout the growing season, with aerated water moving rapidly through the soil column (Padgett et al. 1989). Most soils are Entisols, Inceptisols, or Mollisols, showing a range of development. Depending on valley bottom characteristics, low deciduous-dominated types can persist in the absence of disturbance such as fire or disease. In some areas they are successional to late seral shrub types or coniferous tree-dominated types (Hansen et al. 1995; Padgett et al. 1989).

Tall Willow Dominance Group

Numerous tall willow-dominated community types exist in a variety of settings and have understories dominated by various types of plants. Types dominated by *Salix geyeriana* and *Salix boothii* tend to occur in wide valleys along low-gradient streams. Soils are often fine-textured with organic matter, perennially high water tables, and frequent ponding (Youngblood et al. 1985). Elevations range from 5,300 to 10,300 feet. Types with *Carex utriculata* understories are often associated with beaver ponds (fig. 11). *Salix geyeriana* and *Salix boothii*-dominated types may persist if soil conditions remain wet or mesic. Understory components may be affected by grazing if livestock can access willow stands. Soil drying may lead to succession to coniferous tree-dominated types.

Community types dominated by *Salix exigua* occupy active fluvial areas with recent clearing and sediment deposition in narrow and wide valleys across a wide range of elevations and stream gradients (Hansen et al. 1995). These pioneering types often establish on features where succession to other types may not occur due to frequent flood scour and deposition. At sites that are more stable, *Salix exigua* may persist or may be successional to other willow-dominated types or to coniferous tree-dominated types.

Low Willow Dominance Group

Low willow-dominated community types are typically located in broad valley bottoms at elevations of 8,000 to 9,900 feet or greater. Dominant overstory species include *Salix planifolia* and *Salix wolfii*. Frequent understory species are *Carex aquatilis*, *Carex utriculata*, and *Deschampsia*



Figure 11—Tall willow-dominated community types are maintained by a series of beaver dams in Clear Creek in the Tushar Mountains geographic unit. Photo by D. Max Smith, Forest Service.

cespitosa. Soils are typically Mollisols, Histosols, and Inceptisols. Communities dominated by low willows on wet organic soils are persistent, but lowered water tables and drying of wet meadows may encourage encroachment of conifers. Understory components may be affected by soil drying and grazing as well. Damage to willows from browsing encourages replacement by native or introduced species (Hansen et al. 1995).

Nonwillow Shrub Dominance Group

This group includes several community types that differ in site conditions. *Cornus sericea*-dominated types are found in narrow to broad valley bottoms, often adjacent to active channels. Streams are low to high gradient and elevations are below 7,000 feet. *Cornus sericea* is a pioneer species that colonizes stream bars and stabilizes banks (Hansen et al. 1995). Soils are Entisols, Inceptisols, and Mollisols with fluctuating water tables and aerated water moving through coarse soil layers. In some settings, slow succession to coniferous or deciduous tree-dominated community types may occur (Youngblood et al. 1985).

Dasiphora fruticosa and *Artemisia cana* dominate nonwillow shrub types in moderate to broad valley bottoms adjacent to sagebrush, mountain brush, and forested uplands. They are also found at hill slope springs. Stream gradients are often low to moderate and elevation ranges from 6,000 to 10,700 feet. *Dasiphora fruticosa*- and *Artemisia cana*-dominated types are late seral riparian communities that often grade from willow and herbaceous communities into drier upland communities (fig. 12). The shallow-rooted



Figure 12—Tall willow-, low willow-, nonwillow shrub-, and herbaceous-dominated communities are supported by surface flows and groundwater in the Sevenmile Creek Valley of the Fishlake–Thousand Lake geographic unit. Photo by D. Max Smith, Forest Service.

plants in these vegetation types do little to stabilize streambanks, compared to deeper-rooted plants. Understory components are affected by succession, water availability, and grazing. These types are usually found in well-developed Mollisols. Water tables are at intermediate depths and soils may dry during the growing season.

Herbaceous Dominance Group

Forb-dominated types often occur in confined, high-gradient streambank settings surrounded by coniferous forest. Soils are Entisols, Inceptisols, Mollisols, and Histosols. Elevations range from 8,000 to 10,500 feet. Some types, such as *Veratrum californicum*, form dense, monospecific stands that are quite stable. Some may be converted to other types through heavy grazing.

Graminoid-dominated types often occur in broad valley bottoms along low-gradient streams in floodplains and wet meadows (fig. 13). Several types are also associated with springs and fens. Elevations range from 5,200 to 11,000 feet. *Carex utriculata* and other sedges tend to occur in the wettest areas, such as beaver ponds. Most graminoid-dominated types are found in well-developed Mollisols that have accumulated thick layers of organic matter. *Deschampsia cespitosa* is often found in Alfisols formed by movement of argillic clay into the soil horizons (Youngblood et al. 1985). By accumulating layers of organic matter, fens and wet meadows provide the critical ecosystem service of carbon sequestration (Chimner et al. 2010; Wohl et al. 2012).



Figure 13—This herbaceous-dominated riparian community type on the Markagunt Plateau contains sedges adapted to saturated peat soils characteristic of fens. Photo by D. Max Smith, Forest Service.

Graminoids such as *Carex aquatilis*, *Carex utriculata*, and *Typha latifolia* can colonize recently exposed soil and then form a dense stand that persists if water tables remain high and grazing disturbance is minimal (Hansen 1995). Others, such as *Carex nebrascensis* and *Juncus balticus*, are resistant to grazing and are maintained by this disturbance. Several herbaceous community types include introduced species such as *Agrostis stolonifera*, *Bromus inermis*, *Poa pratensis*, and *Phelum pratense*. These species colonize recently disturbed sites and withstand high levels of grazing, facilitating their displacement of *Calamagrostis canadensis*, *Deschampsia cespitosa*, and other native graminoids.

Unclassified Community Types

Vegetation communities in these types are dominated by trees or shrubs that are relatively rare riparian species or facultative riparian species that grow to larger sizes than they would in upland sites. Overstory trees include *Fraxinus velutinus*, *Acer grandidentatum*, *Quercus gambelii*, and *Cercocarpus ledifolius*.

Fish and Wildlife Habitat

Riparian ecosystems and GDEs exist at the nexus of aquatic and terrestrial communities. As a result, these areas provide critical components of habitat for numerous aquatic and terrestrial animals and are the sole habitats for riparian and wetland obligates. Below are several examples of the importance of riparian ecosystems to fish and wildlife of the DNF and FNF.

Native Fish

The DNF and FNF contain several native fish species of conservation concern (FNF 2006; Hepworth et al. 2001). In the Forests are headwaters of three major river basins and several smaller closed basins. Native fish species have their own habitat requirements but overlap in the use of some instream features. Cutthroat trout (*Oncorhynchus clarkii*) require cold, clear water, deep pools, and overhanging banks. The desert sucker (*Catostomus clarkii*) feeds in swift moving areas but seeks cover in pools during daylight hours. The southern leatherside chub (*Lepidomeda aliciae*) requires cool to cold water and brushy areas near shores. The Virgin spinedace (*Lepidomeda mollispinis mollispinis*) is found in slow-moving water near overhanging banks and shrubs (Sigler and Sigler 1996; Young 2008). Riparian ecosystems are instrumental in creating and maintaining these features. Riparian vegetation filters sediment from overland flows, which helps to maintain water clarity (Correll 1997; Griffin et al. 2014). The root systems of sedges, willows, and other plants stabilize soils, allowing the creation of overhanging banks used by trout for hiding cover and thermal refugia (Winward 2000). The roots of live trees and the fallen trunks and branches of dead trees provide cover and create pools (Cluer and Thorne 2014; Moore and Gregory 1988). Willows and low deciduous trees also shade stream channels, thereby maintaining cool water temperatures during summer months (Beschta 1997). Beaver dams enhance habitat for trout and other native fishes by creating deep pools, regulating water temperatures, and encouraging the growth of riparian vegetation (Weber et al. 2017).

In all but one geographic unit (Canyon Mountains), stream segments are managed to maintain or restore cutthroat trout populations (table 2). These segments are typically in low-order streams that are protected from invasion of nonnative salmonids by natural or human-made barriers (Hepworth et al. 2001). In addition to control of nonnative fish, stream improvement projects, brood stock development, and reintroductions are ongoing to maintain or expand populations in the Forests (CRCT Coordination Team 2006; Lentsch et al. 2000). Stream improvements include restoration of aquatic and riparian habitat features (Young 2008).

Amphibians

Amphibians, including the boreal toad (*Anaxyrus boreas*), have declined throughout the Intermountain Region (Arkle and Pilliod 2015; Robinson et al. 1998). In southern Utah, boreal toads are associated with slow-moving streams, beaver ponds, and springs. Breeding habitats consist of standing water and emergent vegetation such as sedges and rushes (McGee and Keinath 2004; Patla and Keinath 2005). Boreal toads also forage in riparian areas dominated by willows, conifers, and grasses (Bartelt et al. 2004). Riparian corridors can serve as pathways for dispersal among breeding sites as well. Arizona toad (*Anaxyrus microscaphus*), also a species of concern, breeds at lower elevations in narrow, slow-moving streams of the Pine Valley unit (Dahl et al. 2000). In these arid settings, Arizona toads are restricted to aquatic and riparian habitats (Degenhardt et al. 1996). Additional

Table 2—Total miles of perennial streams and total miles currently managed for populations of cutthroat trout in each geographic unit of the DNF and FNF. Data were obtained from the National Hydrography Dataset and state fish and wildlife agencies.

Geographic unit	Sevier Basin stream miles	Upper Colorado Basin stream miles	Lower Colorado Basin stream miles	Bonneville cutthroat trout miles	Colorado River cutthroat trout miles
Escalante	76.0	220.9	0	9.2	26.3
Markagunt Plateau	255.4	0	18.6	39.2	0
Paunsaugunt–Mt. Dutton	178.4	1.6	1.1	40.6	0
Pine Valley	47.6	0	97.0	23.7	0
Boulder Mountain	0.6	152.3	0	0	7.6
Canyon Mountains	12.6	0	0	0	0
Fishlake–Thousand Lake	12.9	119.6	0	0	18.0
Monroe Mountain	175.5	0	0	11.4	0
Pavant Range	172.1	0	0	17	0
Tushar Mountains	368.0	0	0	70	0
White Mountain	174.0	33.9	0	12.3	0

amphibians, including northern leopard frog (*Rana pipiens*), use a variety of floodplain community types for reproduction and foraging (Degenhardt et al. 1996).

Spring-Dependent Species

Numerous aquatic, riparian, and upland species depend on springs in the arid southwest, but relatively little is known about spring-dependent species in the Forests (Sada et al. 2001). Several species of springsnails including *Pyrgulopsis peculiaris*, *Pyrgulopsis pinetorum*, and *Pyrgulopsis santaclarensis* have been documented in spring-fed channels and in the pools of small springs on the Forests (Hershler et al. 2017; Swensen and Kelly 2016). A multi-State agreement is in place to compile information about distribution, status, and habitat; to reduce threats to populations and habitats; and to maintain, enhance, and restore habitats (Springsnail Conservation Team 2017).

Large Mammals

Stream corridors are used as migration routes by elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), moose (*Alces alces*), and pronghorn antelope (*Antilocapra americana*), connecting patches of habitat across landscapes (Sawyer et al. 2005). Conifer-, willow-, and deciduous tree-dominated communities provide seasonal riparian habitat, including crucial winter forage for elk and moose (Collins 1977; Wolfe et al. 2010). Acreage of riparian habitat within winter elk range is high in the Escalante, Boulder Mountains, and White Mountain geographic units (table 3). Riparian

Table 3—Elk and moose habitat in geographic units of the DNF and FNF. Riparian areas were delineated using the 50-year floodplain map and VCMQ data.

Geographic unit	Acres— elk winter range	Acres— elk riparian winter range	Acres— moose range	Acres— moose riparian habitat
Escalante	171,067.4	10,763.2	0	0
Markagunt Plateau	37,570.5	1,682.6	0	0
Paunsaugunt–Mt. Dutton	54,765.6	3,618.0	0	0
Pine Valley	0	0	0	0
Boulder Mountain	94,022.3	6,103.9	0	0
Canyon Mountains	3,574.8	417.8	0	0
Fishlake–Thousand Lake	110,224.9	5,281.4	18,6875.7	7,947.9
Monroe Mountain	91,683.7	2,071.1	0	0
Pavant Range	110,669.3	2,991.6	0	0
Tushar Mountains	73,768.6	2,754.2	0	0
White Mountain	18,3745.8	6,265.4	228,204.9	8,700.4

habitat for moose is also present in the Fishlake–Thousand Lake and White Mountain units. Riparian ecosystems provide food and cover for additional large mammals including black bears (*Ursus americanus*) and cougars (*Felis concolor*) (Ackerman et al. 1984; Hansen et al. 1995; Irwin and Hammond 1985).

Birds

Many species of landbirds, including neotropical migrants, nest in the diverse community types associated with riparian ecosystems. Tall, deciduous tree-dominated types have high structural diversity and are among the most valuable habitats for birds and other wildlife (Smith and Finch 2014). The large size of mature cottonwood trees makes them attractive nest sites for diurnal raptors, owls, and other large birds. Cottonwoods and aspens are critical nesting trees for woodpeckers and other cavity-nesters (Hollenbeck and Ripple 2008; Saab and Vierling 2001). The canopies of tall deciduous trees are also frequently used as foraging sites by foliage-gleaning birds during migration and the nesting season. Where *Acer grandidentatum*, *Quercus gambelii*, *Cercocarpus ledifolius*, and other facultative riparian trees grow large, they may provide canopy nesting sites for large birds, as do aspen and cottonwood, but likely do not provide as many nesting opportunities for cavity-nesters.

Stands of tall willows are especially important nesting habitats for willow flycatchers (*Empidonax traillii*) and other neotropical migrants (Olechnowski 2008; Singer et al. 1994). Willow habitats at lower elevations

(less than 7,900 feet) have high productivity and are population sources for these birds (Hansen et al. 2002; Hansen 2009). The presence of this habitat on National Forest land is important for regional conservation, given losses and degradation on adjacent lands (Hansen and Rotella 2002).

Greater sage grouse (*Centrocercus urophasianus*) is a species previously considered for listing as federally threatened. Priority areas for sage grouse conservation are located within eight of the geographic units (table 4). Though primarily associated with xeric sagebrush uplands, sage grouse rely on willow, nonwillow shrub, and herbaceous-dominated riparian areas as summer brood-rearing habitat (Donnelly et al. 2016). Sage grouse hens seek out these areas to forage on herbaceous vegetation and invertebrates while productivity in upland habitat is unsuitable (Atamian et al. 2010; Fischer et al. 1996). The maintenance of these habitats is a critical component of sage grouse conservation (Dzialak et al. 2011).

Distribution of Riparian and Groundwater-Dependent Ecosystems

The riparian ecosystems assessed in this report occur along perennial and intermittent streams, at springs, and at isolated bodies of water. To describe the distribution of areas that can be considered riparian ecosystems, we combined spatial data layers representing geomorphology, surface flows, groundwater, and vegetation. These features have been used to map riparian ecosystems, but each has their limitations (Goetz 2006; Salo and Theobald

Table 4—Area of geographic units designated as greater sage grouse priority areas for conservation (PACs), as summer brood-rearing habitat by the DNF and FNF, and riparian zones suitable for foraging within summer brood areas. Riparian areas were delineated using the 50-year floodplain map. Suitable riparian zones were identified using VCMQ data.

Geographic unit	Acres—PACs	Acres—summer brood habitat	Acres riparian foraging habitat
Escalante	68,770.4	33,841.0	2,115.9
Markagunt Plateau	148,512.5	49,039.0	2,937.2
Paunsaugunt–Mt. Dutton	124,640.3	57,775.7	5,043.2
Pine Valley	0	0	0
Boulder Mountain	59,583.8	52,991.7	3,194.4
Canyon Mountains	0	0	0
Fishlake–Thousand Lake	114,476.2	98,562.5	3,521.5
Monroe Mountain	19,449.3	11,851.0	147.0
Pavant Range	0	0	0
Tushar Mountains	13,388.4	250.4	5.2
White Mountain	57,499.6	8,247.6	197.1

2016). Mapping geomorphic features associated with riparian ecosystems can demonstrate their potential extent, but changes in hydrology, natural or anthropogenic, may have limited the development or persistence of riparian ecosystems, thereby resulting in an overestimation of riparian extent. Conversely, mapping vegetation may underestimate riparian extent because riparian understory species may be obscured by overstory vegetation and facultative riparian species may be incorrectly classified as upland (Salo and Theobald 2016).

To fully display the potential range of riparian extent, we incorporated both vegetation and geomorphology data into maps. By mapping areas where vegetation has been classified as riparian, we show the current, minimum distribution of riparian ecosystems in the forests. By also mapping portions of valley bottoms influenced by surface flows and groundwater, we show where riparian ecosystems currently have the potential to exist.

The 2012 Planning Rule (36 CFR Part 219) recognizes that groundwater, GDEs, and their associated resources are vital to forest health and sustainability, as well as local and regional biodiversity. Still, most National Forests have limited knowledge of the landscape-scale distribution of GDEs. We compiled information and data from multiple sources to describe the known distribution of GDEs so they can be more readily acknowledged in forest planning activities.

Data Sources

Following the methods of Abood et al. (2012), we created a GIS layer of riparian ecosystem extent that incorporates 50-year flood heights from stream gage data, a 10-meter digital elevation model, soil units (hydric, drainage class, flood frequency, and hydrological soil group), and National Wetland Inventory (NWI) data. We mapped the current distribution of riparian vegetation using data generated by the Vegetation Classification, Mapping, and Quantitative Inventory (VCMQ) program (Nelson et al. 2015). The VCMQ program uses a combination of satellite imagery, aerial photography, and field-sampled data to produce maps of existing vegetation types for each forest. We used the VCMQ shapefiles created for the Forests to develop a layer of vegetation types that were classified as riparian. The low resolution of VCMQ data likely results in an underestimate of riparian extent. By combining the VCMQ and 50-year flood data, we create a map showing the potential extent of riparian ecosystems, as well as the known minimum extent of riparian vegetation.

We combined several sources of data to map potential distribution of GDEs. We obtained shapefiles representing potential karst, major aquifers, faults, and State geologic map compilations from the U.S. Geological Survey (USGS) (Epstein et al. 2002; Horton 2017; USGS 2003). We mapped the location of springs using shapefiles generated by the National Hydrography Dataset (NHD), the DNF, and the Forests' Water Rights and Uses (WRU) program. We obtained shapefiles of potential fens generated by the Colorado Natural History Program (CNHP). Using NWI data and aerial imagery,

CNHP staff located wetlands that are potential fens and ranked them as likely fens, possible fens, and low confidence fens based on the number of fen-like characteristics they observed (Smith et al. 2018, 2020).

In the following sections we summarize distribution patterns of riparian ecosystems and GDEs in the Forests. Distributions within geographic units are provided in appendix C.

Distribution of Riparian Ecosystems

Our combined maps indicate that the potential extent of riparian ecosystems is greatest at the Boulder Mountain unit and is the lowest at the Tushar Mountains (table 5). Riparian vegetation is present in each geographic area, with the greatest extent mapped in the Markagunt Plateau and the smallest extent in the Canyon Mountains. Extensive stands of riparian vegetation are located in the volcanic deposits of Boulder Mountain, the Markagunt Plateau, and the Pavant Range units. Extensive stands are also found in unconsolidated deposits where water emerges from permeable upslope rocks at Escalante, Fishlake–Thousand Lake, White Mountain, and other units. The narrow canyons of Monroe Mountain and the Tushar Mountains contain the most limited potential extent of riparian ecosystems. The Canyon Mountains have the smallest extent of riparian vegetation.

Distribution of Springs

We found several sources of data regarding location and density of springs. There appears to be inconsistent coverage of the Forests among these datasets. Combining these datasets, however, gives us an idea of the minimum spring density for geographic units. Closer examination of spring

Table 5—Characteristics of riparian ecosystem distribution, by geographic unit.

Geographic unit	Perennial stream miles	Intermittent stream miles	50-yr floodplain acres (% of unit)	Potential riparian acres (% of unit)	% VCMQ cover classified as riparian
Escalante	296.9	1,004.1	22,444.8 (5.1)	24,044.6 (5.5)	0.7
Markagunt Plateau	274	1,168.7	21,487.5 (5.3)	24,781.2 (6.1)	1.7
Paunsaugunt–Mt. Dutton	181.1	1,189.9	18,201.7 (4.7)	19,642.2 (5.0)	0.8
Pine Valley	144.6	1,897.8	23,852.7 (5.0)	27,217.6 (5.7)	1.2
Boulder Mountain	152.8	634.3	15,478.4 (6.1)	16,567.9 (6.5)	0.9
Canyon Mountains	12.6	524.6	5,682.7 (4.7)	5,872.3 (4.9)	0.3
Fishlake–Thousand Lake	132.4	538.7	11,158.3 (4.2)	13,057.2 (4.9)	1.4
Monroe Mountain	175.5	345.5	4,543.6 (2.6)	5,880.3 (3.3)	1.3
Pavant Range	172.1	1,359.5	11,227.0 (3.0)	13,343.0 (3.6)	0.9
Tushar Mountains	368	661.1	7,967.1 (2.5)	9,277.9 (2.9)	0.7
White Mountain	208	648	9,267.9 (3.3)	11,349.4 (4.0)	1.2

locations and names is needed to estimate an upper limit to spring density. We found that, though density of springs differs (table 6), springs are critical to maintaining perennial streamflows in all units. Some of the higher densities of mapped springs are found in the Markagunt Plateau, Escalante, Fishlake–Thousand Lake, and Monroe Mountain units. Springs are clustered at faults, volcanic deposits, and unconsolidated deposits at the base of volcanic plateaus.

Distribution of Fens

The CNHP identified 896 potential fens in the DNF. Potential fens are most abundant in the Escalante and Markagunt Plateau units. These were also the only units containing likely fens. Most of the likely fens in the DNF occur between the elevations of 9,000 and 10,000 feet, also in igneous bedrock or unconsolidated alluvium and surficial deposits (Smith and Lemly 2018). Watersheds with large numbers of likely fens are within the Sevier River and Upper Colorado River basins. Potential fens are also present in the southern portions of the Paunsaugunt–Mt. Dutton unit. Several potential fens in the Escalante unit are associated with lakes and have formed floating mats. On the Paunsaugunt Plateau, several potential fens are associated with beaver ponds.

The CNHP identified 2,323 potential fens in the FNF. Potential fens are most abundant in the Boulder Mountain and Fishlake–Thousand Lake units (table 6). Most of the likely fens in the FNF occur between the elevations of 10,000 and 11,000 feet in igneous bedrock or unconsolidated alluvium and surficial deposits (Smith and Lemly 2020). Most of the likely fens are

Table 6—Characteristics of GDE distribution, by geographic unit.

Geographic unit	NHD spring density	WRU spring density	DNF spring density	Acres of potential karst (% of unit)	Acres of potential fens (% of unit)
Escalante	110 (0.0003)	36 (0.00008)	347 (0.0007)	13,028.9 (3.0)	1,021.3 (0.2)
Markagunt Plateau	320 (0.0008)	279 (0.0007)	584 (0.0014)	0	915.5 (0.2)
Paunsaugunt–Mt. Dutton	175 (0.0005)	0	233 (0.0006)	70.1 (0.02)	328.2 (0.1)
Pine Valley	136 (0.0003)	16 (0.00003)	345 (0.0007)	8,179.6 (1.7)	17.1 (0.004)
Boulder Mountain	27 (0.0001)	0	70 (0.0003)	5,319.4 (2.1)	1,927.6 (0.8)
Canyon Mountains	50 (0.0004)	2 (0.00002)	--	20,361.7 (17.0)	1.9 (0.001)
Fishlake–Thousand Lake	93 (0.0003)	359 (0.0013)	--	4,345.4 (1.6)	1,645.6 (0.6)
Monroe Mountain	134 (0.0008)	119 (0.0007)	--	0	502.4 (0.3)
Pavant Range	119 (0.0003)	2 (0.00001)	--	45,444.2 (12.2)	163.3 (0.04)
Tushar Mountains	97 (0.0003)	50 (0.0002)	--	0	226.1 (0.1)
White Mountain	154 (0.0005)	87 (0.0003)	--	25,769.1 (9.1)	506.6 (0.2)

in watersheds of the Upper Colorado River Basin. Mapped fens were also concentrated in the southern portion of Pavant Range, upper elevations of Monroe Mountain and the southern portion of White Mountain.

Distribution of Aquifers and Karst

Colorado Plateaus sandstone aquifers underlie each of the units except for the Canyon Mountains and Pine Valley. These formations provide long-term groundwater storage. Great Basin fill and carbonate aquifers underlie portions of the Canyon Mountains, Pavant Range, Tushar Mountains, and Pine Valley units. These aquifers provide more-rapid transfer of groundwater from recharge sites to discharge sites (Heath 1983). Smaller aquifers have formed in porous volcanic deposits, karst systems, fractured crystalline rocks, and surficial alluvial deposits. These local aquifers are unmapped and yield lower volumes of groundwater than the major aquifers described above (Robson and Banta 1995). Evidence of extensive karst systems, such as sinks and travertine deposits, was documented during level II riparian surveys conducted by Shell Valley Consulting in the Pavant Range. Additional surveys are needed to document the full extent of these systems. Field work is also needed to describe the development of karst in areas such as the Canyon Mountains and White Mountain units, where potential karst has been mapped by the USGS (table 6). Karst-like systems have developed in areas where groundwater flows through lava tubes and breccia in volcanic bedrock. On the Markagunt Plateau and Boulder Mountain, extrusive volcanic rocks allow for the rapid movement of groundwater from recharge to discharge sites.

Summary

We classified riparian ecosystems into seven dominance groups based on characteristics of vegetation types. These ecosystems are important habitats for fish and wildlife, including several sensitive species found in the Forests. Beavers create ponds, which maintain vegetation types that are especially important to sensitive aquatic and terrestrial species. Springs and karst systems are important components of forest hydrology and habitat as well, but additional work is needed to better understand their distributions. Fen mapping from the CNHP indicates that the Boulder Mountain and Fishlake–Thousand Lake units have the greatest densities of fens. Most fens were mapped in areas characterized by volcanic bedrock and unconsolidated deposits at elevations of 9,000 feet or greater. These fen-mapping results are solely based on aerial imagery and should be validated by field surveys.

Anthropogenic Changes to Riparian and Groundwater-Dependent Ecosystems

Archaeological reconstructions suggest human habitation in southern Utah stretches back some 12,000 years. The earliest known inhabitants were Paleoindian hunters, followed by hunter-gatherers of the Desert Archaic Culture (Hinton 1987). The latter inhabited the region between 10,000 B.C. and A.D. 400. These peoples moved in extended family units, hunting small game and gathering the periodically abundant seeds and roots in a slightly more cool and moist Great Basin environment. Archaic hunter-gatherers altered the landscape by hunting large mammals and igniting fires, but it is difficult to determine if these changes resulted in meaningful, long-lasting effects on riparian and wetland ecosystems (Gage and Cooper 2013). Analysis of stone tools in the Escalante Valley has indicated that consumption, and perhaps cultivation of potatoes in riparian areas, was occurring up to 10,900 years before present (Herzog et al. 2018; Louderback and Pavlik 2017). About A.D. 400, the Fremont Culture began to emerge in northern and eastern Utah out of this tradition (fig. 14). The Fremont peoples retained many hunting-gathering characteristics but also incorporated a horticultural component by A.D. 800–900 (Grayson 1993; Lister and Lister 1983). There are remains of Fremont settlements along Interstate



Figure 14—Petroglyphs created by the Fremont Culture near Clear Creek indicate centuries of human influence on riparian ecosystems in the area that now includes the Dixie and Fishlake National Forests. Photo by D. Max Smith, Forest Service.

Highway 70 within the FNF. The Ancestral Puebloan culture was more sedentary and mainly agricultural. Their activities likely influenced riparian ecosystems and GDEs through diversion of surface flows for irrigation and tilling of floodplains. By 1300 A.D., agricultural societies had retreated from Utah to Arizona and New Mexico.

Left in the place of agricultural societies were the hunter and gatherer ancestors of the modern Paiute, Shoshone, and Ute. As with other Native American groups, these cultures altered the composition of the landscape, including riparian ecosystems and GDEs (Kretch III 1999). Prior to introduction of horses and other livestock, groups made annual migrations throughout the Intermountain Region to track the seasonal abundance of plants and animals. In each geographic unit of the Forests, bands of 1 to 10 families would have occupied riparian areas and wetlands while fishing, hunting, and collecting plant-based resources such as rushes and willows (Cuch 2000; Grayson 1993). During the summer, some bands tended small gardens near springs and streams (Hittman 2013). Nomadic groups ignited fires to improve hunting and foraging opportunities. It is likely that riparian ecosystems were influenced by these fires in low and mid elevations of the Forests (Nowacki et al. 2012). Depending on their frequency, these fires may have prevented conifer encroachment and encouraged dominance by shrubs and trees capable of resprouting.

The earliest Euro-American influences on riparian ecosystems occurred during the fur trapping period beginning in the 1820s. Beavers and other furbearers were harvested by Native Americans for food and clothing for thousands of years. However, given the large numbers of furbearers reported by early Euro-American explorers, it is unlikely that intensive trapping occurred in the West until a connection with European markets was established in the early 1800s (Chittenden 1902). European and American fur companies trapped beavers from Great Basin streams and Colorado River tributaries during the early 19th century (Chittenden 1902). Though population declines were noted by the mid-1800s, aggressive trapping continued in Utah until 1899 when beaver harvest was outlawed. Effects of beaver trapping were likely greatest at lower to mid elevations where beaver density was high. Beaver populations recovered quickly in the early 20th century, but it is difficult to determine where beaver populations have returned to their pre-European density and extent (Macfarlane et al. 2017; Persico and Meyer 2013; UDWR 2010). The Utah Division of Wildlife Resources (UDWR) regulates the trapping of beaver with a season from late September to April 1 each year, but there is no limit in the number of animals that can be trapped.

Permanent Euro-American influence of southern Utah began with Mormon settlement of the region in the 1850s. Areas near Parowan and Cedar City were initially settled for the purpose of iron production. Communities were soon established in the nearby valleys and widespread rangeland use began in the 1870s (Arrington 1958; Shamo 2014). Grazing, mining, logging, and water use expanded to the plateaus and mountains

regions as populations grew, altering streams and riparian ecosystems in each geographic unit by the end of the 19th century (Geary 1992; Hinton 1987). As access to open ranges increased in the late 19th century, unregulated herds of sheep and cattle were grazing throughout the Forests. Whereas cattle grazing directly affected riparian vegetation, sheep grazing often resulted in watershed-scale effects on sediment delivery, surface flows, and stream channels (Meeuwig 1960). Forest reserves were established in the late 1890s and early 1900s, in part to protect water resources from overgrazing. Beginning in 1903, forest reserves were incorporated into what would eventually become the Dixie and Fishlake National Forests. The DNF is now headquartered in Cedar City, Utah, and comprises just under 2 million acres. Early settlers referred to the area in southern Utah as Dixie in remembrance of the Southern tier of States in the United States. The FNF, with headquarters in Richfield, Utah, is slightly less than 1.5 million acres in size. It draws its name from Fish Lake, a high alpine lake located in Sevier County within the forest.

Regulated grazing is allowed on both forests for qualifying permittees and is enforced by the agencies. Cattle numbers were reduced, and sheep were removed from much of the range in the late 20th century (Hall 1971). Active sheep allotments are present on the Markagunt Plateau and Paunsaugunt–Mt. Dutton units of the DNF and the Boulder Mountain, Fishlake–Thousand Lake, Monroe Mountain, Pavant Range, and White Mountain units of the FNF. Except in cases of trespass grazing, range management and stocking rates meet the standards of moderate grazing guidelines. However, when livestock are allowed access to riparian areas, they may disturb vegetation and soil and introduce sediment and waste into streams (Armour et al. 1994; Gary et al. 1983; Platts and Nelson 1989).

In addition to iron ore and coal, mining has been permitted for gold, uranium, and other products on and near the Forests (Alexander 1987; Hinton 1987). Oil and gas exploration is ongoing in the region as well. Although many mines have been abandoned, air and water still run through the tunnels. Where running water contacts toxic mineral deposits, or with chemical deposits remaining from mineral extraction, there remains the potential for water pollution. There have been no reports of recent significant problems in either forest. Coal mining is ongoing in the White Mountain unit of the FNF. Effects of coal mining on surface flows, groundwater, and riparian ecosystems are being monitored in this area (Canyon Fuel Company 2017).

Timber harvest has occurred on the Forests since initial Euro-American settlement in the 1850s. Typical of most forests in the region, wood was harvested at low rates in the early decades of the Forests, primarily to support construction of towns, mines, and other developments. Due to their remote and rugged settings and lack of nearby lumber mills, the Forests often failed to meet directives for sustained yields (Alexander 1987). Timber harvest in the region did not increase until the latter half of the 20th century due to technological advances and postwar demand for lumber. Effects of harvest on riparian ecosystems include removal of streamside vegetation and

alterations of stream dynamics resulting from roadbuilding (Fortino et al. 2004). Regulations implemented near the end of the century reduced effects of harvest and roads on waterways. Forest product harvesting is currently permitted on the Forests through Timber Sale Contracts, post and pole permits, Christmas tree permits, personal firewood permits, and other forest product permits. Species taken for timber include Engelmann spruce, aspen, Douglas-fir, white fir, subalpine fir, ponderosa pine, blue spruce, and limber pine (O'Brien and Waters 1998a,b).

Fire is a natural phenomenon. A century of fire suppression coupled with rising temperatures over recent decades have resulted in greater biomass accumulation and a greater risk and incidence of wildfires (Busenberg 2004). Although peaks of forest fires occurred during the Medieval Anomaly (ca. 950-1250 A.D.) and again during the late 1800s, we are currently in a period of significant forest fire deficit, similar to what occurred during the Little Ice Age (1400–1700 A.D.). Regardless of the cause of this deficit or recent mega-fires, individual fires seldom cause concern for riparian ecosystems. However, when fire-fighting activities require passage through streams, wetlands and riparian areas, there is the risk of introducing sediment that may degrade those areas. In addition, the removal of upland vegetation due to fire limit the ability of a watershed to withhold water, blowing out small streams and rivers during storms, resulting in the loss of aquatic and riparian habitat and straightening of the water channel

A variety of recreational activities are permitted on the Forests. Permitted activities include bicycling, camping, climbing, fishing, hiking, horseback riding, hunting, nature viewing, all-terrain vehicle (ATV) riding, picnicking, rock hounding, scenic driving, water activities, and winter sports. Most of those activities require access to drop-off or access points. Access is not normally an environmental issue. However, when driving on trails and unimproved roads, access may require crossing streams. Such crossings may introduce sediments into streams and wetlands, thus causing deterioration in the quality of riparian areas (Goodman and Butler 2008).

Existing Condition of Riparian and Groundwater-Dependent Ecosystems

Methodology

We reviewed scientific literature and reports to identify drivers, stressors, and indicators of current conditions for four KECs for riparian ecosystems and GDEs: surface water and groundwater fluctuations, water quality, channel and floodplain dynamics including condition of spring runout channels, and composition and structure of riparian ecosystems and GDEs. We quantified stressors and indicators within four geographic units (Escalante, Markagunt Plateau, Paunsaugunt–Mt. Dutton, Pine Valley) of the DNF and seven geographic units (Boulder Mountain, Canyon Mountains, Fishlake–Thousand Lake, Mt. Monroe, Pavant Range, Tushar Mountains, White Mountains) of the FNF. We evaluated correlations between stressors and indicators within watersheds using the nonparametric Spearman's rank order correlation. Finally, we identified multiple indicators of condition within geographic units to determine whether sufficient evidence of alteration from the natural range of variation (NRV) was provided for each KEC. Thresholds for evidence of moderate and substantial alteration from NRV were determined from literature or from the indicator's data source.

Surface Water and Groundwater Fluctuations

Drivers

Fluctuations of surface water and groundwater in southwest and south-central Utah are linked to distinct regional climate patterns (Ely et al. 1993; Thiros and Brothers 1993; Young and Carpenter 1965) that are highly influenced by elevation and variation in inter- and intra-annual precipitation (Dixon 1935; Heilweil et al. 2000; Schwinning et al. 2008). Large amounts of precipitation occur as snowfall on high plateaus and mountains during winter (Thiros and Brothers 1993; Young and Carpenter 1965). These high altitudes experience lower temperatures and reduced rates of evapotranspiration (Geldon 2003), which makes snowpack a primary source of streamflow and infiltration to groundwater systems (Bjorklund 1969; Brooks and Mason 2005; Heilweil et al. 2000; Thiros and Brothers 1993). Spring snowmelt is linked to seasonal flooding and high water tables (Thiros and Brothers 1993; Thomas and Taylor 1946; Young and Carpenter 1965), with peak runoff typically occurring between April and June (Thomas and Taylor 1946). Monsoon thunderstorms in July and August also contribute substantial amounts of precipitation (Brooks and Mason 2005; Heilweil et al. 2000; Thomas and Taylor 1946) that drive flash flooding, reduced depth to groundwater, and increased discharge from springs (Brooks and Mason 2005; Heilweil et al. 2000; Mundorff 1971; Thomas and Taylor 1946). Outside periods of snowmelt and monsoon precipitation, groundwater levels are influenced by evapotranspiration (Geldon 2003; Young and Carpenter

1965), which tends to exceed precipitation from April to October (Geldon 2003). Beyond the annual time scale, large fluctuations in water levels are influenced by high inter-annual variability in precipitation (Davis 2005). Large deviations in annual precipitation between years occur as El Niño and La Niña events shift the meeting point of subtropical and polar jet streams north or south of the study area (Davis 2005; Heilweil et al. 2000; Schwinning et al. 2008).

Water fluctuations are also influenced by the geology of the study area, which exists at the transition of the Great Basin and the Colorado Plateau (Heilweil et al. 2000; Mower 1965; Young and Carpenter 1965). The Great Basin section is composed of north-south trending mountain ranges separated by wide, alluvial-filled valleys that drain internally (Banner 1992). These areas are generally composed of complex heterogenous consolidated rock units, the hydraulic properties of which drive infiltration to groundwater systems from precipitation and streamflow (Brooks and Mason 2005). Mountain precipitation not lost to evapotranspiration runs off in streams and a small amount (~5 percent) percolates through fractured bedrock to be discharged at springs or recharge basin fill aquifers at lower elevations (Robson and Banta 1995). Under- and inter-basin flow of groundwater through fractures in carbonate bedrock contribute substantial amounts of recharge to the aquifers in western Utah (Robson and Banta 1995). There appears to be a high degree of connectivity, with long-term water level trends and discharge from springs linked to precipitation and streamflow (Brooks and Mason 2005; Mundorff 1971).

The Great Basin meets the High Plateaus section of the Colorado Plateau in the Pine Valley Mountains of the DNF (Brooks and Mason 2005). The High Plateaus are characterized by sandstone and shale fault blocks capped by basalt, lava flows, and evidence of Pleistocene glaciation including glacial lakes, cirques, moraines, and glacial deposits (Banner 1992; Dixon 1935). Like the Great Basin, precipitation at high elevations is the main source of streamflow and recharge to groundwater systems (Bjorklund 1969; Flint and Denny 1958; Thiros and Brothers 1993). In the High Plateaus, large amounts of precipitation infiltrates through jointed lava flows and limestone solution channels (Bjorklund 1969; Flint and Denny 1958; Thiros and Brothers 1993), eventually discharging where these fractures intersect the land surface or where consolidated rock units contact valley-fill deposits (Thiros and Brothers 1993). Discharge at springs tends to occur in valleys bordered by volcanic rock (Mundorff 1971) and this is an important source of baseflow in surface water systems during drier months (Thiros and Brothers 1993).

Beavers impact water fluctuations by constructing dams in low-order streams, with especially strong effects in locations with a series of dams along the longitudinal gradient (Collen and Gibson 2001; Grasse 1954). By slowing runoff and storing water, beaver ponds raise the level of local surface and groundwater (Andersen and Shafroth 2010; Collen and Gibson 2001; Gibson and Olden 2014; Westbrook et al. 2006) and increase aquifer recharge (Collen and Gibson 2001; Lowry 1993; Westbrook et al. 2006). The large

storage capacity provided by beaver ponds moderates both high and low flows by collecting runoff during peak flow and releasing it slowly during dry periods (Collen and Gibson 2001; Gibson and Olden 2014; Westbrook et al. 2006). In some cases, the introduction of beaver dams has transitioned intermittent streams to perennial flows (Collen and Gibson 2001; Gibson and Olden 2014; Westbrook et al. 2006). Additionally, beaver dams increase the frequency, extent, duration, and depth of overbank flooding (Gibson and Olden 2014; Westbrook et al. 2006), spreading their impacts laterally and longitudinally through the riparian system (Westbrook et al. 2006). It is estimated that watersheds in southern Utah include only 1 percent of the existing capacity for beaver dams and that historic riparian vegetation conditions supported significantly more pervasive dam building (Wheaton and Macfarlane 2014).

Stressors

Surface water and groundwater fluctuations are stressed by activities or forces that alter connectivity between ground and surface water systems or that impact the timing, frequency, duration, magnitude, or rate of change in high and low flows. These activities and forces can be natural or anthropogenic and include wildfire, vegetation mortality, drought, dams, diversions, roads, trails, timber harvest, and livestock grazing (table 7).

Wildfire, vegetation mortality due to insects and disease, and drought are natural disturbances to water fluctuations. Depending on burn severity, fire can have major hydrologic impacts such as flash flooding or severe sedimentation that alters connectivity between ground and surface water systems (Doerr et al. 2006; Ice et al. 2004). The timing of water fluctuations can be altered by widespread vegetation mortality, which is linked to greater infiltration to groundwater systems in late summer months (Bearup et al. 2014). Long-term trends in water levels of both ground and surface water systems within the study area are associated with climate conditions, with less precipitation, low water table levels, and reduced streamflow occurring during drought (Schwinning et al. 2008; Young and Carpenter 1965). While fire, vegetation mortality, and drought are natural stressors, their effects can be amplified by anthropogenic activities. Fire suppression has led to accumulation of large fuel loads compared to historical conditions, driving an increase in the size and frequency of high severity fire (Schoennagel et al. 2004). Changes in climate that include warmer temperatures and reduced winter precipitation (Cleland et al. 2017) could prolong drought and subsequently alter hydrology throughout the study area.

Dams, diversions, roads and trails, timber harvest, and livestock grazing are anthropogenic stressors to water fluctuations. Timing, magnitude, and frequency of flows can be profoundly altered by dams and diversions, which consistently reduce peak and base flows and release water at different times for different durations than would occur under a natural flow regime (Graf 1999; Magilligan and Nislow 2005; Winter et al. 1998). Impervious surfaces added to the landscape by roads and trails, as well as the alteration of hillslope contours caused by these features, can decrease infiltration and

Table 7—Values of stressors present on the Dixie and Fishlake National Forests, organized by geographic unit.

Geographic unit	Forest	Road density	Percent roads unimproved	Trail density	Floodplain road density	Floodplain trail density	Floodplain recreation site density
Escalante	Dixie	0.002	83.9	0.001	0.005	0.002	0.003
Markagunt Plateau	Dixie	0.004	79.4	0.002	0.007	0.003	0.006
Paunsaugunt–Mt. Dutton	Dixie	0.003	89.4	0.001	0.006	0.003	0.004
Pine Valley	Dixie	0.002	63.4	0.0005	0.005	0.001	0.004
Boulder Mountain	Fishlake	0.002	90.7	0.001	0.004	0.001	0.007
Canyon Mountains	Fishlake	0.001	93.4	0.001	0.006	0.002	0.005
Fishlake–Thousand Lake	Fishlake	0.002	65.1	0.001	0.004	0.004	0.016
Monroe Mountain	Fishlake	0.002	60.9	0.002	0.005	0.007	0.006
Pavant Range	Fishlake	0.001	76.1	0.001	0.005	0.005	0.003
Tushar Mountains	Fishlake	0.002	68.6	0.002	0.007	0.006	0.018
White Mountain	Fishlake	0.002	72.6	0.001	0.006	0.002	0.011

Table 7 (continued)—Values of stressors present on the Dixie and Fishlake National Forests, organized by geographic unit.

Unit	Forest	Diversion density	Dams per stream mile	Percent unit RMU	Percent unit RMU active	Percent floodplain high/ very high wildfire hazard potential	Percent floodplain burned by moderate/high severity wildfire
Escalante	Dixie	0.003	0.019	91.1	100	25.6	0.7
Markagunt Plateau	Dixie	0.008	0.025	91.7	89.4	26.0	1.0
Paunsaugunt-Mt Dutton	Dixie	0.001	0.004	99.9	89.7	27.3	6.2
Pine Valley	Dixie	0.018	0.046	71.4	97.5	81.0	7.4
Boulder Mountain	Fishlake	0.003	0.022	99.9	100	14.1	0.4
Canyon Mountains	Fishlake	0.002	0.002	94.2	100	84.8	31.8
Fishlake-Thousand Lake	Fishlake	0.005	0.024	99.9	100	19.9	0.2
Monroe Mountain	Fishlake	0.004	0.021	87.5	100	40.7	0.3
Pavant Range	Fishlake	0.001	0.004	95.6	100	77.3	3.8
Tushar Mountains	Fishlake	0.004	0.031	98.7	100	52.2	5.1
White Mountain	Fishlake	0.005	0.032	92.2	100	47.4	0.2

increase surface runoff (Forman and Alexander 1998). Additionally, roads and trails are unnatural sources of fine sediment that can obstruct natural flow paths between ground and surface water systems (Forman and Alexander 1998). The hydrologic effects of timber harvest depend on management (Bosch and Hewlett 1982). For example, clear cutting is associated with increased surface runoff and sedimentation that can disrupt natural surface and groundwater networks (Bosch and Hewlett 1982). Lastly, livestock grazing is associated with reduced upland and riparian vegetative cover, reduced stability, increased runoff, and downcutting of streams. Ultimately this process can lead to lower water tables and drying of perennial water sources (Krueper 1993, 1996).

Climatic conditions are especially influential on natural flow regimes. Warmer temperatures and altered precipitation regimes generally result in less snowpack, earlier snowmelt, and more precipitation in the form of rain, all forces that alter the timing and magnitude of flows (Cayan 1996; Hamlet et al. 2005). Furthermore, increased temperatures result in higher rates of evapotranspiration and altered distributions of plants that draw on groundwater sources (Chen et al. 2011; Rind et al. 1990; Weiss et al. 2009). Within the study area, average temperatures of all four seasons in recent years have been higher than those of the previous century (Cleland et al. 2017). Winter and spring precipitation has decreased across the DNF and the FNF, while precipitation during summer and fall has substantially increased (Cleland et al. 2017). Natural groundwater and surface water fluctuations are strained by these changes in temperature and precipitation, with all other stressors acting cumulatively (IAP 2016).

The most common stressors to groundwater and surface water fluctuations on the DNF and FNF were dams, diversions, and roads, each of which was identified as a stressor in 7 of the 11 geographic units (table 7). Dams are located in all geographic units, with the highest densities occurring in the Pine Valley, Tushar Mountains, and White Mountain units (table 8). The majority (61 percent) of dams are small or insignificant regulating dams that impound less than 20 acre-feet of water. Significant dams that are inspected and impound more than 20 acre-feet of water are present on both Forests, together accounting for 34 percent of dams in the study area. Points of diversion are located in all geographic units, with 40 percent being undeveloped stream segments where stock may drink (table 9). An additional 32 percent are surface diversions in streams, rivers, creeks, or any other above-ground water rights. On the DNF, many springs with water use claims and development are included within the surface diversions count (table 9; Brooke Shakespeare, USDA Forest Service, Cedar City, UT, personal communication, March 5, 2020). Nineteen percent of diversions are underground wells, tunnels, sumps, and underground drains and 4 percent are diversions located at springs. Return points where water that has been nonconsumptively used returns to the natural stream accounts for 0.7 percent of diversions within the study area. Lastly, according to the USFS Terrestrial Condition Assessment (TCA) (Cleland et al. 2017), there are 4,371 miles of road on the DNF and 3,002 miles of road on the FNF. Of these road miles, 80 percent and 74 percent were classified as unimproved, respectively.

Table 8—Number of dams of each code in geographic units of the Dixie and Fishlake National Forests. Data were obtained from the Utah Division of Water Rights.

	Code[a]										
Geographic unit	**0**	**7**	**50**	**57**	**200**	**250**	**300**	**307**	**500**	**800**	**Total**
Escalante	-	10	-	-	5	-	-	1	-	8	24
Markagunt Plateau	-	19	-	-	8	-	-	-	-	3	30
Paunsaugunt–Mt. Dutton	-	3	1	-	1	-	-	-	-	-	5
Pine Valley	2	84	1	-	4	1	-	-	-	1	93
Boulder Mountain	-	2	-	-	3	-	1	2	-	9	17
Canyon Mountains	-	1	-	-	0	-	-	-	-	-	1
Fishlake–Thousand Lake	-	6	-	-	2	-	2	-	-	6	16
Monroe Mountain	-	1	-	-	8	-	-	-	-	2	11
Pavant Range	-	3	-	-	1	1	-	-	1	-	6
Tushar Mountains	1	18	-	-	10	-	3	-	-	-	32
White Mountain	1	10	-	6	-	-	1	-	-	3	21
Total	4	157	2	6	42	2	7	3	1	32	256

[a] Dam codes are: 0 = Small regulating, or insignificant dams that impound more than 20 acre-feet of water; 7 = Small regulating, or insignificant dams that impound 20 acre-feet of water or less; 50 = Small, insignificant flood control structure impounding more than 20 acre-feet of water; 57 = Small, insignificant flood control structure impounding 20 acre-feet of water or less; 200 = Inspected dams that are neither flood control nor industrial and impound more than 20 acre-feet of water; 250 = Inspected dams that are neither flood control nor industrial and impound more than 20 acre-feet of water; 300 = Inactive dams that are neither flood control or industrial and impound more than 20 acre-feet of water; 307 = Inactive dams that are neither flood control nor industrial and impound 20 acre-feet of water or less; 500 = Never-been-inspected (needs investigation); 800 = Inspected by other agency/Inspection report must be submitted to Dam Safety Office.

Livestock grazing was also a fairly common stressor, identified as impacting hydrologic function of at least 20 percent of the land area in five geographic units. A long history of grazing exists throughout the region, with impacts of past overstocking evident in many locations. Gregory and Moore (1931) noted obvious runoff and stream trenching and U.S. Forest Service (1944) described excessive erosion and damaging floods as a result of overgrazing. The landscapes of the DNF and FNF have been transformed by decades of intense grazing and subsequent restoration efforts (Hall 2001; Kauffman et al. 1997). While many ranges across the study area may be rehabilitated, it is likely the hydrologic impacts of historic overgrazing linger (Hall 2001; Kauffman et al. 1997).

Finally, more minor disturbances to groundwater and surface water fluctuations included tree mortality, trails, and wildfire, which were each identified as stressors in two geographic units. Similar to other locations throughout the southern Rocky Mountains, areas of the DNF and FNF have experienced spruce mortality due to the spruce beetle (DeRose et al. 2011; Hansen et al. 2010; Jorgensen and Jenkins 2011). Spruce mortality is linked to increases in surface water flows due to reduced interception

Table 9—Number of points of diversion and their type by geographic unit on the Dixie and Fishlake National Forests. Data were obtained from the Utah Division of Water Rights.

Geographic unit	Type of right							Total
	Point to point	Rediversion	Return	Spring	Surface	Underground	Abandoned well	
Escalante	960	86	9	20	224	188	1	1,488
Markagunt Plateau	325	80	9	106	1,565	1,160	14	3,259
Paunsaugunt–Mt. Dutton	148	1	1	6	141	62	1	360
Pine Valley	486	15	3	136	543	488	8	1,679
Boulder Mountain	560	55	6	3	122	5	-	751
Canyon Mountains	20	-	-	3	135	30	-	188
Fishlake–Thousand Lake	984	89	6	63	236	37	3	1,418
Monroe Mountain	250	4	4	11	257	106	1	633
Pavant Range	71	-	4	6	266	48	-	395
Tushar Mountains	469	2	37	72	356	283	1	1,220
White Mountain	796	19	6	138	256	38	2	1,255
Total	5,069	351	85	564	4,101	2,445	31	12,646

of snow and less transpiration (Love 1955; Mikkelson et al. 2013). Trails are located throughout both Forests, with the highest densities occurring in the Monroe Mountain, Pavant Range, Tushar Mountains, and Markagunt Plateau Units. While data were not available on the impacts of trails alone, the USFS Watershed Condition Framework (WCF) (Potyondy and Geier 2011) suggests at least a moderate likelihood of road and trail networks substantially altering hydrologic regimes in seven geographic units. Additionally, the WCF indicates that lack of maintenance of these features is a concern in all but two units within the study area. Lastly, high severity wildfire followed by monsoon thunderstorms have influenced water fluctuations throughout southern Utah. Burned Area Emergency Response reports completed for wildfires that have occurred on the DNF and FNF indicate that potential postfire reductions in infiltration range from 30–380 percent and that major flooding can occur in response to precipitation in the burned area (USFS 2012a,b, 2017).

We identified some correlation at the watershed scale between stressors that frequently occur together, as well as some associations between indicators and stressors. The WCF Water Quantity indicator suggested significant departure of flows from natural hydrographs across large sections of the study area. Watersheds with greater departure from natural flow regimes based on the WCF Water Quantity indicator also tended to have impaired road and trail conditions and altered climatic patterns that included

higher fall precipitation and warmer spring, fall, and winter temperatures. Additionally, watersheds with large alterations according to the WCF Water Quantity indicator were more likely to have lost connectivity between large amounts of historic aquatic habitat, suggesting structures like dams and diversions have contributed to habitat fragmentation. Across both Forests, we found watersheds with high diversion density also tended to have high road density, trail density, greater tree mortality, and more land within range management units. This result suggests that water fluctuations within watersheds are likely to experience compounded impacts from multiple interacting stressors.

Results

Surface Water Systems

Water fluctuations in surface water systems on the DNF had generally been impacted by multiple interacting stressors, whereas water fluctuations in surface water systems on the FNF appeared to be fairly resistant. Based on indicators of water fluctuations including conifer and upland species encroachment, water quantity, and deviations in winter precipitation and temperature, 26 percent of the DNF area was likely within the NRV and 74 percent of the DNF was likely moderately altered from the NRV (fig. 15). Comparatively, 93 percent of the FNF was likely within the NRV and 7 percent of the FNF was likely moderately altered from the NRV. On the

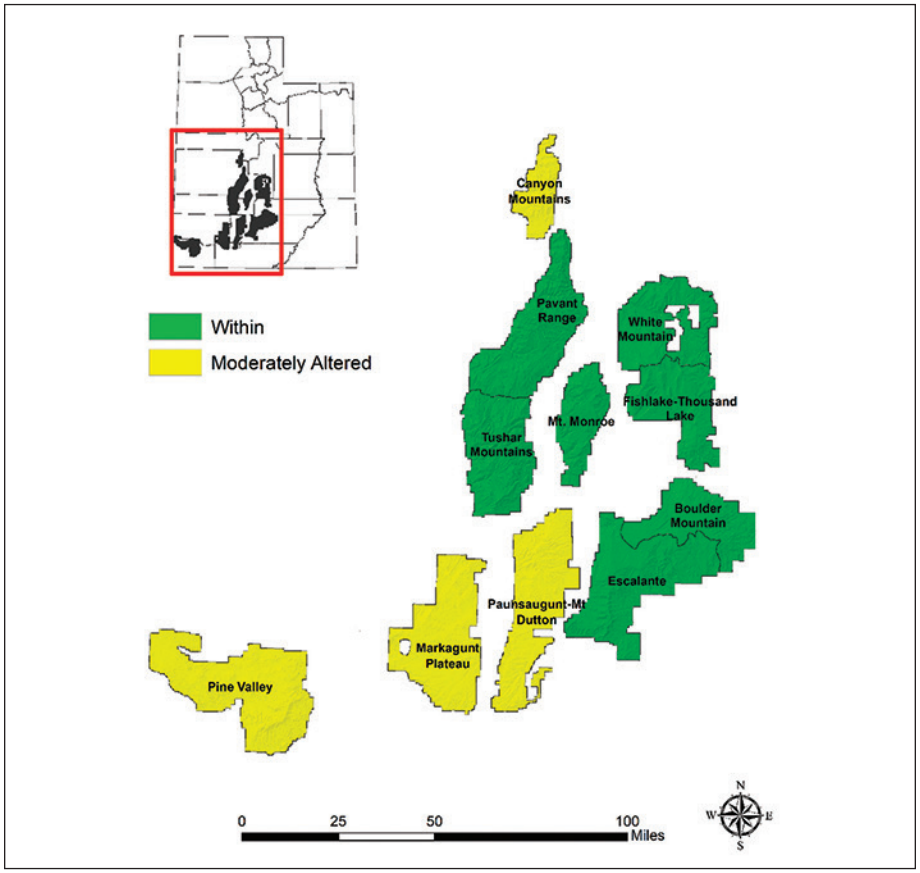


Figure 15—NRV status of surface water and groundwater fluctuations on the Dixie and Fishlake National Forests.

DNF, each geographic unit showed evidence of at least minor alterations to groundwater and surface water fluctuations. While the Escalante unit was classified as within the NRV, both water quantity and higher winter temperatures suggest riparian and aquatic ecosystems in this unit are potentially vulnerable to further stressors or more dramatic changes in climate. The remaining DNF units—Markagunt Plateau, Paunsaugunt–Mt. Dutton, and Pine Valley—showed additional evidence of altered hydrologic regimes. Many watersheds in the Markagunt Plateau exhibit major alterations to natural flow regimes. In the Paunsaugunt–Mt. Dutton unit a large percentage of riparian areas converted to upland species, suggesting reduced magnitude, frequency, and duration of high flows. Nearly half of perennial streams in the Pine Valley unit converted from riparian cover to conifers, also suggestive of altered high flows. The winter temperature of all units has increased moderately in recent years. Winter precipitation, which is a major source of surface water runoff and groundwater recharge, has not substantially changed across the DNF. However, substantial alterations to precipitation regimes have occurred and are likely altering natural flow regimes. All DNF units have received 25–39 percent and 8–30 percent more precipitation in fall and summer, respectively. Additionally, Pine Valley has lost 17 percent of spring precipitation. Together these indicators suggest a high likelihood of moderate alteration in surface water fluctuations across the DNF.

While six of the seven geographic units on the FNF were considered within the NRV, all units showed evidence of at least minor impacts to water fluctuations in surface systems. Even units considered to be within the NRV have experienced large amounts of conifer encroachment, changes in water quantity, or large decreases in winter precipitation. The Canyon Mountains was the only FNF unit to be classified as moderately altered from the NRV for surface water fluctuations. Large amounts of riparian areas in the Canyon Mountains have converted to conifers and upland species and this unit has experienced large shifts in the precipitation regime. Alterations in the timing of precipitation is an issue across the FNF, with large increases in precipitation occurring during summer and fall. This suggests that while surface water fluctuations generally remain intact across much of the FNF, systems are vulnerable to additional stressors and greater shifts in climate.

GDEs

The importance of springs as sources of base flow is well documented throughout southern Utah (Bjorklund 1969; Christiana 1991; Danielson and Sylla 1982; Gregory 1949, 1951; Mower 1965; Richardson 1907; Stephens 1975; Young and Carpenter 1965). Precipitation, especially snow that falls on the high plateaus and mountains of both Forests, recharges groundwater systems and discharges at springs throughout the region. Across the DNF and FNF, spring discharge is correlated with precipitation, and as a result is responsive to climate and highly variable across space (Bjorklund 1969; Christiana 1991; Danielson and Sylla 1982; Gregory 1949; Stephens 1975). Some springs, particularly those that emerge from faults around the Pavant Range and Tushar Mountains, have relatively stable hydrographs (Mower

1965; Richardson 1907; Young and Carpenter 1965). Water fluctuations at GDEs can be altered by diversions, groundwater pumping, soil compaction from roads or livestock grazing, and climate change. There was some evidence on both Forests of localized impacts to water fluctuations at GDEs. However, we did not locate sufficient data related to the condition of water fluctuations at GDEs on either Forest and were unable to assess the NRV status.

See appendix D for additional methodology and descriptions of groundwater and surface water fluctuations within each geographic unit.

Water Quality

Drivers

Major drivers of water quality include climate, chemistry of precipitation, biologic and biochemical processes, geology, and duration of contact between water, soils, and rock (Hem 1985). Regional climate, especially humidity and precipitation patterns, influences the amount of water present in the system and therefore concentrations of solutes and pollutants (Hem 1985). Additionally, the temperature, amount, distribution and chemical composition of precipitation throughout the study area contribute to weathering patterns that drive sediment loads and dissolved solutes (Hem 1985). These precipitation properties, including chemical composition and pH, are controlled by reactions in the atmosphere and are highly variable across space and time (Hem 1985).

Water quality is further affected by ecological and biochemical processes controlled by biota, including formation processes and reactions within soils (Hem 1985). As precipitation infiltrates and moves through soil, eventually becoming runoff or groundwater, the composition is influenced by dissolution of minerals, nitrogen fixation, selective removal of nutrients by plants, concentration of solutes by evapotranspiration, and biochemical processes that produce carbon dioxide (Hem 1985). Lastly, aquatic biota within water bodies produce oxygen, consume carbon dioxide, and decompose organic matter, contributing to diurnal fluctuations in stream metabolism, dissolved oxygen, and pH (Hem 1985).

Watershed geology, including rock composition and geothermal activity, also influences water quality. Throughout the study area, weakly consolidated rock layers with high relief, steep slopes and sparse vegetative cover contribute to high rates of erosion and naturally elevated sediment loads, salt concentrations, and high temperatures (Fremont River Watershed Steering Committee 2002; Harris and Judd 2004; Virgin River Watershed Management Plan 2006). Soil and rock formations in some locations of the study area naturally contain large amounts of soluble minerals such as chloride, sodium, calcium, magnesium, and sulfate that accumulate in the upper soil layer as water evaporates (Harris and Judd 2004; Virgin River Watershed Management Plan 2006). Runoff from snowmelt and storms erode and carry sediment from these upland areas, ultimately depositing it in streams and other waterbodies (Virgin River Watershed Management Plan

2006). Geothermal activity, including hot springs within the study area, also contribute extremely high concentrations of dissolved solids and naturally elevate stream temperature, which in turn influences chemical reaction rates (Hauer and Hill 2007; Hem 1985; Virgin River Watershed Management Plan 2006).

Stressors

Stressors to water quality include natural and anthropogenic activities that alter water temperature, sediment loads, or the concentration of nutrients, minerals, and pollutants (table 7; Bilotta and Brazier 2008; Dauer et al. 2000; Johnston 1991; Sánchez et al. 2007). Concentrations of nutrients, pollutants, and naturally occurring solutes can be altered by increasing inputs or changing the amount of water in the system. Eutrophication and low dissolved oxygen can occur where algal blooms have been triggered by large nutrient loads (Anderson et al. 2002; Smith et al. 1999). Sedimentation can impact stream temperatures by reducing the depth of waterbodies (Einstein 1950) or by obstructing interstitial spaces that link surface and groundwater systems (Richards and Bacon 1994; Wood and Armitage 1997). Shallower systems or those with diminished groundwater inputs tend to have higher water temperatures (Poole and Berman 2001). Large sediment inputs can further degrade water quality by transporting pollutants that threaten aquatic biota and municipal water supplies. Lastly, suspended sediments reduce light penetration, leading to less autochthonous production and impacts to trophic relationships (Wood and Armitage 1997).

Wildfires and drought are both natural stressors to water quality. Water temperature, nutrient concentrations, and sediment loads within aquatic systems can be temporarily degraded following wildfire. The loss of shade-providing riparian vegetation increases the solar inputs to streams and other water bodies, ultimately increasing temperature (Poole and Berman 2001; Shakesby and Doerr 2006; Spencer et al. 2003). Ash flows generally occur with the first precipitation event in a burned landscape. They provide a pulse of highly bioavailable nutrients that can lead to hypoxia and elevated levels of ammonium, trace metals, and ferrocyanides (Bixby et al. 2015). Depending on watershed characteristics and whether postfire treatments were applied, increased erosion and debris flows can increase inputs of sediment to streams, lakes, and GDEs (Benda et al. 2003; Shakesby and Doerr 2006). Drought influences water quality by reducing the amount of water in aquatic systems and increasing the concentration of nutrients and solutes (Mosley 2015). Diminished flows during dry periods allow accumulation of sediment and reduce the flushing rate of water bodies (Mosley 2015). Stream temperatures are higher during drought, which has implications for rates of productivity and respiration that contribute to dissolved oxygen concentrations (Mosley 2015). Lastly, during droughts nutrient inputs from watersheds tend to be reduced, potentially reducing concentrations within waterbodies and streams (Mosley 2015).

Anthropogenic factors that influence water quality include burning of fossil fuels, agriculture, diversions, roads, recreation, mining, timber

harvest, spread of invasive species, and loss of riparian cover. Combustion of fossil fuels and high intensity agriculture are two major sources of elevated nitrogen loading to aquatic systems (Carpenter et al. 1998). Runoff from fertilized fields or from grazed areas also increase inputs of nitrogen and phosphorus (Carpenter et al. 1998). Diversions, pumping, or other activities that remove water increase mineral and solute concentrations. Mining can introduce trace metals, increase phosphorus loading, and alter the amount of water in the system (Lines 1985). Roads, particularly those located within floodplains, are unnatural sources of sediment, which can increase levels of heavy metals, salinity, turbidity, and alter dissolved oxygen (Forman and Alexander 1998). Recreation areas, including trails and campsites can increase sediment inputs and affect water quality through refuse disposal (Crabill et al. 1999; Varness et al. 1978). Livestock grazing can increase sedimentation and temperature by trampling banks and removing shade-providing vegetation (Fleischner 1994) and livestock waste contributes to higher nutrient loads (Carpenter et al. 1998). Timber harvest projects can increase sedimentation to streams from erosion at the harvest site (Rashin et al. 2007). Nonnative species, particularly saltcedar (*Tamarix* spp.), can impact water quality by excreting salt and consuming large amounts of water that reduce flows and increase salinity levels (Barrows 1996). Lastly, stressors can be buffered by intact riparian zones that filter sediment and nutrients and buffer stream temperatures; however, loss of riparian cover and conversion to development, invasive species, or agriculture reduces this service (Clinton 2011).

The most common stressors to water quality on the DNF were roads, diversions, degraded soil conditions, and loss of riparian cover, with some observed effects from grazing and recreation. On the FNF, the primary stressors to water quality were roads, degraded soil conditions, and invasive species, with some secondary effects from loss of riparian cover, timber harvest, and diversions. Roads were identified as a stressor in all but one unit in the study area. This is consistent with water quality assessments completed in the region that identified road densities to exceed recommended thresholds (Harris and Judd 2004). Across the study area, watersheds with impaired function for the WCF Water Quality Problems attribute tended to have a larger percentage of unimproved roads, high densities of roads and trails within floodplains, and low maintenance of roads, trails, and water crossings. Additionally, watersheds with high road densities tended to have high diversion densities, meaning watersheds are likely to experience compounded impacts from these stressors. Diversions were identified as a stressor in all four geographic units of the DNF but in only two units of the FNF. Dewatering of streams appeared to contribute to localized water quality issues on the DNF. For example, watersheds with increased water quality problems, such as excessive nutrients, also had altered flow regimes. Lastly, degraded soil conditions, including excessive erosion, altered productivity, or soil contamination, were identified as stressors in all but two geographic units in the study area. These characteristics appear to be linked to impacted water quality, as impaired function for soil erosion, soil productivity, and soil

contamination were associated with impaired function for WCF water quality problems.

Results

Water quality on the DNF and FNF appears to be fairly resistant to multiple interacting stressors. Based on the condition of riparian and wetland vegetation, the percentage of perennial streams converted to nonriparian cover, stream temperature, impaired waters, substrate cementation, and other water quality problems, 100 percent of the DNF and 83 percent of the FNF were considered within the NRV for water quality; there was insufficient information to evaluate the NRV status of water quality for the remaining 17 percent of the FNF (fig. 16).

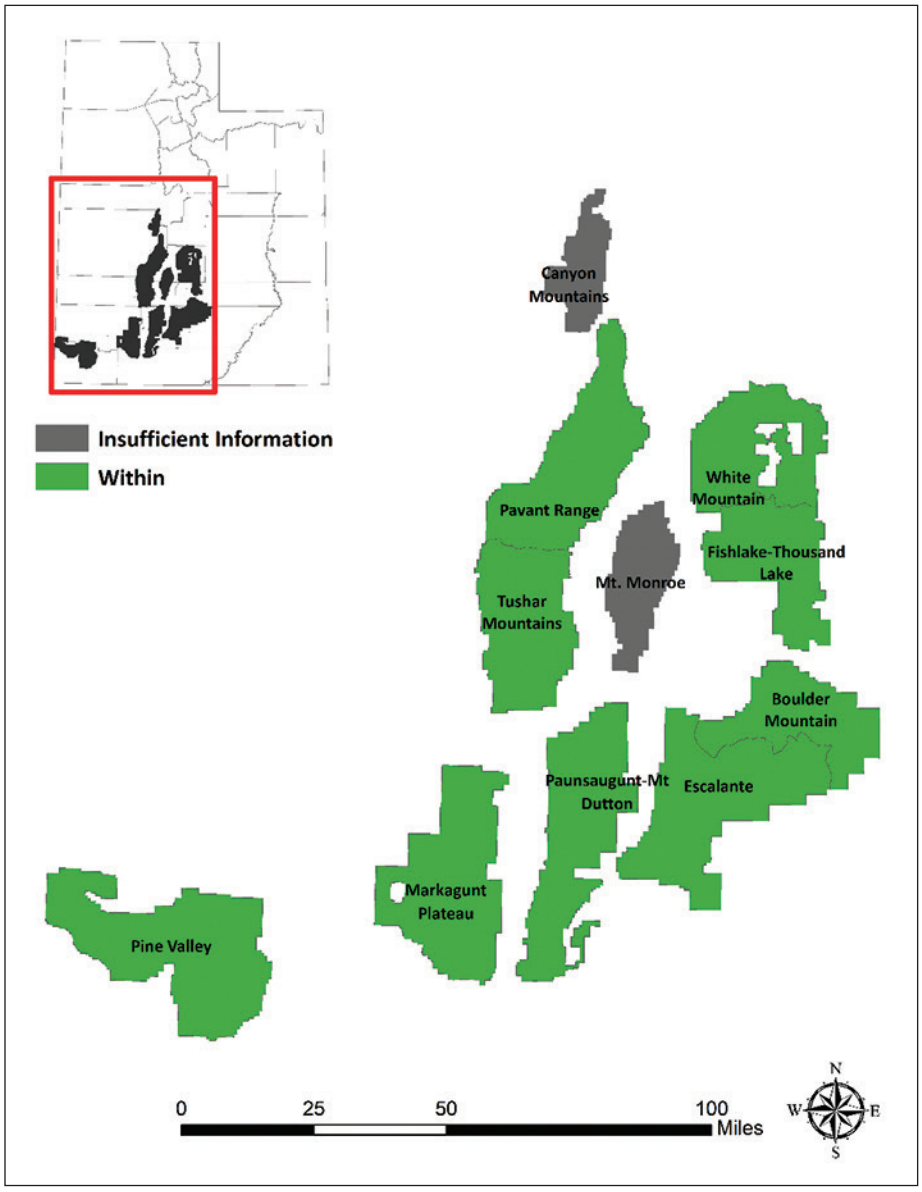


Figure 16—NRV status of water quality on the Dixie and Fishlake National Forests.

While no units on the DNF were classified as altered from the NRV for water quality, there was evidence of impacts from stressors in all DNF units. Excessive sediment, nutrients, and/or chemical pollution beyond natural levels appears to be a concern across the entire DNF, and especially in the Markagunt Plateau and Paunsaugunt–Mt. Dutton Units. Impacts from these problems may be buffered by intact and functional riparian and wetland areas. Only small percentages of riparian areas and wetlands on the DNF have been converted to development or agriculture and these systems are generally in a functional condition that reduces erosion, buffers stream temperatures, allows for biological filtering, and improves water quality. Lastly, stream temperatures across the DNF tend not to exceed water quality standards during August, when temperatures are likely to be warmest.

Like the DNF, the majority of the FNF was classified as within the NRV for water quality. However, all FNF units showed some evidence of alteration to water quality. Conversion of riparian areas to development or agriculture is more common on the FNF, particularly in the Canyon Mountains and White Mountain units where nearly 20 percent of perennial streams have converted to these alterative cover types. Damage to riparian and wetland vegetation on the FNF has reduced the ability of these systems to provide the critical ecosystem service of improving water quality by buffering temperatures and filtering sediments and nutrients. Many stream channels in the FNF have received excessive amounts of sediments that have caused substrates to become cemented. However, stream temperatures across the FNF remain sufficiently low during summer months to support cold water fisheries; the percentage of impaired waters is low, and water quality problems like excessive nutrients are generally limited.

See appendix E for additional methodology and descriptions of water quality within each geographic unit.

Channel and Floodplain Dynamics

Drivers

Geology, topography, climate, and beaver activity are primary drivers of the amount and balance of water and sediment that influences channel and floodplain dynamics over time. Fluvial v-shaped valleys are common throughout the Great Basin section of the study area (Minshall et al. 1989). These valleys form in steep gradient, low-order streams (Minshall et al. 1989) that drain the fault-block mountain ranges of the Great Basin. Higher in watersheds, erosion in v-shaped channels tends to exceed deposition, actively downcutting channels through bedrock (Minshall et al. 1989). The sediments eroded from these upper reaches are generally transported to the alluvial basins at the base of each mountain range (Minshall et al. 1989). The large sedimentary geologic systems of the Colorado Plateau are comprised of alternating soft and hard rock formations (Bailey 1935). Paired with a topography of descending high plateaus, this geology has contributed to diverse stream channel formations that alternate between narrow, steep canyons and wide alluvial floodplains where streams have migrated laterally across weaker geologies (Bailey 1935).

In addition to geology and topography, climate contributes to channel and floodplain dynamics by driving changes in water availability. During dry periods, streams tend to aggrade and form new floodplains due to increased sediment inputs and reduced water availability (Bailey 1935). In contrast, wetter periods are associated with downcutting and terrace formation (Bailey 1935). In the Great Basin, streams flowing through steep v-shaped canyons typically maintain sufficient power to flush sediments from the system. Upon reaching the base of its canyon, streamflow dissipates and sediments are deposited (Minshall et al. 1989). Generally, these canyons only experience streamflow for brief periods after storm events, limiting development of active floodplains (Minshall et al. 1989). Bailey (1935), Hayden (2011), and Townsend et al. (2019) identified aggradation as the dominant process occurring in valley bottoms since the Holocene, with these centennial- to millennial-time periods of aggradation associated with dry climates. During wetter periods with large magnitude floods, episodes of downcutting have occurred, most recently between the 1880s and early 1900s (Hayden 2011; Townsend et al. 2019). Bailey (1935), Hayden (2011), and Townsend et al. (2019) identified aggradation as the dominant process occurring in valley bottoms since the Holocene, with these centennial-to millennial-time periods of aggradation associated with dry climates. During wetter periods with large magnitude floods, episodes of downcutting have occurred, most recently between the 1880s and early 1900s (Hayden 2011; Townsend et al. 2019).

Finally, beaver activity contributes to the condition of channel and floodplain dynamics. Beavers modify channels and floodplains by cutting wood and building dams that trap sediment, slow runoff, and build wide, low-gradient, alluvial valleys (Gurnell 1998; Naiman et al. 1988). These meadows generate a step pattern along a stream's longitudinal profile. Additionally, beaver dams increase variation in channel width, depth, and geomorphologic diversity. Overall, beaver activities tend to stabilize channels and build more complex longitudinal and lateral floodplain profiles (Gurnell 1998).

Stressors

Stressors to channel and floodplain dynamics are activities and forces that alter the balance between water and sediment supplies within stream systems or limit lateral movement of the channel across its floodplain. They can be natural or anthropogenic and include drought, wildfire, roads, recreation, diversions, dams, grazing, and timber harvest (table 7).

Drought and wildfire are examples of natural stressors to channel and floodplain dynamics. Both can reduce vegetative cover in the uplands and riparian areas, leading to accelerated erosion and sedimentation of channels. During drought, stream power is reduced, sediments aren't flushed from the system, and channels aggrade (Bailey 1935). Additionally, drought interacts with other stressors, such as livestock grazing, and amplifies their effects (Emmerich and Heitschmidt 2002). Depending on burn severity, wildfires can increase hydrologic and geomorphologic activity by increasing both runoff and sediment inputs from the uplands (Doerr et al. 2006; Inbar et al. 1998; Johansen et al. 2001; Shakesby and Doerr 2006). Where soils are

hydrophobic following fire, infiltration is reduced, overland flow increases, and streams experience larger flows. (Ice et al. 2004; Neary et al. 2003). If infiltration is reduced and overland flow is increased, streams may experience greater runoff that removes the sediment supply and downcuts the channel (Ice et al. 2004; Neary et al. 2003). In contrast, large amounts of erosion, debris flows, and landslides following fire can contribute massive amounts of sediment to the channel (Shakesby and Doerr 2006).

Roads and recreation infrastructure such as trails and campgrounds can impact channel and floodplain dynamics by providing an unnatural source of sediment and by physically altering channel structure. Roads that parallel streams often confine channels and limit lateral migration (Forman and Alexander 1998; Jones et al. 2000; Trombulak and Frissell 2000). Where roads cross streams, culverts or armored stream crossings are generally installed. Culverts can confine the channel and result in downstream scouring and plunge pools (Abt et al. 1985). Crossings that do not occur at bridges can cause streams to become wider and shallower with flattened banks (Forman and Alexander 1998; Jones et al. 2000; Trombulak and Frissell 2000). Trails and campgrounds can have similar effects by increasing sediment inputs and trampling streambanks. Lastly, artificial banks installed to protect roads and recreation structures can disconnect the stream from its floodplain and simplify the structure of the channel (Forman and Alexander 1998; Jones et al. 2000; Trombulak and Frissell 2000). Roads and ATV trails are an impactful stressor throughout the entire study area, with most riparian surveys describing increased sedimentation or confinement from roads as an issue in at least one reach. Sedimentation, trampled streambanks, and litter from campers were also described in many reaches throughout the assessment area.

Dams and diversions influence channel and floodplain dynamics by altering both water and sediment supplies. These features decrease the magnitude of floods that move sediment downstream, connect the stream to its floodplain, and reshape the channel (Winter et al. 1998). Additionally, dams trap sediments upstream and starve downstream systems of sediment, resulting in downcutting of channels and coarser substrates (Kondolf 1997). Active floodplain area is reduced by 79 percent in regulated streams, and inactive floodplain area is 3.6 times larger than comparable unregulated reaches (Graf 1999). Additionally, floodplain complexity is reduced by 37 percent following regulation and within the United States, interior western rivers are most susceptible to these changes (Graf 1999). There are multiple examples throughout the study area of diversions removing all flow from reaches or dams contributing to altered sediment dynamics.

Timber harvest and grazing both remove vegetative cover and can contribute to accelerated erosion and increased sedimentation of channels. Timber harvest is not a common stressor throughout the study area, but some riparian surveys do note impacts to channel and floodplain dynamics from logging in the uplands. In contrast, grazing is a major stressor to channel and floodplain dynamics across both the DNF and FNF. In addition to removing

vegetation, impacts from grazing include trampled banks, over-widening streams, and unnatural sources of sediment from cattle trails. The effects of overgrazing that accompanied European settlement of the West are well documented. The removal of stabilizing vegetation and compaction of soils led to increased erosion and overland flow (Armour et al. 1994; Packer 1953). Eventually, channels throughout the West became incised (Armour et al. 1994; Packer 1953) and entirely disconnected from their floodplains. There is extensive evidence throughout the study area that livestock grazing has resulted in reduced cover of stabilizing vegetation, compacted soils, increased erosion, and incised channels. These impacts have been noted in at least one reach of almost all riparian surveys conducted within the study area.

The most common stressors to channel and floodplain dynamics on the DNF were roads, diversions, and grazing, with some observed effects from dams and recreation. On the FNF, the main stressors to channel and floodplain dynamics were roads, recreation, and grazing, with secondary effects from dams and diversions. Roads were identified as a stressor in all of the DNF units and in four of the seven FNF units. Across the study area, watersheds with channels and floodplains in poor condition as indicated by the WCF Channel Shape and Function attribute tended to have higher road densities, greater percentage of roads classified as unimproved, high proximity of roads and trails to streams and waterbodies, and low maintenance of roads and trails. Watersheds with high road densities also tend to have higher percentages of unconfined reaches in very poor to moderate condition. Additionally, high densities of trails within floodplains are linked to high percentages of confined reaches classified as impacted and high percentages of unconfined reaches in very poor to moderate condition. Like roads, grazing was identified as a stressor in all the DNF units and four of the seven FNF units. Numerous impacts from livestock grazing, such as trailing, trampled banks, and incised channels were well documented across both forests in riparian surveys. Additionally, watersheds with rangelands in poor condition were linked to impaired channel shape and function including evident channel degradation and/or aggradation, widening channels, and extensive reaches where streams are disconnected from their floodplain. Lastly, there was some evidence that secondary stressors including invasive species, timber harvest, and high severity burns have impacted channels and floodplains. Watersheds with high percentages of unconfined reaches in very poor to moderate condition also tend to have larger amounts of land within timber harvest projects and high severity burns. Lastly, these watersheds also tend to have larger patches of tamarisk and Russian olive within the floodplain.

Results

Channel and floodplain dynamics on the DNF appear to have been impacted by multiple interacting stressors. On the FNF, channel and floodplain dynamics seem to be somewhat resistant to stressors, but there was a wider range of conditions than the DNF. Based on five indicators of channel and floodplain condition, we found 54 percent of the DNF was moderately

altered from the NRV and 46 percent of the DNF was outside the NRV. On the FNF, 60 percent was within the NRV, 33 percent was moderately altered from the NRV, and 7 percent was outside the NRV for channel and floodplain dynamics (fig. 17).

Nearly all indicators in all units on the DNF showed evidence of impacted channels and floodplains. All units had high percentages of unconfined reaches in very poor to moderate condition and low percentages of riparian areas that had not converted to an alternative cover type. All units had channels with increased width-to-depth ratios, evidence of channel degradation and/or aggradation, and evidence of downcutting to the extent that some streams were no longer connected to their floodplain. On the DNF, actively downcutting channels typically occur in alluvial valley

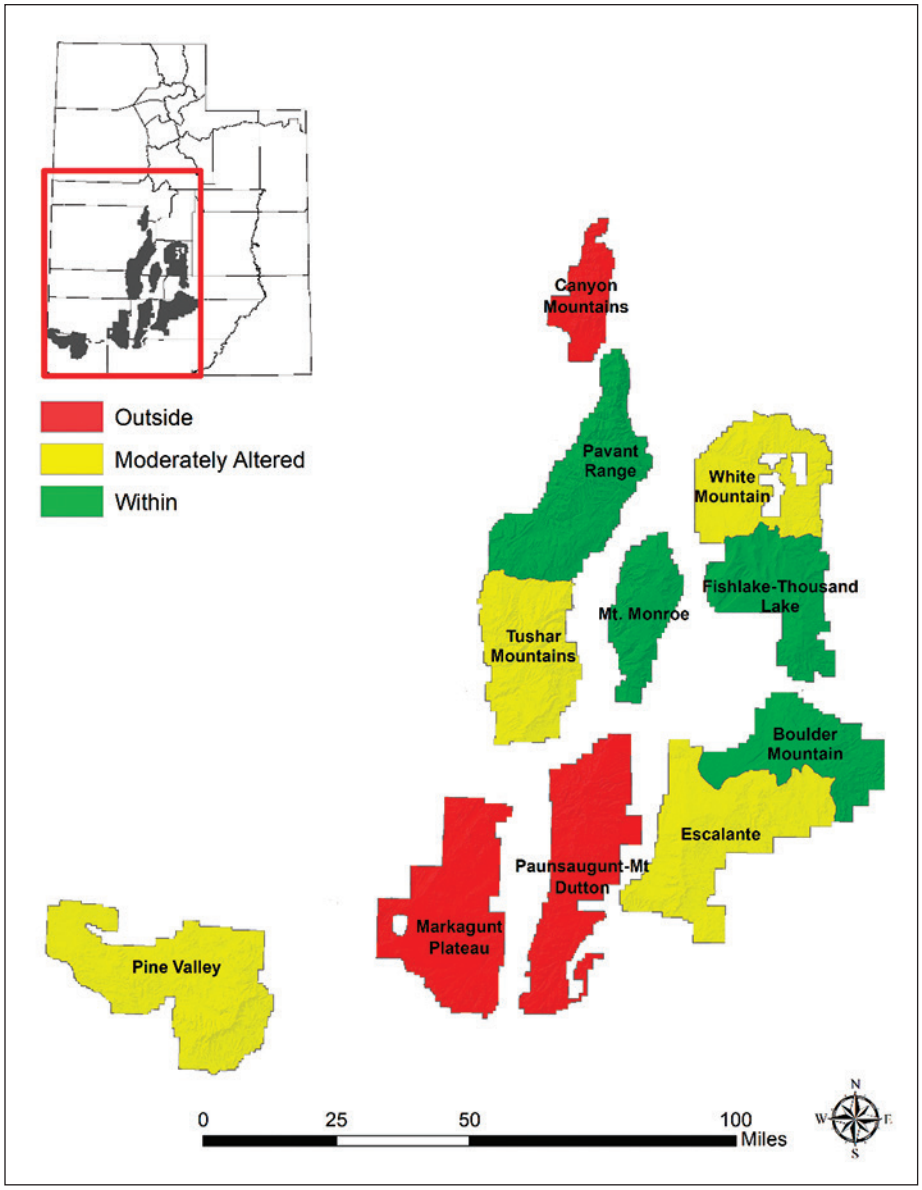


Figure 17—NRV status of channel and floodplain dynamics on the Dixie and Fishlake National Forests.

fills, and the downcutting is arrested once the stream encounters bedrock (Brooke Shakespeare, USDA Forest Service, Cedar City, UT, personal communication, March 5, 2020). These channel conditions were most prominent in the Markagunt Plateau. Bank stability was less impacted across the DNF, with only moderate alterations in the Paunsaugunt–Mt. Dutton and Pine Valley Units. Similarly, the percent of confined reaches classified as impacted tended to be fairly low across the DNF, particularly in the Escalante and Pine Valley Units.

Channels and floodplains were in relatively better condition on the FNF. However, even though four of the seven FNF units were classified as within the NRV, these units still showed evidence of some impacts to the condition of channels and floodplains. Fairly large percentages of riparian areas have converted to alternative cover in all units and most of these units have fairly high percentages of unconfined reaches in very poor to moderate condition. However, channels in FNF units classified as within the NRV do not show signs of widening, are generally vertically stable, and have connectivity between stream and floodplain that remains high. Additionally, streambanks are generally in good condition with regard to stability and all FNF units considered to be within the NRV had relatively low percentages of confined reaches classified as impacted. FNF units classified as moderately altered from the NRV had particularly high percentages of unconfined reaches in very poor to moderate condition and fairly high percentages of change in riparian cover. Finally, the Canyon Mountains of the FNF were classified as outside the NRV for channel and floodplain conditions. This was due to extremely high percentage of riparian areas converted to alternative cover, high percentage of confined reaches classified as impacted, and a high percentage of unconfined reaches in very poor to moderate condition.

See appendix F for additional methodology and descriptions of channel and floodplain dynamics within each geographic unit.

Spring Runout Channel Dynamics

Drivers

The primary drivers of spring runout channel dynamics are flow regimes and sediment inputs (Griffiths et al. 2008; Whiting and Stamm 1995). The hydrographs of spring-dominated channels tend to be less variable than runoff channels (Whiting and Moog 2001). Sediments in spring channels tend to be variable in size with cobbles and boulders generally only present at the head of springs. Typically, springflow-dominated channels lack fine sediments or algae, indicating that sediments are regularly flushed from the system (Whiting and Moog 2001; Whiting and Stamm 1995). The muted hydrograph and limited sediment inputs that are characteristic of springs lead to channels with steep banks and dense vegetative cover, armored beds, greater sinuosity, weakly developed bars, and lower width-to-depth ratios (Griffiths et al. 2008; Whiting and Moog 2001; Whiting and Stamm 1995).

Stressors

Stressors to the condition of spring runout channels include forces or activities that alter spring flow regimes, sediment inputs, or channel structure (table 7; USDA FS 2012). Diversions, regulation, and spring development can alter the amount of flow in the channel as well as the timing or magnitude of pulses (Kendy and Bredehoeft 2006; Sophocleous 2002). Road construction, recreation, and livestock grazing can increase the sediment load and overwhelm the system with sediment that cannot be cleared. These activities can also lead to trampled channel banks and shallower channels. Runout channels affected by trampling, erosion, entrenchment, ditching, or redirection of flow can lead to extreme degradation or the complete elimination of a runout channel.

Results

For most of the DNF and all of the FNF, little information was available about the dynamics of spring runout channels. In the Escalante geographic unit, however, GDEs were surveyed using a modified version of the level I methodology in 2013, 2014, and 2015. Of the 115 sites identified as GDEs, 59 percent had water flowing in channels. Landforms were determined to be stable at 79 percent of sites and 64 percent of channels were judged to be functioning properly.

Composition and Structure of Riparian and Groundwater-Dependent Ecosystems of the Dixie and Fishlake National Forests

In this section we assess the composition and structure of riparian ecosystems and GDEs, a KEC. We describe vegetation community types that were recorded in survey plots and mapped with remote sensing. We use these datasets to determine the status of composition and structure in relation to the NRV. We also summarize descriptions of springs and groundwater-supported wetlands.

Riparian vegetation is fundamentally coupled to the hydrogeology and habitat quality of valley bottoms. The composition and the structure (both vertical and horizontal) of vegetation are influenced by and have an influence on streamflows and geomorphology (Cluer and Thorne 2014). Certain plant species, such as *Carex aquatilis* and *Salix exigua*, have extensive roots systems and numerous shoots that trap sediment and stabilize streambanks during high flows, thus creating and maintaining features that benefit aquatic and terrestrial communities (Griffin et al. 2014; Winward 2000). Willows such as *Salix boothii* and deciduous trees such as *Alnus incana* stabilize streambanks and regulate water temperatures by shading stream channels (Beschta 1997). Cottonwoods, boxelders, and other tall deciduous trees provide nest sites and seasonal foraging opportunities for wildlife, including dozens of bird species (Smith and Finch 2014). By maintaining a connection with groundwater, deep-rooted trees and shrubs transport this resource to above-ground communities throughout a floodplain (Smith and Finch 2017). Sedges, rushes, and grasses provide cover and forage for amphibians, reptiles, waterbirds, and small mammals (Frey and Malaney 2009; Medin and Clary 1990, 1991). An evaluation of riparian vegetation is therefore critical to assessing the composition and structure of riparian ecosystems.

The current composition of plants, animals, and other biota must be evaluated to inform management decisions affecting springs, fens, and other GDEs (Kreamer et al. 2015). An understanding of composition in reference to natural conditions highlights where there is a need for change. This information is, however, scarce relative to information on riparian ecosystems. Site-specific reports about springs, fens, and other wetlands are summarized in this section but were not used in our evaluation of KEC status.

Methodology

We reviewed scientific literature to identify drivers and stressors that influence composition and structure of riparian ecosystems and GDEs. We also selected indicators of current composition and structure in relation to the NRV. We quantified stressors and indicators at the scale of the geographic unit in each Forest. Stressors, indicators, and data sources are described in appendix A.

To determine whether composition and structure are within the NRV, moderately altered, or outside of the NRV in each unit, we examined drivers, stressors, and indicators and then considered the following:

1. Are expected riparian vegetation dominance groups and community types present?
2. Do the ratings of riparian plant composition reflect desired functioning conditions?
3. Does remotely sensed riparian vegetation match the expected natural conditions along most stream segments?
4. Are stressors few, local, and reversible?
5. Is there evidence that anthropogenic effects are improving?

We used these questions to calculate a composition and structure index score. For each geographic unit, we gave "yes" answers a score of 1 and "no" answers a score of 0. If the total score was 4 to 5, we determined that composition and structure is **within** the NRV; if the score was 2 to 3, we determined that composition and structure is **moderately altered**. If the score was 0 to 1, we determined that composition and structure is **outside** of the NRV.

Drivers

Composition and structure of riparian vegetation varies among settings, with physical processes acting at multiple scales to shape the communities adjacent to streams and other bodies of water. Elevation, climate, geology, and biotic communities interact to craft geomorphic features along streams, which influence the vegetation types that can establish through primary and secondary succession (Hough-Snee et al. 2015; Youngblood et al. 1985). Broad, unconfined valley bottoms are created by past glaciations or accumulation of alluvial sediments behind landslides and beaver dams (Westbrook et al. 2011). These areas contain floodplains, benches, and terraces that are colonized by cottonwood, willow, and herbaceous-dominated community types (Gregory et al. 1991; Gruell 1980). Narrower, bedrock-confined valley bottoms typically contain coniferous tree-, low deciduous tree-, and tall deciduous tree-dominated community types (fig. 18).

Riparian and wetland ecosystems are also shaped by current surface water and groundwater dynamics. Growth and survival of deep-rooted plants such as cottonwoods and willows are dependent on stable groundwater connections (Bilyeu et al. 2008). These connections are maintained by processes such as floods, springs, beaver dams, and accumulation of instream wood (Montgomery et al. 2003; Pollock et al. 2014; Stromberg 2001). Where present, karst systems influence surface flows through storage and transport of groundwater (Godfrey 1985; Mills 1989). By raising water tables and distributing surface flows, beaver dams encourage the establishment of willow- and herbaceous-dominated community types (Gibson and Olden 2014; Marshall et al. 2013).



Figure 18—Conifer- and low deciduous tree-dominated community types are found along this confined section of the Beaver River in the Tushar Mountains geographic unit. Photo by D. Max Smith, Forest Service.

A variety of natural disturbances influences composition and structure of riparian communities in confined and unconfined settings. In high-order streams, reproduction of cottonwoods, willows, and other pioneering species occurs in response to valley bottom scour and sediment deposition (fig. 19). These conditions occur during years with heavy precipitation and spring runoff (Baker 1990; Dykaar and Wigington 2000). In low-order streams at higher elevations, flood disturbance is typically less severe. Late seral vegetation, which includes sedges and willows, stabilizes streamside soils, creating overhanging banks and narrow stream channels (fig. 20) (Winward 2000). Moderate- to high-severity wildfire results in above-ground mortality of trees and shrubs but can encourage establishment of deciduous species through sprouting or germination (Dwire and Kauffman 2003; Gruell 1980; Smith et al. 2009; Wolf et al. 2007). Flooding, beaver activity, and ice flows can also cause reduction of height and clonal sprouting of willows and cottonwoods (Wilding et al. 2014).

Water availability and geomorphic setting are the primary bottom-up drivers of GDE composition (Cooper and Merritt 2012; Magee and Kentula 2005; Stevens and Meretsky 2008). Climate and geology interact to shape volume and chemistry of groundwater, which is a determinant of plant and animal community composition of springs and fens (Chimner et al. 2010; Lemly and Cooper 2011; Sada et al. 2001). In fens of the Mountain West, composition and structure of vegetation is largely influenced by physical and chemical characteristics (Chimner et al. 2010; Lemly and Cooper 2011; Wolf and Cooper 2015). Peatland plant communities vary among geomorphic



Figure 19—In response to highly variable flows in Sand Creek in the Fishlake–Thousand Lake geographic unit, tall deciduous tree-dominated community types have colonized several benches and terraces above the active channel. Photo by D. Max Smith, Forest Service.



Figure 20—Relatively stable flows in the upper Fremont River in the Fishlake–Thousand Lake geographic unit result in heavily vegetated streambanks stabilized by late seral herbaceous-dominated community types. Photo by D. Max Smith, Forest Service.

settings such as sloping fens, patterned fens, and floating mat fens. This variation is driven by gradients in water table depth and duration of surface inundation (Cooper and Andrus 1994). Fens are typically dominated by herbaceous vegetation, particularly sedges and mosses, but shrubs and trees are present in some situations (Hansen et al. 1995; Lemly and Cooper 2011). Rich fens, fed by high pH water from carbonate bedrock, have high species richness whereas poor fens, with low pH from iron-rich bedrock, have low species richness but support plant species typically found in other regions (Chimner et al. 2010; Chimner 2011).

Stressors

There are numerous stressors, both natural and anthropogenic, affecting the structure and composition of riparian ecosystems and GDEs (table 7). Because of high productivity and frequently exposed soil, these areas are especially vulnerable to colonization by introduced plants (Richardson et al. 2007). Plants with potential to spread into riparian areas include herbaceous thistles, forage grasses, and woody species such as Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix* spp.). Following disruption of natural processes, these invasive plants replace native species, but they often provide poor habitat and continue to alter the natural dynamics of floodplains (Frey and Malaney 2009; Smith and Finch 2014).

In coniferous tree-dominated landscapes, fire helps to maintain natural riparian vegetation by preventing encroachment and dominance by conifers and other late-successional species (Kleindl et al. 2015). Widespread suppression of wildfire has therefore led to changes in riparian composition in landscapes adapted to frequent fire (Hall 1971; Gruell 1980). In low elevation floodplains, fire can result in mortality of native deciduous trees and facilitate replacement by invasive and upland species (Smith et al. 2009). Though moderate to high severity wildfires are increasing in frequency, much of the forest area has a high wildfire hazard risk resulting from decades of fire suppression (table 7).

Dams, diversions, and roads can disrupt surface flows that shape a stream's geomorphology and connect the channel to its floodplain. Additionally, these structures disrupt natural processes of scour and deposition. By altering the volume and timing of surface flows or removing them altogether, dams and diversions reduce the extent of riparian vegetation in affected areas (Dewine and Cooper 2007). Roads and other forms of development restrict the movement of stream channels, thereby limiting the horizontal structure of riparian vegetation to a subsection of the historical floodplain (Forman and Alexander 1998; Jones et al. 2000; Salo and Theobald 2016; Trombulak and Frissell 2000).

Livestock and wildlife herbivory influence the composition, vertical structure, and coverage of riparian vegetation. Impacts of cattle grazing include decreased cover of native plants and increased cover of introduced plants (Hansen et al. 1995; Platts and Nelson 1989). Growth is also affected by wild ungulate browsing, beaver herbivory, and flooding behind beaver dams (Gruell 1980). Removal of beaver from watersheds has resulted in

stream incision and lowered water tables (Pollock et al. 2014). These changes prompt the loss of willow and herbaceous communities and encourage the encroachment of conifers and upland plants into valley bottoms (Marshall et al. 2013). Recreational use of riparian areas creates additional stressors in the form of direct damage to vegetation and the introduction of invasive species.

Springs are among the ecosystems most threatened by anthropogenic activities in the western United States. (Stevens and Meretsky 2008). Spring developments for irrigation and livestock include installation of headboxes, diversion of flows to troughs and other structures, and construction of ponds within GDEs (Sada et al. 2001). These activities have adverse effects on plants and animals at GDEs, but spring-dependent species can persist in properly developed springs (Gurrieri 2020; Unmack and Minckley 2008).

Wildlife and livestock directly affect GDEs through grazing and browsing of vegetation. Grazing and browsing can also cause soil compaction, hummocking, headcutting, and other disturbance (Sada et al. 2001). Effects of recreation include vegetation trampling, soil compaction, and alteration of the natural runout channels for soaking pools. Natural stressors also include wildfire, drought cycles, and geological events, such as earthquakes (Wood et al. 1985). As a result of fire suppression, conifer and sagebrush encroachment reduces the extent of willows and wetlands at springs (Gruell 1980). In fens and other wetlands, disturbance to soils by ditching, trailing, and stream incision reduces soil saturation, resulting in oxidation and degradation of peat (Chimner and Cooper 2003).

Indicators

We combined data from several sources to describe the composition and structure of riparian ecosystems in each geographic unit. We compiled a list of vegetation communities from level II and level III riparian surveys and organized these types into dominance groups. Level II surveys were conducted on one occasion for each stream reach, in 1994 or 1995 in the DNF and in 2002, 2003, 2004, 2005, or 2006 in the FNF. Level III sites are measured every 5 years in both Forests. For each level III site, we listed communities observed during the most recent measurements.

To approximate the area and location of dominance groups, we clipped a shapefile of existing vegetation to the 50-year floodplain map. We also included existing vegetation classified as riparian that was outside of the 50-year floodplain, including vegetation associated with potential fens, as mapped by the CNHP.

We used data produced through the Riparian Condition Assessment Tool (R-CAT) to estimate the percentage of reaches affected by conversion to conifers, upland shrubs and grasses, and invasive species (Macfarlane et al. 2017). We also used R-CAT results to describe the physical setting of stream reaches as confined or unconfined. We summarized plot-level data collected using the level II and level III methodologies on the DNF (fig. 21) and the FNF (fig. 22). We used these datasets to identify the riparian vegetation types that are present and calculate the percentage of stream segments judged to contain native, late seral riparian vegetation that maintains bank stability.

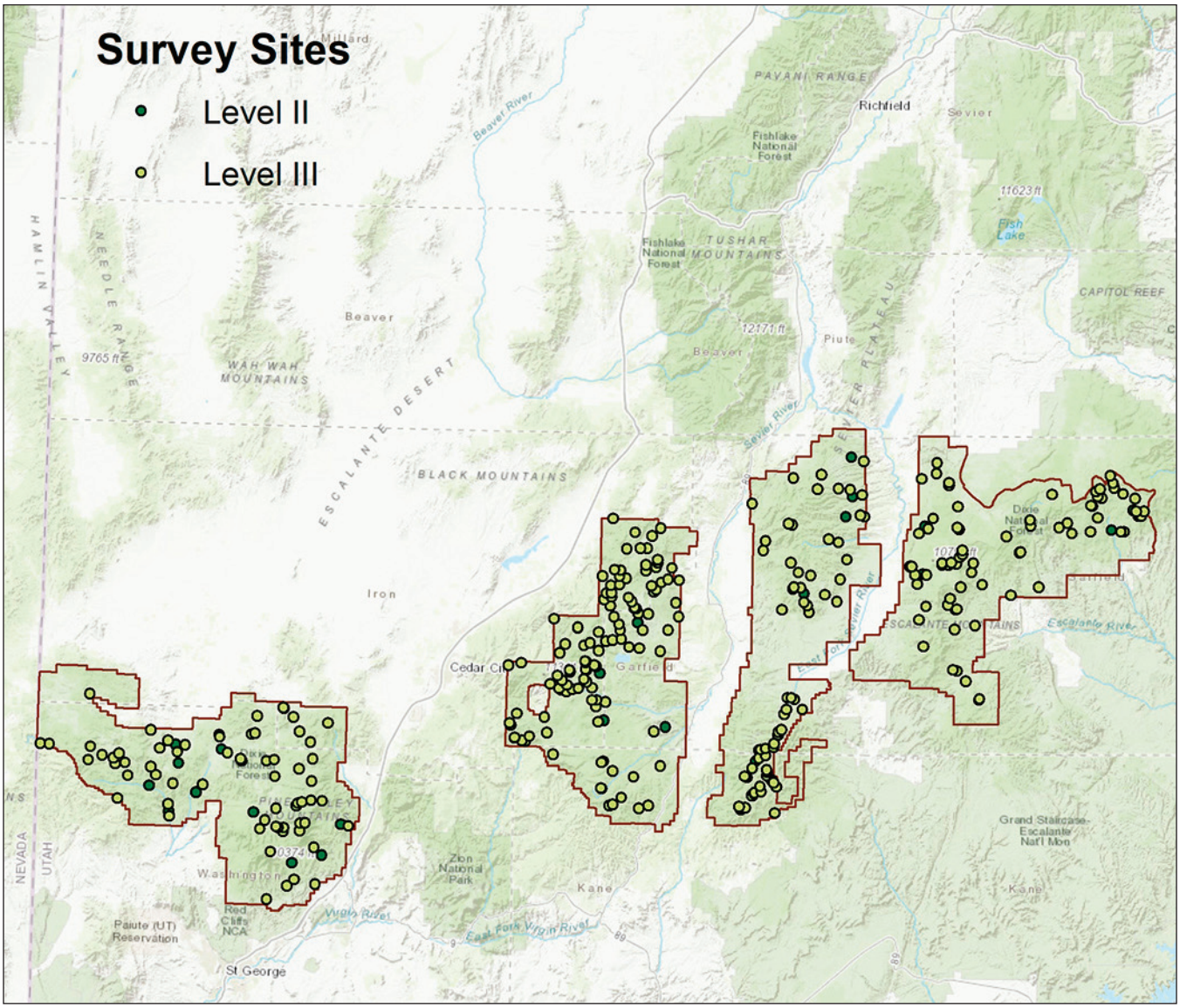


Figure 21—Location of level II and level III survey sites in geographic units of the Dixie National Forest.

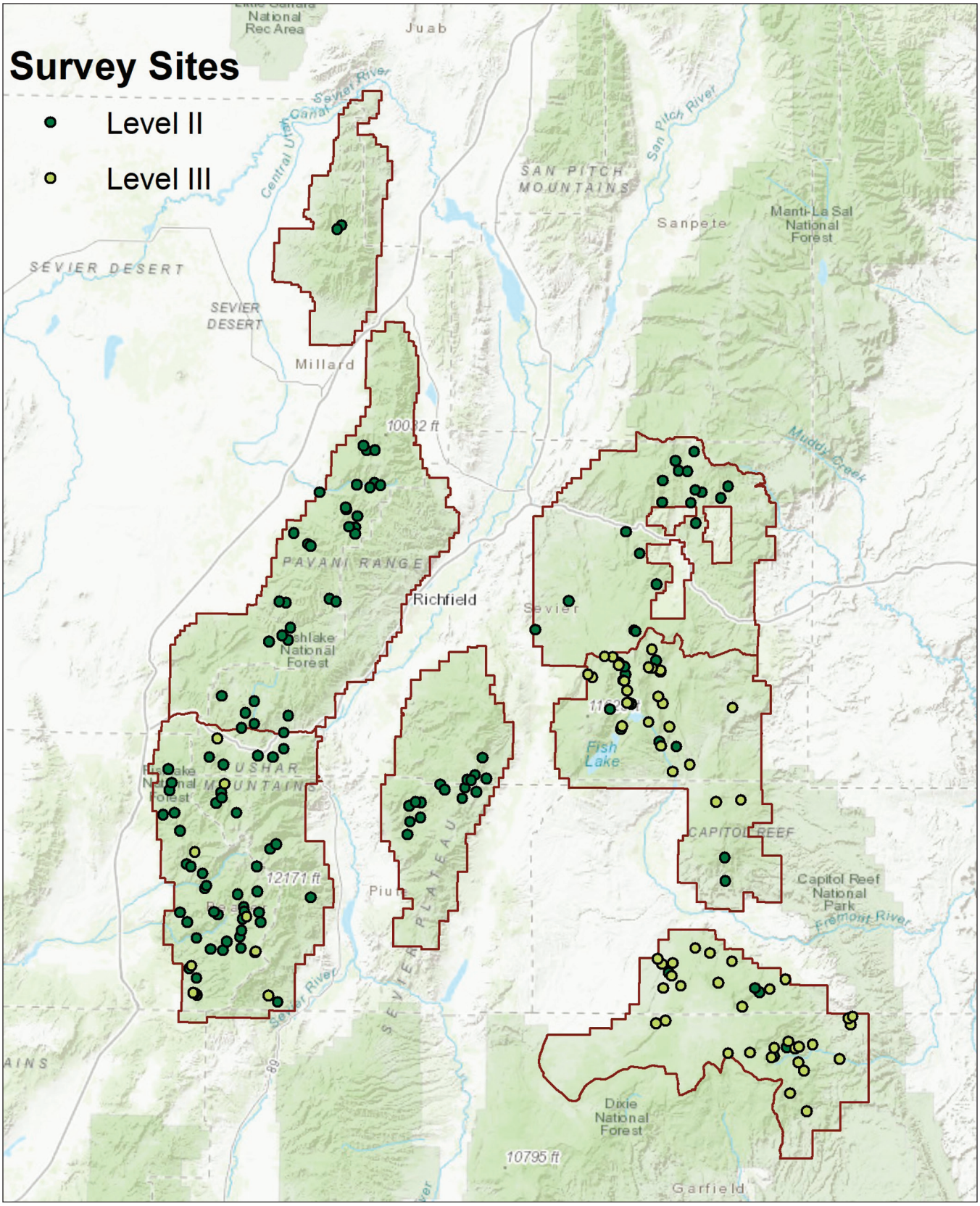


Figure 22—Location of level II and level III survey sites in geographic units of the Fishlake National Forest.

Results

Level II and level III surveys reported community types dominated by coniferous trees, tall deciduous trees, low deciduous trees, tall willow trees, nonwillow shrubs, and herbaceous plants at each geographic unit in the DNF (table 10). Low willow-dominated types were found at the Markagunt Plateau and Paunsaugunt–Mt. Dutton units. Coniferous tree-, tall deciduous tree-, and herbaceous-dominated community types were observed at each geographic unit in the FNF (appendix B). Low deciduous- and tall willow-dominated types were found at each unit except for the Canyon Mountains. Low willow-dominated types were found at the Boulder Mountain, Fishlake–Thousand Lake, Tushar Mountains, and White Mountain units. Nonwillow shrub-dominated types were found at every unit except for Boulder Mountain, Canyon Mountains and White Mountain.

For most of the DNF, little information is available about plants and animals associated with springs and fens, except for the Escalante unit, which contains spring-fed wetlands, some of which may be fens (fig. 23; appendix G). Information about plant and animal communities associated with GDEs is limited in all areas of the FNF. Level II riparian surveys in the Pavant Range found that spring channels support dense growth of bittercress (*Cardamine cordifolia*) and other herbaceous plants in the channel and along the stream margin. Vertical expanses of moss, lichens, and herbaceous vascular plants flourish where spring channels spill over steep outcroppings in the Pavant Range and Thousand Lake Plateau (fig. 24). Several springs in the Fillmore Ranger District were found to provide habitat for a rare species of spring snail (*Pyrgulopsis peculiaris*; Swensen and Kelly 2016). Damage to springs from livestock was reported in level II riparian surveys at each geographic

Table 10—Percentage of dominance groups in the 50-year floodplain, as mapped by VCMQ.

Geographic unit	Forest	Coniferous tree	Herbaceous	Riparian shrub/tree	Upland shrub	Upland woodland
Escalante	Dixie	32.1	5.1	15.9	21.7	19.8
Markagunt Plateau	Dixie	27.9	22.4	8.3	25.6	7.5
Paunsaugunt–Mt. Dutton	Dixie	23.7	9.8	8.1	44.6	11.6
Pine Valley	Dixie	3.3	9.4	8.2	26.1	49.1
Boulder Mountain	Fishlake	16.0	21.9	16.1	23.9	18.2
Canyon Mountains	Fishlake	0.4	49.6	2.0	9.8	37.8
Fishlake–Thousand Lake	Fishlake	4.7	12.8	17.8	32.9	21.3
Monroe Mountain	Fishlake	6.4	4.7	39.3	22.5	22.2
Pavant Range	Fishlake	8.1	3.9	13.5	19.8	54.1
Tushar Mountains	Fishlake	21.4	2.7	22.3	8.6	41.7
White Mountain	Fishlake	3.3	9.7	20.5	19.0	43.9



Figure 23—This herbaceous-dominated community in the Escalante geographic unit is supported by groundwater and has accumulated peat, making it a potential fen. Photo by the Dixie National Forest.



Figure 24—This spring flows over rocks and logs, creating a unique community of mosses, lichens, and vascular plants near Chalk Creek in the Pavant Range. Photo by Shell Valley Consulting.

unit. These surveys also report that water is impounded and diverted from springs for livestock, campgrounds, and municipal use (fig. 25). As expected, most of the area mapped as potential fens overlaps herbaceous-dominated communities (table 11). The only exception is the White Mountain unit of the FNF, in which most of the area mapped as potential fens overlaps riparian tree- and shrub-dominated community types.



Figure 25—This spring in the Canyon Mountains has been impounded and is affected by heavy livestock use. Photo by D. Max Smith, Forest Service.

Table 11—Percentage of dominance groups corresponding to potential fens, as mapped by CNHP and VCMQ.

Geographic unit	Forest	Coniferous tree	Herbaceous	Riparian shrub/tree	Upland shrub	Upland woodland
Escalante	Dixie	3.0	46.3	20.0	1.6	0.1
Markagunt Plateau	Dixie	2.7	76.1	15.7	3.5	0.7
Paunsaugunt–Mt. Dutton	Dixie	9.2	83.4	6.2	1.2	0.02
Pine Valley	Dixie	1.1	87.1	6.7	1.5	3.4
Boulder Mountain	Fishlake	8.9	65.8	9.2	1.4	1.1
Canyon Mountains	Fishlake	0	0	40.0	0	60.0
Fishlake–Thousand Lake	Fishlake	1.5	48.1	25.4	10.4	1.6
Monroe Mountain	Fishlake	1.2	48.5	28.3	20.9	0.9
Pavant Range	Fishlake	0.4	50.4	23.5	12.7	13.0
Tushar Mountains	Fishlake	18.0	51.0	19.5	5.3	3.0
White Mountain	Fishlake	1.4	22.3	36.2	16.0	14.2

Based on spatial and plot-level data, composition and structure is outside of the NRV in three geographic units (Pine Valley in the DNF; Canyon Mountains and Tushar Mountains in the FNF). The remaining geographic units are moderately altered from the NRV (fig. 26). Several stressors were present in each geographic unit when level II surveys were conducted. These include surface flow diversions, roads, ATV use, and livestock grazing. In addition, beaver activity was observed at only a few streams in each unit. Heavy livestock use has removed vegetative cover from streambanks and diminished the structure of woody vegetation. These effects are not uniform throughout any unit. Instead, the severity of livestock use varies among stream reaches and watersheds. Damage to riparian vegetation and aquatic ecosystems by ATVs and other forms of recreation was widespread in the Forests. Herbaceous nonnative species include *Cirsium vulgare*, *Cirsium arvense*, and *Bromus tectorum*.

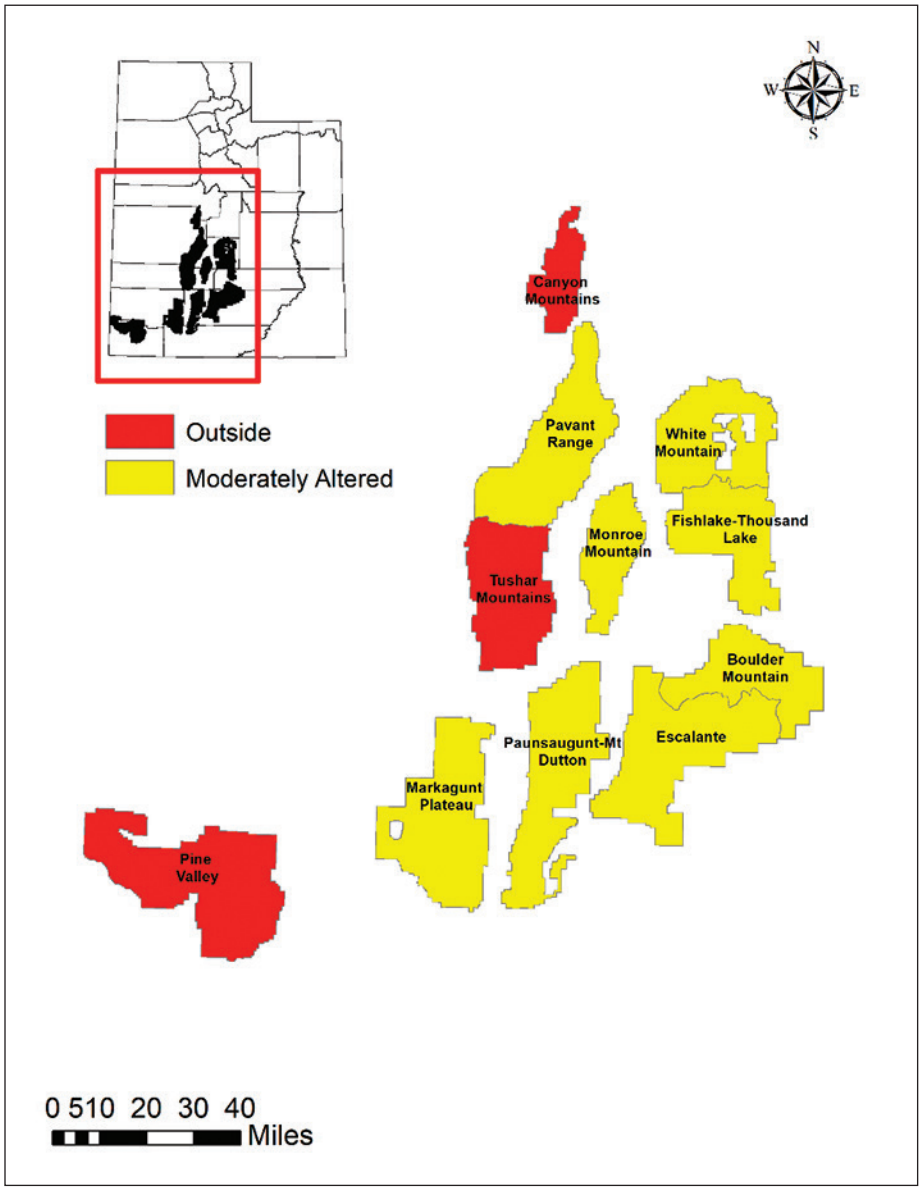


Figure 26—NRV status of composition and structure of riparian and groundwater-dependent ecosystems on the Dixie and Fishlake National Forests.

Levels of stressors and indicators showed some variation among DNF geographic units (appendix G). We found that the Escalante unit had moderate levels of stressors relative to the other DNF units (table 7). Effects of dams and diversions are greatest in the Markagunt and Pine Valley units. Nonnative and invasive species are most prevalent in the Paunsaugunt–Mt. Dutton unit, most likely as result of range improvement projects on the Paunsaugunt Plateau. In this area, riparian ecosystems in the East Fork Sevier River watershed were converted from a system with abundant beaver ponds and willow-dominated community types to a system with fewer ponds and with streamside vegetation dominated by nonnative herbaceous communities (Robinson et al. 1998). Riparian vegetation along most stream miles in the DNF has been converted from what would be expected under natural conditions, based on R-CAT results (table 12) Late seral vegetation communities were abundant at survey sites in all units except for Pine Valley. Despite numerous stressors and indicators of departure from the NRV in the DNF, we found evidence that composition and structure of riparian ecosystems are improving towards natural conditions at the Escalante and Paunsaugunt–Mt. Dutton units (appendix G).

We found greater variation in stressors and indicators at FNF geographic units. The Boulder Mountain unit has low road density, high percentages of late seral vegetation, and active beaver colonies in several watersheds. According to R-CAT results, Boulder Mountain was the only unit in which departure of riparian vegetation from natural conditions was low along most stream miles (table 12). At the Tushar Mountains, floodplain road density

Table 12—Percentage of stream miles affected by certain types of riparian vegetation conversion or no change, as determined by the Riparian Condition Assessment Tool (R-CAT).

Geographic unit	Conifer encroachment	Upland grass/shrub encroachment	Invasive conversion	Agriculture	Development	No change
Escalante	28.6	4.1	1.1	0.6	9.0	46.3
Markagunt Plateau	32.5	17.3	2.5	0.2	10.8	33.2
Paunsaugunt–Mt. Dutton	15.6	34.7	12.1	0.1	4.2	29.7
Pine Valley	49.2	12.2	0.5	4.2	6.5	25.9
Boulder Mountain	33.0	3.3	0.6	0.6	3.7	55.6
Canyon Mountains	34.8	37.2	1.9	0	18.2	4.4
Fishlake–Thousand Lake	25.2	23.1	0.5	0.2	6.4	46.1
Monroe Mountain	49.9	3.9	0.3	1.0	3.4	40.1
Pavant Range	40.3	11.0	0	2.6	3.3	39.4
Tushar Mountains	48.5	11.5	0.2	0.1	8.8	28.0
White Mountain	24.8	8.2	1.0	0.4	21.1	38.9

is high, as are fire hazard potential and area burned by wildfire (table 7). In addition, many Tushar Mountain stream segments are affected by beaver removal and invasive plant species. Invasive species are especially prevalent along Clear Creek in the Tushar Mountains, Pavant Range, and Salina Creek in the White Mountain units. Late seral vegetation communities were abundant at survey sites in all units (table 13). We found that indicators of composition and structure are improving at the Fishlake–Thousand Lake geographic unit but have drastically declined at the Canyon Mountains. Stressors contributing to declines at the Canyon Mountains likely include beaver removal, high severity wildfire, livestock grazing, diversions, and herbicide application (Swensen and Kelly 2016). At the Fishlake–Thousand Lake unit, conditions were notably poor during level II surveys of the U M Creek watershed in 2002 but had improved by 2009. Improvements in vegetation cover and composition were attributed to grazing exclosures and ATV restrictions (Shell Valley Consulting 2009). Values of stressors and indicators were moderate at the Monroe Mountain, Pavant Range, and White Mountain units.

Table 13—Plot-level indicators of native, late seral vegetation. Values represent the percentage of sites judged to have later seral or potential native community (PNC) vegetation during level II surveys in the Dixie National Forest; the percentage of sites judged to have a stable or upward forage trend during level II surveys in the Fishlake National Forest; and percentage of sites in desired condition (a high percentage of greenline vegetation composed of late-seral communities) during the most recent level III surveys in the Dixie and Fishlake National Forests.

Geographic unit	Percent late seral/PNC (level II)	Percent stable/upward forage trend (level II)	Percent desired condition (level III)
Escalante	46.5	NA	63.3
Markagunt Plateau	45.8	NA	73.0
Paunsaugunt–Mt. Dutton	32.3	NA	70.3
Pine Valley	39.3	NA	52.4
Boulder Mountain	59.6	NA	74.2
Canyon Mountains	NA	95.3	NA
Fishlake–Thousand Lake	NA	53.6	73.1
Monroe Mountain	NA	84.5	NA
Pavant Range	NA	81.1	NA
Tushar Mountains	NA	70.9	40.0
White Mountain	NA	86.8	NA

Summary

It is difficult to describe the NRV for composition and structure of riparian ecosystems, given their dynamic nature and long-term human influences. It is also difficult to describe the NRV for GDEs because of a general lack of information and data. Riparian vegetation community types and GDEs are affected by multiple stressors including roads, livestock use, and nonnative plant species. We therefore determined that composition and structure is either outside of the NRV or moderately altered in each of the geographic units. Based on available data, composition and structure are closest to the NRV at the Boulder Mountain, Escalante, Paunsaugunt–Mt. Dutton, and Fishlake–Thousand Lake units. Conditions are furthest from the NRV at the Canyon Mountains, Tushar Mountains, and Pine Valley units. Declining conditions have been noted at riparian ecosystems and GDEs in the Canyon Mountains. In contrast, conditions have seen great improvement at sites in the Fishlake–Thousand Lake unit. These results highlight the need for continued monitoring and adaptive management of riparian ecosystems and GDEs in the Forests.

Conclusions

Overall Patterns and Trends

We combined results from field investigations and spatial analyses to assess the distribution and condition of riparian ecosystems and GDEs throughout the DNF and FNF (appendix H). Level II and level III riparian surveys found that important wildlife habitats, such as cottonwood stands, herbaceous wetlands, and tall willows, are present in each geographic unit. Cottonwood-dominated vegetation types are prevalent along streams in the Canyon Mountains and Pavant Range. Tall willow-dominated types occur in each unit and are abundant at Monroe Mountain, White Mountain, Markagunt Plateau, and Pine Valley. Expansive herbaceous-dominated community types are located in the Fishlake–Thousand Lake, Boulder Mountain, Markagunt Plateau, and Paunsaugunt–Mt. Dutton units. In addition to wildlife habitat, these vegetation types play key roles in the maintenance of streambank stability, water quality, and carbon storage.

Springs maintain surface flows and support aquatic and riparian habitats throughout the Forests. Springs are present in a variety of geological settings but appear most abundant in areas that are heavily faulted or characterized by unconsolidated deposits below volcanic plateaus. Wetlands most likely to be fens are abundant in high elevation, volcanic landscapes such as the Boulder Mountain and Fishlake–Thousand Lake geographic units. Level II GDE inventories are needed to confirm the presence of fens and document associated species in these areas.

Evaluation of KECs revealed clear differences in the overall condition of riparian ecosystems among geographic units. The unit most affected by anthropogenic activities was the Canyon Mountains, where channel, floodplain, and vegetation dynamics were operating outside of the NRV and surface water and groundwater fluctuations are moderately altered. This low elevation, arid range has few perennial stream segments relative to the other units, so stressors are heavily concentrated on scarce riparian ecosystems. On the other hand, KECs were operating within the NRV or were moderately altered at several units including Boulder Mountain, Escalante, Fishlake–Thousand Lake, Monroe Mountain, and Pavant Range. These units have higher elevations and abundant surface water resources, which may increase the resistance and resilience of riparian ecosystems to multiple stressors.

Management Issues/ Data Gaps

In conducting this assessment, we found recurring issues for riparian ecosystems and GDEs. To maintain the ecological integrity of these ecosystems, these issues should be addressed through additional research that will inform changes to forest management plans.

Beavers

Beaver dam complexes maintain potential natural conditions in unconfined valley bottoms. These complexes include willow stands and herbaceous-dominated wetlands that are critical habitat for wild ungulates, small mammals, amphibians, waterbirds, sage grouse, and neotropical migrant birds (Arkle and Piliod 2015; Frey and Malaney 2009; Hossack et al. 2015; McKinstry et al. 2001; Medin and Clary 1990, 1991).

The influence of beaver dams is absent from many, if not most stream systems in the Forests. Several watersheds, including the East Fork Sevier River in the DNF and Clear Creek in the FNF, have active beaver dam complexes, but densities remain lower than historical levels. At other streams, beaver dams are present, but they do not provide the long-term stability and beneficial effects of larger beaver dam complexes. Due to shortages of building materials such as aspen and willow, these dams are frequently breached during high flows, which exposes soil, increases sediment movement, and makes riparian areas vulnerable to livestock impacts. Under these conditions, the beneficial ecosystem effects of beaver dams will not be realized until woody riparian vegetation is restored and beaver populations have increased. Additional information is needed to determine where beaver dams are functioning, where reintroductions are succeeding, and where dams could best be used to maintain or restore perennial flows to benefit native fish, amphibians, sage grouse, and other wildlife.

Highways, Roads, and Recreation

The construction of roads and highways has influenced riparian ecosystems in each unit. The dynamics of riparian ecosystems are especially affected by highway construction in the Pavant Range, Tushar Mountains, and White Mountain units. ATV use was frequently described in level II surveys as a stressor to riparian vegetation and aquatic communities. Condition in the Fremont River watershed improved following restrictions put in place between 2002 and 2009. Given the popularity of the Forests for recreation, including motorized vehicle use, managers may consider identifying and protecting additional sensitive areas from disturbance caused by ATV use.

Livestock Use

In each geographic unit, grazing effects were reported to be minor to moderate at streams and springs, but in certain locations effects on vegetation and soil were severe. Improvements in vegetation and soil condition in the U M Creek watershed, however, showed that riparian ecosystems can recover if livestock are excluded from sensitive areas. Livestock influences were noted at most of the sites visited for GDE surveys in the Escalante unit of the DNF. Based on observations from level II riparian surveys, it is likely that livestock are influencing the soil, vegetation structure, and water quality of GDEs in other units as well. A comparison of GDE conditions at managed areas versus conditions at reference areas (such as wilderness sites or livestock exclosures) would help the Forests evaluate livestock effects on GDEs and their capacity for recovery.

Surface Flows

Multiple stressors are impacting the timing and volume of surface flows, especially on the DNF. Increases in temperature and decreases in winter and spring precipitation will likely decrease the volume of flows and change the timing of peak flows. Such changes would impact the reproduction, survival, and growth of riparian vegetation, with consequences for fish and wildlife populations. Climate-induced changes to surface flows would further impact riparian ecosystems in units such as the Markagunt Plateau and Pine Valley, where numerous diversions and impoundments have already altered natural flow regimes.

Groundwater

The distribution of springs drives the dynamics of streams, riparian ecosystems, and wetlands throughout the study area. Many, if not most, streams on the Forests originate at springs and aquatic ecosystems are maintained by groundwater during the dry portions of the year. Groundwater also supports recreation, agriculture, and local municipalities. Climate-induced changes to surface flows may increase demands on groundwater while also decreasing the amount available for use. Investigations are needed to identify groundwater pathways, such as karst systems and other aquifers, in each geographic unit. With this information, managers can assess the distribution and vulnerability of GDEs and identify locations of groundwater storage and discharge that are most resilient to changes in temperature and precipitation.

Level II and Level III Surveys

Our analyses include plot data from level II and level III surveys. For the purposes of our assessment, both methodologies had strengths and limitations. We found the level II surveys to be useful for identifying the riparian vegetation types and seral stages present in the Forests at that time of data collection. Their descriptions of GDEs, beaver dams, and other features found while systematically surveying streams were useful as well. Level II data were of limited use for assessing current conditions, however, because it has been at least 25 and 14 years since they were collected in the DNF and FNF, respectively. Level III surveys provides useful quantitative data for judging current greenline conditions based on a site's potential. These surveys were, however, generally lacking descriptions of features such as GDEs and beaver dams. Level III surveys were conducted throughout the DNF (fig. 21) but were limited to the Fishlake–Thousand Lake and Tushar Mountains units of the FNF (fig. 22). To develop a better understanding of riparian ecosystem conditions, level III surveys should be expanded to include the Canyon Mountains, Pavant Range, Monroe Mountain, and White Mountain geographic units. If resources are limited, managers may consider giving priority to sites where cutthroat trout, boreal toad, springsnails, and other species of concern are known to occur. In addition, it would be useful to repeat the systematic level II surveys of as many streams as possible in each Forest. In addition to describing riparian community types and current conditions, these surveys could be used to evaluate levels of beaver activity and find undescribed GDEs. Results would help the Forests address the data gaps described above.

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Appendix A. Data Used to Assess Riparian and Groundwater-Dependent Ecosystems

Table A.1—The source and description of data used to assess the ecological integrity of riparian and groundwater-dependent ecosystems located on the Dixie and Fishlake National Forests.

Variable	Source(s)	Explanation
Perennial stream miles	National Hydrography Dataset	Total length of stream segments with year-round surface flows
Intermittent stream miles	National Hydrography Dataset	Total length of stream segments with seasonal surface flows and accessible groundwater
50-yr floodplain map	Rocky Mountain Research Station	Area generated with data representing 50-year flood heights, valley bottom widths, riparian soils, and wetland coverage
Potential riparian acres	50-year Flood Map, U.S. Forest Service Vegetation Classification, Mapping, and Quantitative Inventory	Potential riparian estimated by combining 50-year floodplain map and map of vegetation classified as riparian by VCMQ
% vegetation classified as riparian	U.S. Forest Service Vegetation Classification, Mapping, and Quantitative Inventory	Vegetation classified as riparian woody or herbaceous woody
NHD spring density	National Hydrography Dataset	Number of springs per acre, as mapped by the NHD
WRU spring density	U.S. Forest Service Water Rights and Uses Databases	Number of springs per acre, as mapped in the DNF and FNF WRU database
DNF spring density	Dixie National Forest Geodatabase	Number of springs per acre, as mapped in the DNF geodatabase
Acres of potential karst	U.S. Geological Survey	Amount of area with carbonate bedrock with the potential for karst formation
Acres of potential fens	National Wetlands Inventory, Colorado Natural History Program	Amount of area covered by wetlands that are potentially fens
Road density	U.S. Forest Service Terrestrial Condition Assessment	Road miles per acre of geographic unit
% of roads unimproved	U.S. Forest Service Terrestrial Condition Assessment	Percentage of roads that are unpaved and non-graveled
Trail density	U.S. Forest Service National Dataset	Recreation trail miles per acre
Floodplain road density	U.S. Forest Service Terrestrial Condition Assessment, 50-Year Floodplain Map	Road miles per 50-year floodplain acre
Floodplain trail density	U.S. Forest Service National Dataset, 50-year Floodplain Map	Trail miles per 50-year floodplain acre
Floodplain recreation sites	U.S. Forest Service National Dataset, 50-Year Floodplain Map	Number of recreation sites per 50-year floodplain acre

(continued on next page)

Variable	Source(s)	Explanation
Diversion density	Utah Division of Water Rights Database, U.S. Forest Service Water Rights and Uses Database	Number of water diversion points per acre
Dams per stream mile	Utah Division of Water Rights Database, US Forest Service Water Rights and Uses Database	Number of diversion or retention dams per acre
% unit RMU	U.S. Forest Service National Dataset	Percentage of the area overlapping range management units (grazing leases)
% unit RMU active	U.S. Forest Service National Dataset	Percentage of the area overlapping actively grazed range management units
% unit harvested	U.S. Forest Service National Dataset	Percentage of the area with timber harvest
% harvests clearcut	U.S. Forest Service National Dataset	Percentage of the area with timber harvest using clearcut methods
% high severity burn	U.S. Forest Service Terrestrial Condition Assessment	Percentage of the area burned by high severity wildfires between 1984 and 2014
Winter temperature deviation	U.S. Forest Service Terrestrial Condition Assessment	Percent change in winter temperature
Winter precipitation deviation	U.S. Forest Service Terrestrial Condition Assessment	Percent change in winter precipitation
Floodplain high/very high WHP	U.S. Forest Service Terrestrial Condition Assessment	Percentage of 50-year floodplain with high or very high wildfire hazard potential
Moderate/high wildfire severity	U.S. Forest Service Terrestrial Condition Assessment	Percentage of 50-year floodplain experiencing moderate to high severity wildfire between 1984 and 2014
Conversion to conifer	Riparian Condition Assessment Toolbox	Mean proportion of conifer encroachment occurring along stream reaches
Conversion to grass/shrub	Riparian Condition Assessment Toolbox	Mean proportion of upland vegetation encroachment occurring along stream reaches
Water quantity score	U.S. Forest Service Watershed Condition Classification	Indicator of change in magnitude, duration and timing in relation to natural hydrograph
Riparian/wetland vegetation condition	U.S. Forest Service Watershed Condition Classification	Indicator of function of native vegetation at streams and water bodies
Conversion to development/agriculture	Riparian Condition Assessment Toolbox	Percentage of stream reaches where vegetation has converted from riparian to developed or agriculture cover
Stream temperature	U.S. Forest Service NorWeST Stream Temperature Database	Average August stream temperature
WCC impaired waters	U.S. Forest Service watershed Condition Classification	Percentage of water bodies listed as impaired by the state

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Variable	Source(s)	Explanation
WCC water quality problems	U.S. Forest Service watershed Condition Classification	Indicator of water quality issues above natural or background levels
Embeddedness	U.S. Forest Service Level II Riparian Surveys	Indicator of cementation of streambed substrate
% of unit impaired	Utah Department of Environmental Quality	Percentage of water bodies listed as impaired by the state
Channel shape and function	U.S. Forest Service Watershed Condition Classification	Indicator that width-depth ratio is within expected range
% of stream with no change	Riparian Condition Assessment Toolbox	% of stream segment with no change from riparian vegetation
% of confined stream impacted	Riparian Condition Assessment Toolbox	% of confined segment with conversion of riparian vegetation and replacement by developed land
% of unconfined streams very poor to moderate	Riparian Condition Assessment Toolbox	% of confined segment with conversion of riparian vegetation and floodplain development
% of reaches with good stability	U.S. Forest Service Level II Riparian Surveys	Average percentage of streambanks classified as stable
Conversion to invasive vegetation	Riparian Condition Assessment Toolbox	Mean proportion of conversion to invasive species occurring along stream reaches
Stream confinement	Riparian Condition Assessment Toolbox	Percentage of stream reaches classified as confined by the Riparian Condition Assessment procedure
Floodplain composition	U.S. Forest Service Vegetation Classification, Mapping, and Quantitative Inventory	% cover of vegetation types within the 50-year floodplain, as classified by the VCMQ program
Late/PNC	U.S. Forest Service Level 2 Riparian Surveys	Percentage of stream reaches with successional status classified as in late succession or potential natural community
Stable/upward forage trend	U.S. Forest Service Level 2 Riparian Surveys	Percentage of stream reaches with forage trend, based on condition and composition of vegetation, that was classified as stable or upward
Desired condition	U.S. Forest Service Level 3 Riparian Surveys	Percentage of sites determined to be in desired condition based on overall trend, seral status, stability rating, and ground cover

Appendix B. Dominance Groups and Community Types of the Utah Plateaus Floristic Section

Table B.1 begins on the next page.

Table B.1—Dominance groups and community types, including citations, of the Utah Plateaus floristics section.

Dominance group	Community type	Elevation range (feet)	Valley bottom width	Geomorphic features	Soil types	Soil particle sizes	Soil water regimes	References
Coniferous tree	Conifer/ *Aconitum columbianum*	6,000–10,500	No data	Terraces, streambanks, springs	No data	Fine to coarse, organic	Variable and fluctuating	Padgett et al. 1989
	Conifer/ *Dasiphora fruticose*	9,000–9,600	No data	Terraces, hillslopes	Mollisols	Fine to coarse	Variable and fluctuating	Padgett et al. 1989
	Conifer/ *Equisetum arvense*	7,360–9,200	Moderate to broad	Terraces, floodplains, meadows, shallow ponds, hillslopes, springs, fens	Entisols, Inceptisols, Mollisols, Histosols	Fine to coarse	Variable and fluctuating	Bowerman 1999; Crowe et al. 2004; Hansen et al. 1995; Padgett et al. 1989; Youngblood et al. 1985
	Conifer/ *Poa pratensis*	7,250–8,300	Moderate to broad	Terraces, meadows	Mollisols	Fine to coarse	Variable and fluctuating	Manning and Padgett 1995; Padgett et al. 1989
Tall deciduous tree	*Acer negundo/ Cornus sericea*	Below 6,500	No Data	Terraces, benches	Entisols, Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Padgett et al. 1989
	Populus angustifolia/ Betula occidentalis	4,760–7,480	Narrow to broad	Terraces, floodplains streambanks	Entisols, Mollisols	Fine to coarse	Variable and fluctuating	Manning and Padgett 1995; Padgett et al. 1989; Walford 2001
	Populus angustifolia/ Cornus sericea	Below 7,000–above 7,300	Narrow to broad	Terraces, benches, floodplains, bars, shallow ponds	Entisols, Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Bowerman 1999; Crowe et al. 2004; Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989; Youngblood et al. 1985
	Populus angustifolia/ Poa pratensis	3,840–8,040	Moderate to broad	Terraces, floodplains	Entisols, Inceptisols, Mollisols	Fine to coarse	Dry	Bowerman 1999; Padgett et al. 1989; Youngblood et al. 1985
	Populus angustifolia/ Rhus trilobata	5,200–6,600	Narrow to broad	Terraces, floodplains	Entisols, Inceptisols, Mollisols	Fine to coarse	Dry	Manning and Padgett 1995; Padgett et al. 1989
	Populus angustifolia/ Rosa woodsii	6,200–7,200	Narrow to broad	Terraces	Entisols, Mollisols	Fine to coarse	Dry	Manning and Padgett 1995; Padgett et al. 1989

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Table B.1 (continued)—Dominance groups and community types, including citations, of the Utah Plateaus floristics section.

Dominance group	Community type	Elevation range (feet)	Valley bottom width	Geomorphic features	Soil types	Soil particle sizes	Soil water regimes	References
	Populus tremuloides/ Poa pratensis	7,700–9,000	Moderate to broad	Terraces, benches, floodplains, hillslopes, springs	Entisols, Mollisols	Fine to coarse	Variable and fluctuating	Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989
Low deciduous tree	*Alnus incana/ Cornus sericea*	5,700–7,200	Narrow	Streambanks	Entisols, Mollisols	Fine to coarse, organic	Variable and fluctuating	Manning and Padgett 1995; Padgett et al. 1989
	Alnus incana/ Mesic Forb	5,600–9,200	Narrow to broad	Terraces, floodplains, streambanks, springs	Entisols, Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Crowe et al. 2004; Manning and Padgett 1995; Padgett et al. 1989
	Alnus incana/ Mesic Graminoid	5,600–9,000	Narrow to broad	Benches, floodplains, streambanks, bars	Entisols, Inceptisols, Mollisols	Fine to coarse, organic	Variable and fluctuating	Manning and Padgett 1995; Padgett et al. 1989; Walford 2001
	Betula occidentalis/ Cornus sericea	Below 6,500–above 7,500	Narrow to broad	Terraces, benches floodplains, streambanks	Entisols, Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Manning and Padgett 1995; Padgett et al. 1989; Walford 2001
	Betula occidentalis/ Mesic Forb	6,000–7,000	Narrow to broad	Terraces, streambanks, springs	Entisols, Mollisols	Fine to coarse	Variable and fluctuating	Manning and Padgett 1995; Padgett et al. 1989
	Betula occidentalis/ Poa pratensis	6,000–7,800	Narrow to broad	Terraces, streambanks, springs	Entisols, Mollisols	Fine to coarse	Dry	Manning and Padgett 1995; Padgett et al. 1989
Tall willow	*Salix bebbiana/* Mesic Graminoid	6,900–9,200	Moderate to broad	Terraces, meadows hillslopes	Entisols, Mollisols	Fine to coarse	Variable and fluctuating	Padgett et al. 1989
	Salix boothii/ Carex aquatilis	7,400–8,800	Moderate to broad	Terraces, springs	Mollisols, Histosols	Fine to coarse, organic	Saturated	Padgett et al. 1989
	Salix boothii/ Carex nebrascensis	6,900	No data	Benches, springs	Mollisols, Histosols	No data	Variable and fluctuating	Padgett et al. 1989; Youngblood et al. 1985

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Table B.1 (continued)—Dominance groups and community types, including citations, of the Utah Plateaus floristics section.

Dominance group	Community type	Elevation range (feet)	Valley bottom width	Geomorphic features	Soil types	Soil particle sizes	Soil water regimes	References
	Salix boothii/ Carex utriculata	6,200–9,200	Moderate to broad	Terraces, floodplains, streambanks, shallow ponds, hillslopes, springs	Entisols, Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Saturated	Bowerman 1999; Padgett et al. 1989; Youngblood et al. 1985, Walford 2001
	Salix boothii/ Mesic Forb	5,300–10,300	Narrow to broad	Benches, floodplains, meadows, hillslopes, springs	Entisols, Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Padgett et al. 1989; Walford 2001
	Salix boothii/ Mesic Graminoid	6,700–9,800	Moderate to broad	Terraces, benches, floodplains, streambanks	Entisols, Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Variable and fluctuating	Padgett et al. 1989
	Salix boothii/ Poa pratensis	6,360–9,820	Moderate to broad	Terraces	Entisols, Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Padgett et al. 1989; Youngblood et al. 1985
	Salix exigua	Below 5,500–6,760	No data	Benches, streambanks, bars, shallow ponds	Entisols, Mollisols	Fine to coarse	Variable and fluctuating	Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989
	Salix exigua/ Mesic Forb	6,560–8,060	Narrow to broad	Terraces, benches, streambanks, meadows	Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Manning and Padgett 1995; Padgett et al. 1989
	Salix exigua/ Mesic Graminoid	6,000–7,700	No data	Terraces, meadows	Entisols, Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Variable and fluctuating	Padgett et al. 1989
	Salix exigua/ Poa pratensis	Below 7,000	Narrow to broad	Terraces, streambanks, bars, meadows	Entisols, Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
	Salix geyeriana/ Carex aquatilis	8,500–9,500	Moderate to broad	Meadows, springs	Mollisols, Histosols	Fine to coarse, organic	Variable and fluctuating	Padgett et al. 1989

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Table B.1 (continued)—Dominance groups and community types, including citations, of the Utah Plateaus floristics section.

Dominance group	Community type	Elevation range (feet)	Valley bottom width	Geomorphic features	Soil types	Soil particle sizes	Soil water regimes	References
	Salix geyeriana/ Deschampsia cespitosa	6,400–9,300	Moderate to broad	Floodplains, meadows	Inceptisols, Alfisols, Mollisols	Fine to coarse	Variable and fluctuating	Crow et al. 2004; Padgett et al. 1989
	Salix geyeriana/ Mesic Forb	8,600–10,000	Moderate to broad	Terraces, benches, floodplains, meadows, hillslopes	Entisols, Mollisols	Fine to coarse	Variable and fluctuating	Bowerman 1999; Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
	Salix geyeriana/ Mesic graminoid	6,500–8.300	Narrow to broad	Terraces, benches, floodplains, meadows, springs	Entisols, Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Variable and fluctuating	Manning and Padgett 1995; Padgett et al. 1989; Walford 2001
	Salix lasiolepis/ Bench	5,500–6,700	Narrow to broad	Benches, streambanks	Entisols, Inceptisols, Mollisols	Fine to coarse	Dry	Manning and Padgett 1995; Padgett et al. 1989
Low willow	*Salix planifolia/ Carex aquatilis*	9,000 and above	Moderate to broad	Floodplains, streambanks, meadows, shallow ponds, springs	Inceptisols, Mollisols, Histosols	Fine, organic	Variable and fluctuating	Hansen et al. 1995; Padgett et al. 1989; Walford 2001
	Salix wolfii/ Carex aquatilis	8,500–9,900	Narrow to broad	Terraces, floodplains, streambanks, meadows, hillslopes, basins, springs	Entisols, Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Variable and fluctuating	Hansen et al. 1995; Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
	Salix wolfii/ Deschampsia cespitosa	8,000–9,400	Moderate to broad	Terraces, benches, floodplains, meadows, hillslopes	Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Saturated	Hansen et al. 1995; Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
Nonwillow shrub	*Artemisia cana/ Deschampsia caespitosa*	6,900–9,200	Narrow to broad	Meadows	Alfisols, Mollisols	No data	Variable and fluctuating	Crow et al. 2004; Padgett et al. 1989
	Artemisia cana/ Festuca ovina	9,200–10,700	Moderate to broad	Meadows	No data	Fine to coarse	Dry	Padgett et al. 1989
	Artemisia cana/ Poa pratensis	7,500–7,700	Moderate to broad	Terraces, benches, meadows, hillslopes, springs	Mollisols	Fine to coarse	Variable and fluctuating	Padgett et al. 1989; Youngblood et al. 1985

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Table B.1 (continued)—Dominance groups and community types, including citations, of the Utah Plateaus floristics section.

Dominance group	Community type	Elevation range (feet)	Valley bottom width	Geomorphic features	Soil types	Soil particle sizes	Soil water regimes	References
	Cornus sericea/ Heracleum lanatum	Below 7,000	No data	Terraces, benches, floodplains, streambanks	Entisols, Inceptisols, Mollisols	Fine to coarse, organic	Variable and fluctuating	Bowerman 1999; Padgett et al. 1989; Youngblood et al. 1985
	Dasiphora fruticosa/ Deschampsia cespitosa	6,000–9,500	Moderate to broad	Terraces, floodplains, meadows, hillslopes, springs	Inceptisols, Alfisols, Mollisols	Fine to coarse	Variable and fluctuating	Hansen et al. 1995; Padgett et al. 1989; Youngblood et al. 1985
	Dasiphora fruticosa/ Poa pratensis	7,900–10,000	Moderate to broad	Terraces, floodplains, meadows, hillslopes	Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Bowerman 1999; Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
Herbaceous	*Caltha leptosepala*	9,000–10,200	No data	Floodplains, meadows, hillslopes, springs	Inceptisols, Histosols	Fine to coarse, organic	Saturated	Padgett et al. 1989
	Carex aquatilis	8,000–11,000	Narrow to broad	Benches, floodplains, streambanks, meadows, shallow ponds, springs	Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Saturated	Crow et al. 2004; Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
	Carex microptera	6,500–9,500	Narrow to broad	Terraces, benches, meadows	Entisols, Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Manning and Padgett 1995; Padgett et al. 1989; Youngblood et al. 1985
	Carex nebrascensis	Below 8,700	Narrow to broad	Terraces, benches, floodplains, streambanks, meadows, hillslopes, basins, springs	Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Variable and fluctuating	Crow et al. 2004; Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989; Youngblood et al. 1985
	Carex pellita	5,200–9,200	Narrow to broad	Terraces, floodplains, meadows, basins, springs	Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Crow et al. 2004; Manning and Padgett 1995; Padgett et al. 1989

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Table B.1 (continued)—Dominance groups and community types, including citations, of the Utah Plateaus floristics section.

Dominance group	Community type	Elevation range (feet)	Valley bottom width	Geomorphic features	Soil types	Soil particle sizes	Soil water regimes	References
	Carex simulata	8,500–9,200	Narrow to broad	Terraces, benches, floodplains, meadows, springs, fens	Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Saturated	Crow et al. 2004; Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
	Carex utriculata	6,000–9,800	Narrow to broad	Terraces, benches, floodplains, streambanks, meadows, shallow ponds, basins, springs, fens	Entisols, Inceptisols, Mollisols, Histosols	Fine to coarse, organic	Saturated	Crow et al. 2004; Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
	Deschampsia cespitosa	9,500–11,000	Moderate to broad	Terraces, floodplains, meadows, shallow ponds, hillslopes, basins, springs	Entisols, Inceptisols, Alfisols, Mollisols, Histosols	Fine to coarse	Variable and fluctuating	Crow et al. 2004; Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
	Eleocharis palustris	7,300–9,900	Narrow to broad	Benches, streambanks, meadows, shallow ponds, springs	Inceptisols, Mollisols, Histosols	Fine, organic	Variable and fluctuating	Crow et al. 2004; Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989
	Juncus arcticus	6,000–8,300	Narrow to broad	Terraces, benches, floodplains, meadows, basins, springs	Inceptisols, Mollisols, Histosols	Fine to coarse	Variable and fluctuating	Crow et al. 2004; Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989; Walford 2001; Youngblood et al. 1985
	Poa pratensis	5,200–8,600	Narrow to broad	Terraces, benches, meadows	Inceptisols, Mollisols	Fine to coarse	Dry	Hansen et al. 1995; Manning and Padgett 1995; Padgett et al. 1989; Youngblood et al. 1985
	Veratrum californicum	8,000–10,500	Narrow to broad	Benches, floodplains, meadows, hillslopes, springs	Inceptisols, Mollisols	Fine to coarse	Variable and fluctuating	Crow et al. 2004; Manning and Padgett 1995; Padgett et al. 1989; Youngblood et al. 1985

Appendix C. Distribution of Riparian and Groundwater-Dependent Ecosystems in Geographic Units of the Dixie and Fishlake National Forests

We mapped the distribution of riparian ecosystems and GDEs in each geographic unit. We combined data from several sources to identify potential riparian extent, distribution of riparian vegetation, distribution of springs, and distribution of fens. We also mapped geological features that influence the distribution and extent of these resources.

Following the methods of Abood et al. (2012), we created a GIS layer of riparian ecosystem extent that incorporates 50-year flood heights from stream gage data, a 10-meter digital elevation model, soil units (hydric, drainage class, flood frequency, and hydrological soil group), and NWI data. We mapped the current distribution of riparian vegetation using data generated by the VCMQ program (Nelson et al. 2015). We selected vegetation types in the VCMQ shapefiles that were classified as woody riparian or herbaceous riparian. We used our 50-year floodplain map to show the potential extent of riparian ecosystems, and we used maps of riparian vegetation to show the known extent of riparian vegetation.

To map geological drivers of GDEs, we obtained shapefiles representing potential karst, major aquifers, faults, and bedrock geology from the USGS (Epstein et al. 2002; Horton et al. 2017; USGS 2003). We mapped the location of springs using shapefiles generated by the NHD, the DNF, and the Forests' WRU program. To map fens, we obtained shapefiles of potential fens generated by the CNHP using NWI data and analysis of aerial imagery (Smith and Lemly 2018, 2020). CNHP staff located potential fens and ranked their confidence by classifying wetlands as likely fens, possible fens, or low confidence fens based on the number of fen-like characteristics they observed through aerial imagery. We also used information collected by the Forests during level II riparian surveys to identify springs and potential fens.

Unit Summaries

Escalante

The Escalante unit, with streams in the eastern portion draining to the Upper Colorado River Basin and streams in the western portion draining to the Sevier River Basin, contains unconsolidated deposits and sedimentary rocks at lower elevations and volcanic rocks associated with the Aquarius Plateau at upper elevations (fig. C.1). Numerous faults are present as well (fig. C.2). Nearly 3 percent of the unit is composed of carbonate bedrock with potential for karst formation. These deposits are in the western portion of the unit. Volcanic rocks are present at upper elevations. Colorado Plateaus sandstone aquifers underlie the entire unit.

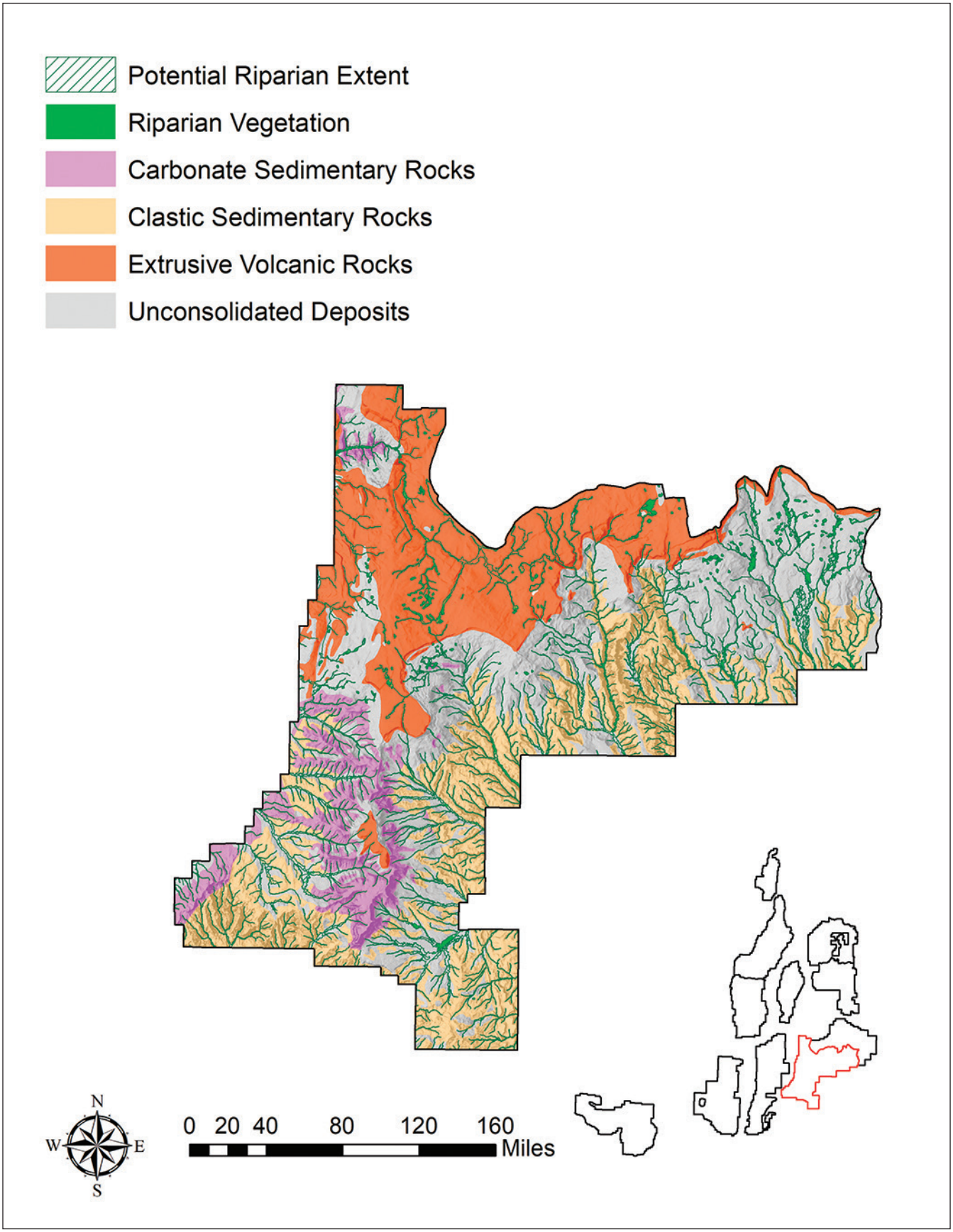


Figure C.1—Distribution of riparian ecosystems in the Escalante geographic unit.

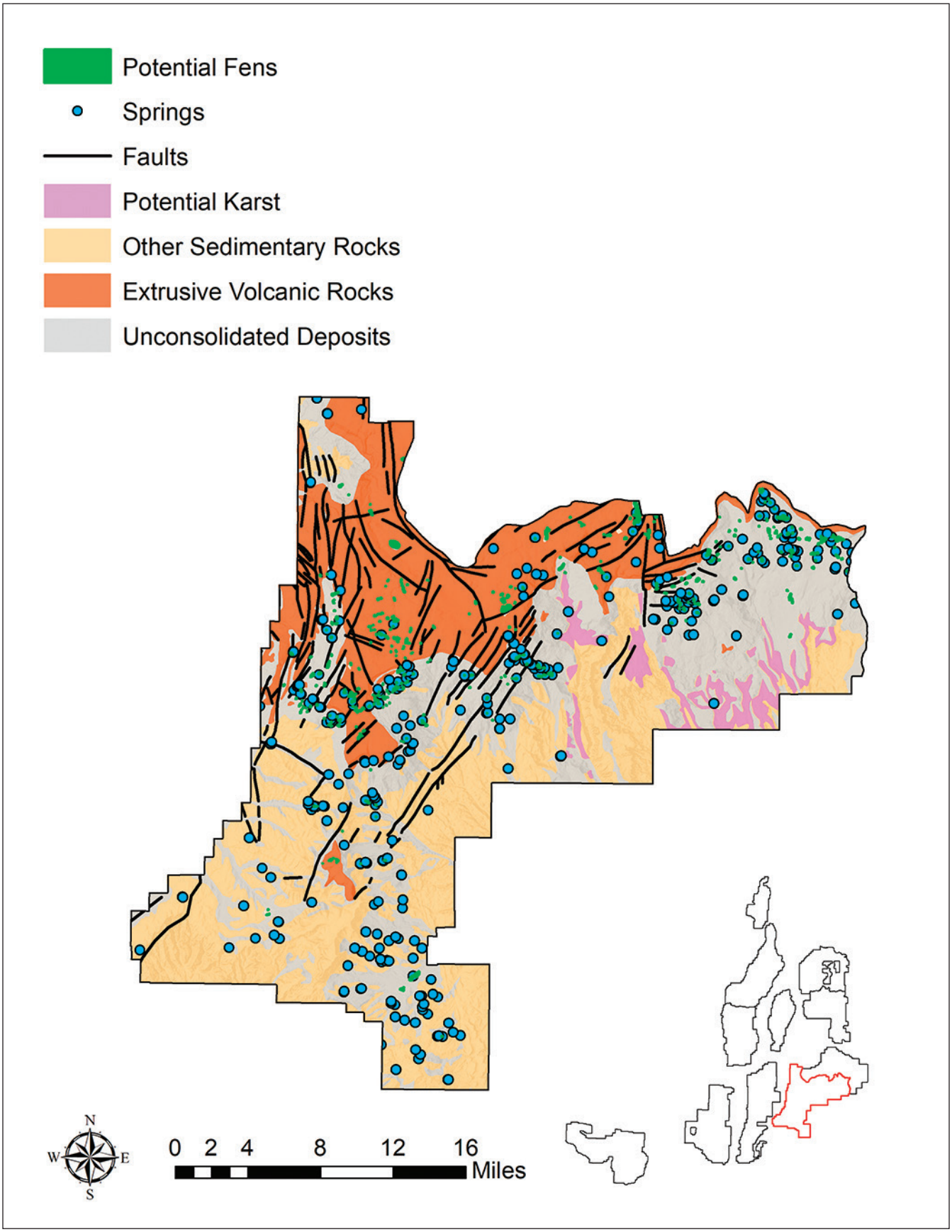


Figure C.2—Distribution of GDEs in the Escalante geographic unit.

Patches and bands of riparian vegetation are abundant in unconsolidated deposits of the northeastern and northwestern portions of the unit, where surface flows emerge from the slopes of the Aquarius Plateau. Areas with extensive riparian vegetation include Antimony Creek, Pine Creek, Boulder Creek, and Salt Gulch.

There are at least 347 known springs (0.0007/acre). Springs are scattered throughout the unit, with most occurring in the Escalante River headwaters. Numerous spring clusters are associated with unconsolidated deposits flanking the Aquarius Plateau and Escalante Mountains. Other clusters are associated with a network of faults in the northern portion of the unit. Level II riparian surveys found that West Fork Deer Creek, East Fork Deer Creek, Center Creek, and Birch Creek are fed by numerous springs. Fibrist soils indicate potential fens along East Fork Deer Creek, West Fork Deer Creek, East Fork Boulder Creek, Center Creek, and Birch Creek. Several GDEs were surveyed in 2013, 2014, and 2015, using a modified version of the level I methodology. Of the 115 sites identified as GDEs, 13 percent had extensive standing water, 49 percent had patches of standing water, and 59 percent had water flowing in channels. Three wetlands with peat depths of 30 cm or greater were noted along Deep Creek in the Pine Creek watershed. Another such wetland was found in the Upper Valley Creek watershed. The CNHP identified 0.23 percent of the unit as potential fens, with 608.1 acres of low confidence fens, 273.6 acres of possible fens, and 139.6 acres of likely fens. Most of these wetlands are associated with springs, volcanic bedrock, and unconsolidated deposits in the northern portion of the unit. The largest mapped likely fen in the DNF is found along the East Fork of Boulder Creek in the northeastern corner of the unit (Smith and Lemly 2018).

Markagunt Plateau

The Markagunt Plateau, which includes watersheds in the Lower Colorado River Basin and the Sevier River Basin, is composed of volcanic rocks at upper elevations, with sedimentary rocks and unconsolidated deposits at lower elevations (fig. C.3). There is no carbonate bedrock with potential for karst formation in the unit (fig. C.4). Volcanic rocks are present throughout. Colorado Plateau sandstone aquifers underlie 93 percent of the unit. Basin and Range fill aquifers underlie 1 percent.

Patches and bands of riparian vegetation are abundant throughout the volcanic highlands on the eastern slope of the unit. Narrower bands of riparian vegetation are present in sedimentary canyons at the southern end. Areas with extensive riparian vegetation include Panguitch Creek, Mammoth Creek, and Asay Creek. Beaver activity was observed during level II surveys, with active dams noted at Butler Creek and Caddy Creek.

There are at least 584 known springs (0.0014/acre), the greatest density of any geographic unit. Springs are scattered across the unit and are abundant on the eastern and western slopes. Large clusters of springs are associated with faults and volcanic rocks. Level II riparian surveys found that Duck creek is fed by groundwater in subsurface volcanic rocks. The stream

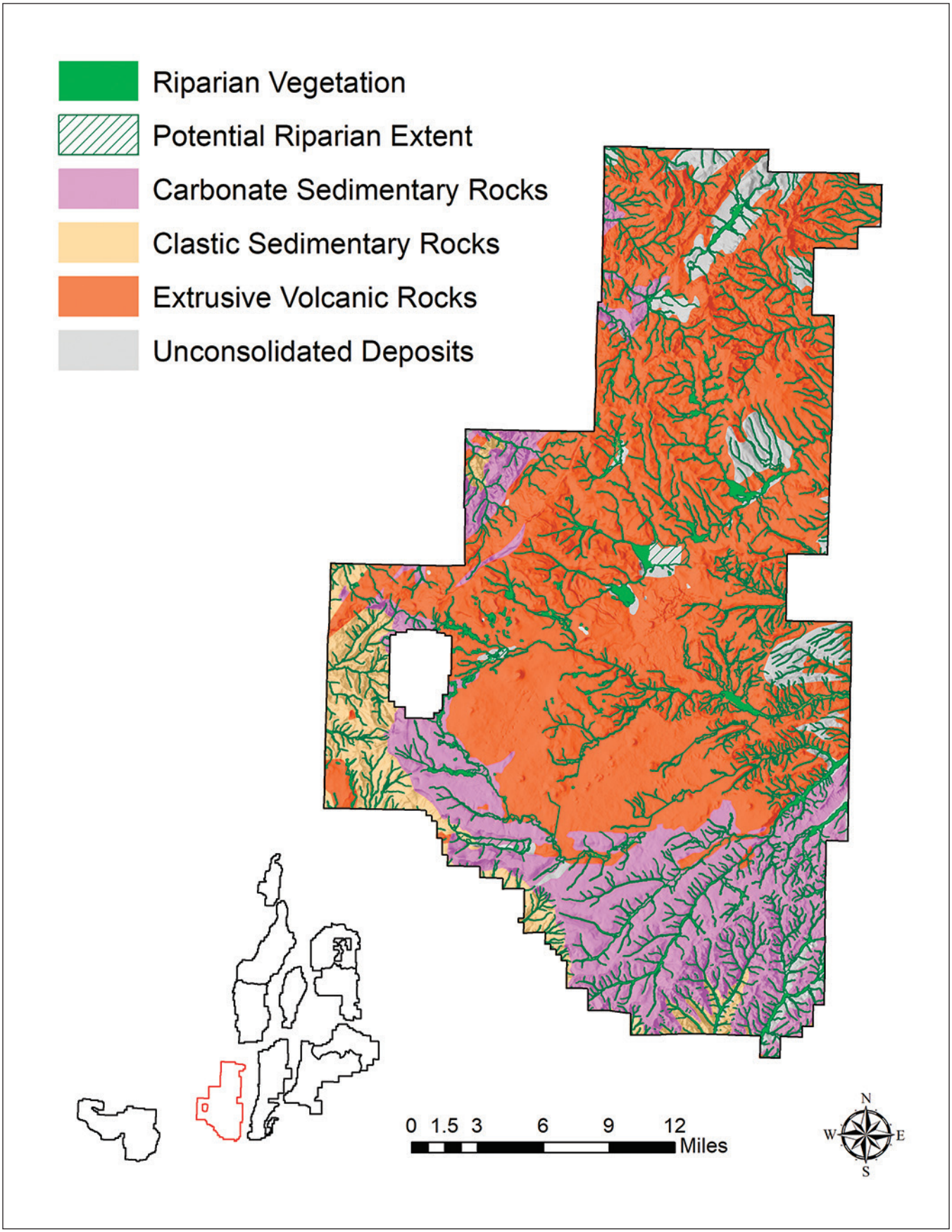


Figure C.3—Distribution of riparian ecosystems in the Markagunt Plateau geographic unit.

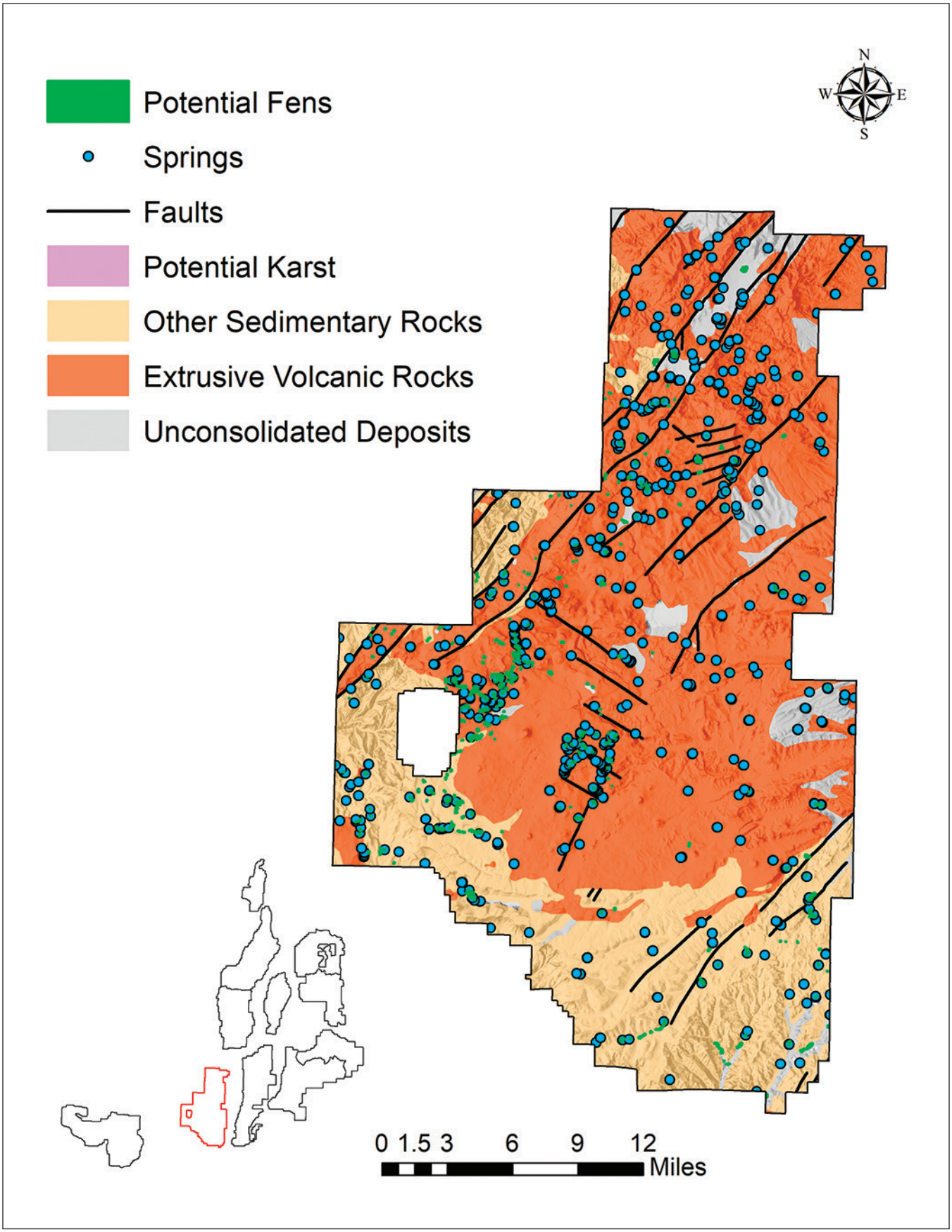


Figure C.4—Distribution of GDEs in the Markagunt Plateau geographic unit.

eventually sinks into a volcanic aquifer that discharges into the Asay Creek watershed. Mammoth springs create perennial flows for Mammoth Creek. Fibrist soils indicate potential fens along Duck Creek and Bunker Creek. The CNHP identified 0.23 percent of the unit as potential fens, with 661.5 acres of low confidence fens, 198.9 acres of possible fens, and 55.1 acres of likely fens. The second largest mapped likely fen in the DNF is in the headwaters of Long Valley Creek, on the western side of the unit. Most of the mapped fens are associated with springs in volcanic and sedimentary bedrock in the western half of the unit.

Paunsaugunt–Mt. Dutton

This unit consists of the sedimentary Paunsaugunt Plateau in the south and the largely volcanic Sevier Plateau in the north (fig. C.5). The Paunsaugunt Plateau contains the East Fork Sevier River watershed draining into the Sevier River Basin, and small segments of streams draining south into the Lower Colorado River Basin. The Sevier Plateau composes the northern portion, with streams of the Sevier River Basin draining the eastern and western slopes. Less than 1 percent of the unit is composed of carbonate bedrock with potential for karst formation (fig. C.6). These deposits are limited to one area on the eastern edge of the Paunsaugunt Plateau. Volcanic rocks are present in the northern end of the Sevier Plateau. Colorado Plateaus sandstone aquifers underlie the entire unit.

The sedimentary deposits of the East Fork Sevier River watershed contain an extensive network of riparian vegetation. Bands of riparian vegetation are narrower in the volcanic canyons of the Sevier Plateau. Areas with extensive riparian vegetation include the East Fork Sevier River, Cottonwood Creek, Prospect Creek, and Deep Creek. Beaver dams and complexes were observed at Deep Creek, Mountain Spring Fork Deer Creek, and West Fork Hunt Creek on the Sevier Plateau and at Upper Kanab Creek on the Paunsaugunt Plateau during level II surveys in 1994 and 1995.

There are at least 233 known springs (0.0006 per acre). Springs are abundant in the northern and southern portions of the unit. A cluster of springs is located near a network of faults on the Sevier Plateau. Springs are also abundant in areas of both plateaus without faults. Level II riparian surveys found springs that maintain perennial flows and wet meadows at Blubber Creek and Upper Kanab Creek. Surveys also found Fibrist soils and sinkholes, indicating potential fens along Blubber Creek. Fibrists were also present along the Mountain Spring Fork of Deer Creek, Podunk Creek, Crawford Creek, and Upper Kanab Creek. The CNHP identified 0.1 percent of the unit as potential fens, with 264.9 acres of low confidence fens, 62.1 acres of possible fens, and 1.2 acres of likely fens. Some of these wetlands are associated with springs on the Sevier Plateau. The largest concentrations are found in valley bottoms on the Paunsaugunt Plateau.

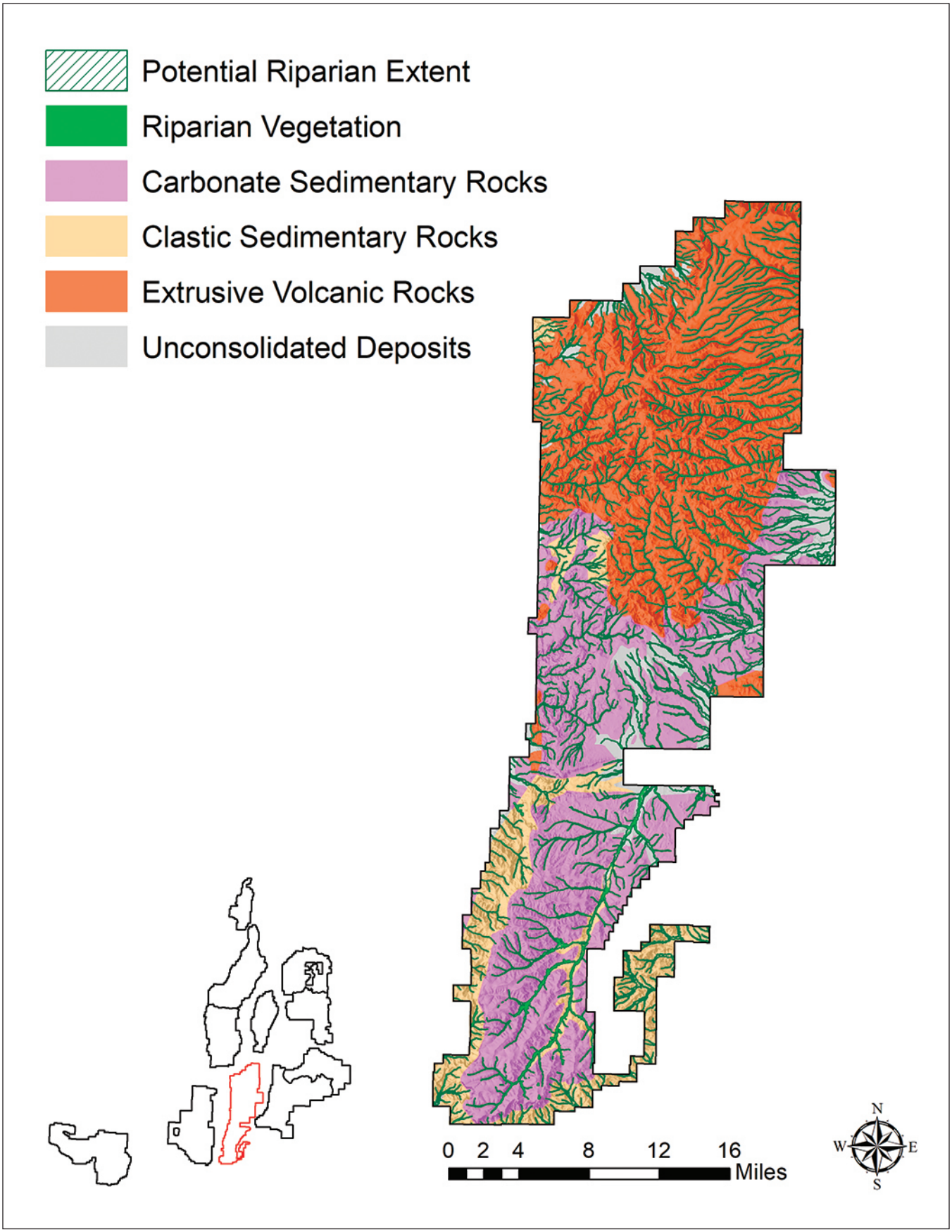


Figure C.5—Distribution of riparian ecosystems in the Paunsaugunt–Mt. Dutton geographic unit.

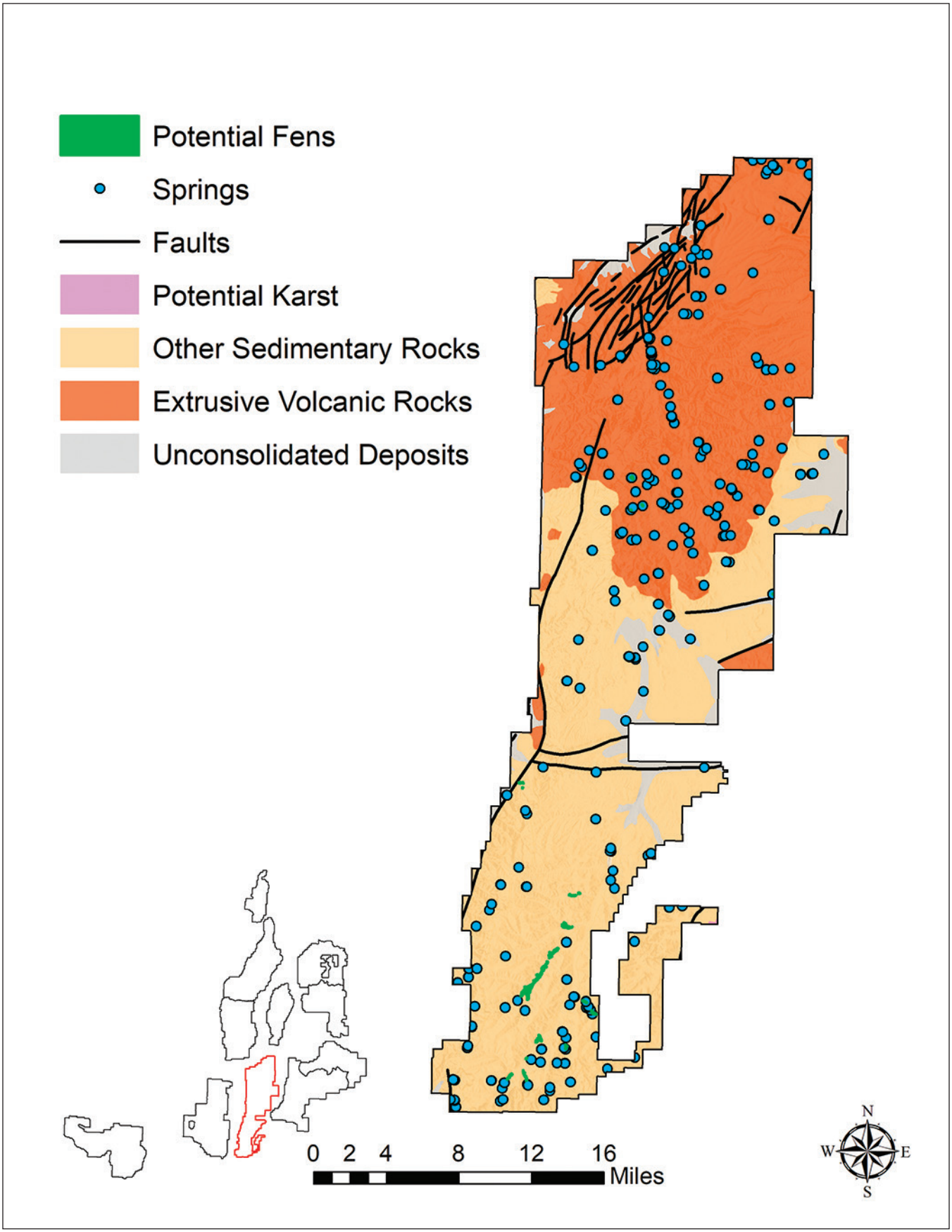


Figure C.6—Distribution of GDEs in the Paunsaugunt–Mt. Dutton geographic unit.

Pine Valley

The southern portion of this unit contains watersheds in the Lower Colorado River Basin. The northern portion contains watershed of several closed basins. The Pine Valley unit contains a mixture of sedimentary, crystalline, and volcanic rocks (fig. C.7). Nearly 2 percent of the unit is composed of carbonate bedrock with potential for karst formation (fig. C.8). These deposits are located on the southeastern slopes of the Pine Valley Mountains. Basin and Range fill aquifers underlie 7 percent of the unit.

Extensive patches and bands of riparian vegetation are associated with unconsolidated deposits and erosive sedimentary rocks in the western and central portions of the unit. Areas with extensive riparian vegetation include streams on the east slope of the Pine Valley Mountains, The Pinto Creek drainage, the Shoal Creek Drainage, and the Santa Clara River drainage.

There are at least 345 known springs (0.0007 per acre). These springs are scattered across the unit. Clusters of springs are associated with extensive networks of faults throughout the unit. Clusters are also present in unconsolidated deposits on the southeastern slopes of the Pine Valley Mountains. Level II surveys found springs contributing to perennial flows at Spring Creek in Ox Valley, Shinbone Creek, and Leeds Creek. Surveys also found Fibrist soils, indicating potential fens along Spring Creek in Ox Valley and along the upper Santa Clara River. The CNHP identified 0.004 percent of the unit as potential fens, with 13.8 acres of low confidence fens, 3.3 acres of possible fens, and no likely fens. Many of these wetlands are associated with springs in the Pine Valley Mountains.

Boulder Mountain

Boulder Mountain includes the volcanic summit of the Aquarius Plateau which drains into the Upper Colorado River Basin on its eastern, northern, and southern slopes, and into the Sevier River Basin on its western slope (fig. C.9). Groundwater recharge occurs at the summit of the plateau and discharge occurs in the volcanic, unconsolidated, and sedimentary slopes at lower elevations (Hall 1971). Over 2 percent of the unit is composed of carbonate bedrock with potential for karst formation (fig. C.10). These deposits are in the northern and eastern slopes of the plateau. Volcanic rocks are present in the upper elevations. Colorado Plateaus sandstone aquifers underlie the entire unit.

Riparian ecosystems are scattered across the summit, with many patches of riparian vegetation isolated from one another by the drainage of surface water into the volcanic rocks. Areas with extensive riparian vegetation include Oak Creek and Spring Gulch.

There are at least 70 known springs (0.0003/acre). Most springs are in unconsolidated deposits on lower slopes in the eastern, northern, and western portions of the unit. Others are associated with faults in the western portion of the unit. Level II riparian surveys found an extensive spring system supplying water to the upper reaches of Pine Creek. Fibrist soils indicate potential fens along Behanin Creek and Pleasant Creek. CNHP identified

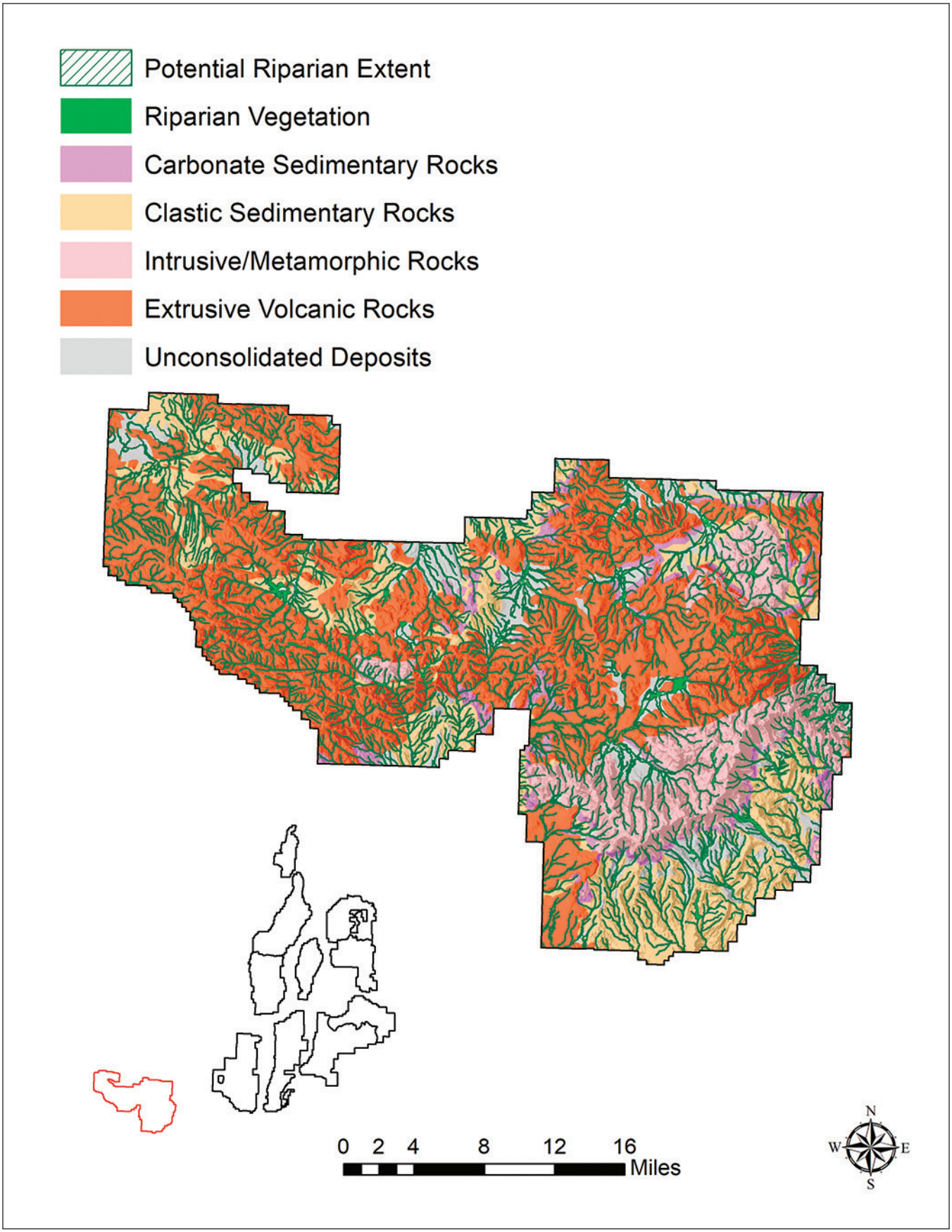


Figure C.7—Distribution of riparian ecosystems in the Pine Valley geographic unit.

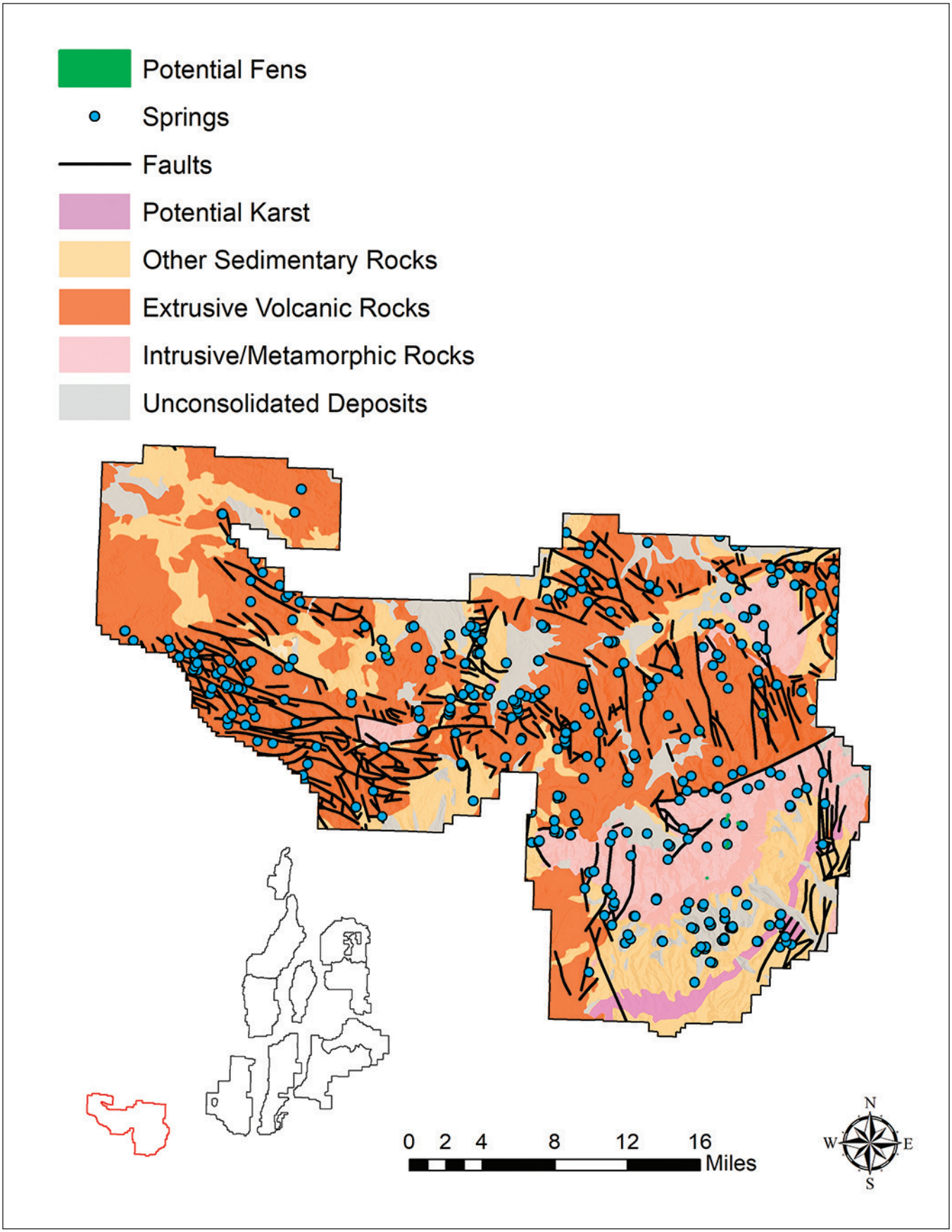


Figure C.8—Distribution of GDEs in the Pine Valley geographic unit.

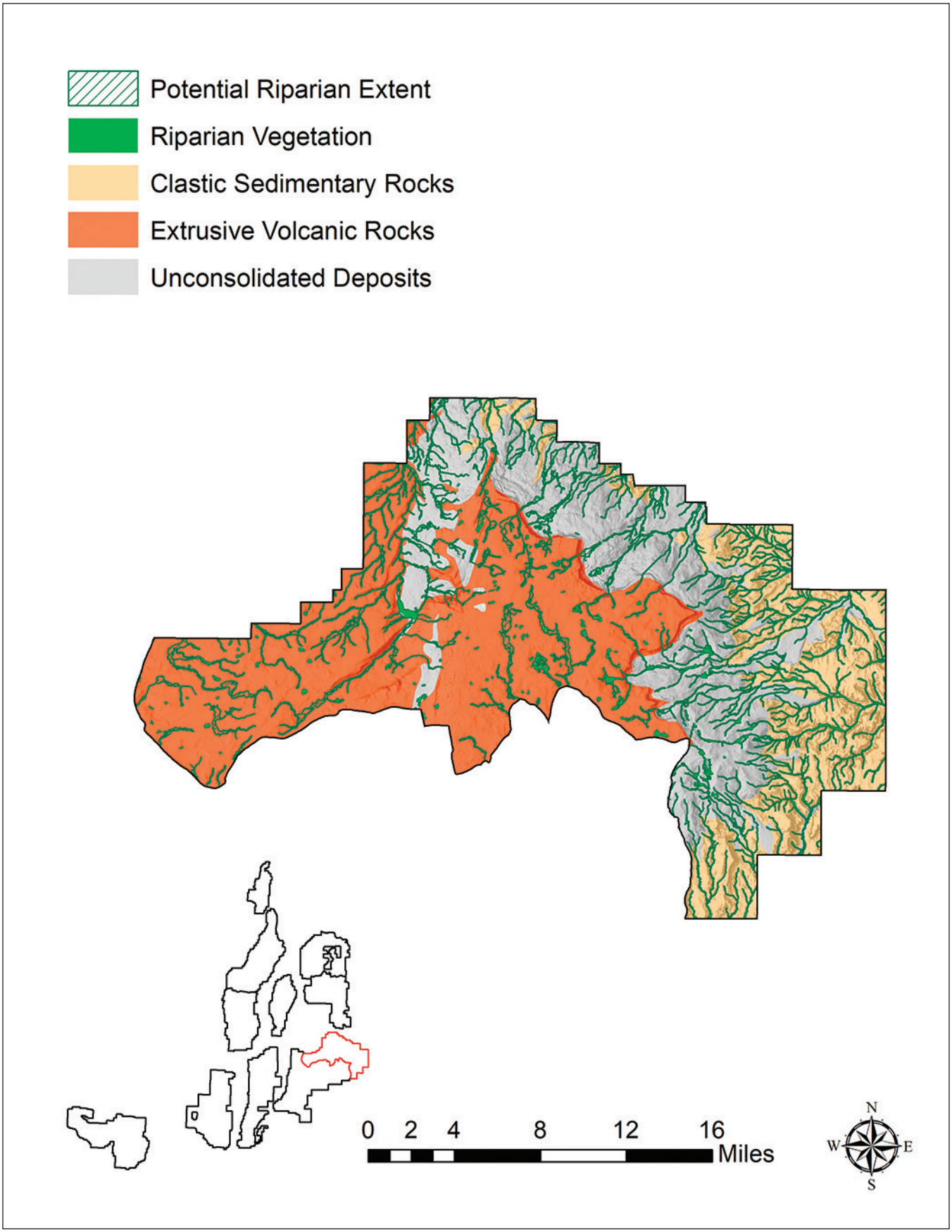


Figure C.9—Distribution of riparian ecosystems in the Boulder Mountain geographic unit.

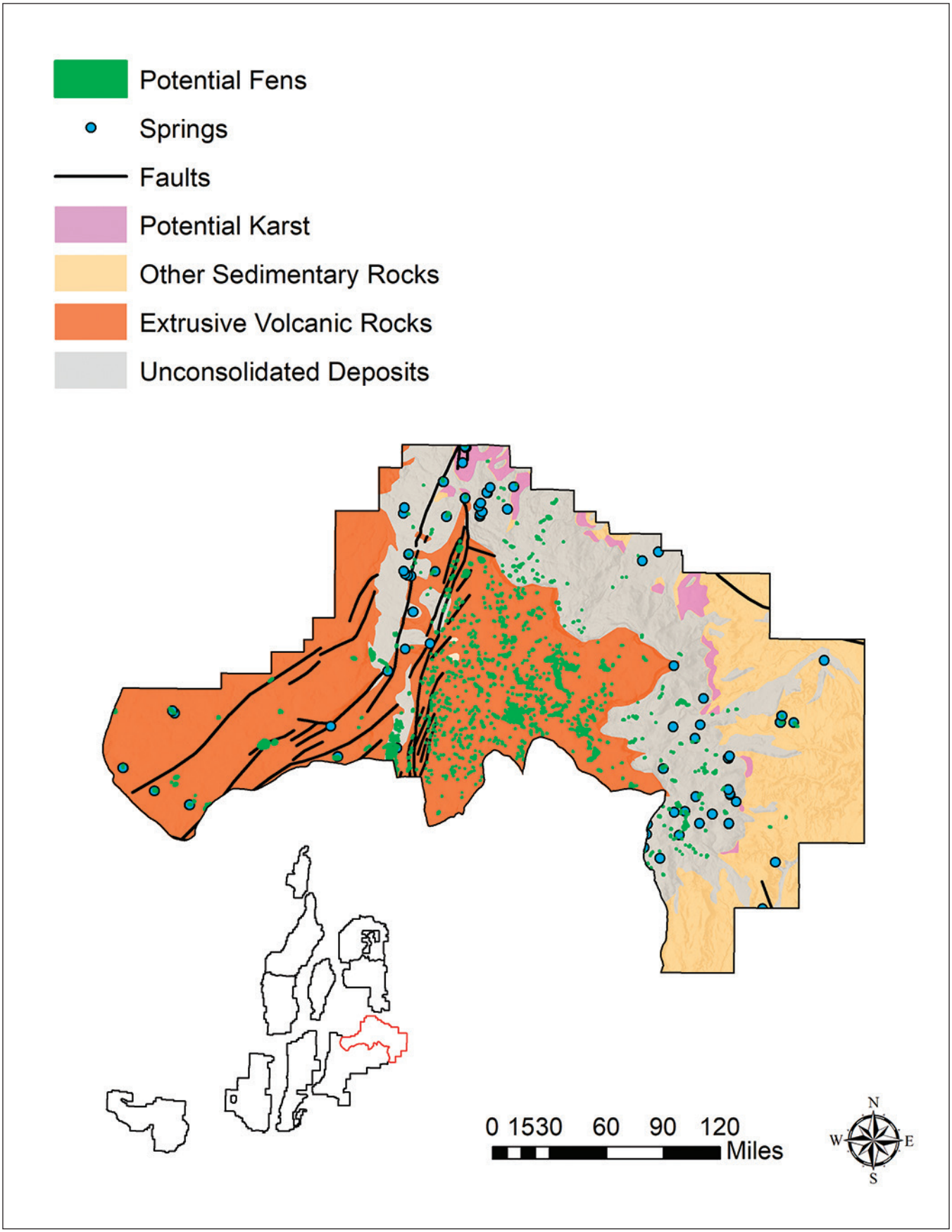


Figure C.10—Distribution of GDEs in the Boulder Mountain geographic unit.

0.8 percent of the unit as potential fens, the largest percentage of any unit. CNHP found 795.6 acres of low confidence fens, 502.8 acres of possible fens, and 629.2 acres of likely fens. There is a large complex of likely fens in the Boulder Meadows area (Smith and Lemly 2020). Other hotspots for fens include Boulder Creek, Rock Spring Draw, and Pleasant Creek. Large concentrations of mapped fens are associated with volcanic bedrock and unconsolidated deposits.

Canyon Mountains

The Canyon Mountains contain several watersheds that are part of the Sevier River Basin. The Canyon Mountains contain overlapping layers of carbonate and crystalline bedrock (fig. C.11). Carbonate layers with the potential for karst formation cover nearly 17 percent of the geographic unit. These layers are in the northern and southern portions of the range. Volcanic formations cover a very small area of the unit (fig. C.12). In addition to carbonate aquifers, Basin and Range fill aquifers underlie 45 percent of the unit's area.

In this arid range, perennial stream segments are limited to the western slope, as are most patches of riparian vegetation mapped by VCMQ. Areas with riparian vegetation include Eightmile Canyon and lower Oak Creek. Riparian ecosystems are largely limited to stream channels downstream of undiverted springs. Extent of riparian vegetation is also limited by the natural lack of floodplain development in erosion-resistant quartzite and limestone canyons.

There are at least 50 known springs (0.0004/acre), most of which are on the western slope of the range. Many springs are in fractured quartzite and unconsolidated deposits on the western slope. A level II riparian survey of Oak Creek found that the perennial portion of the creek begins at a large spring and the flow is enhanced by another spring downstream. The perennial flows created by these springs support riparian habitats, aquatic ecosystems, and a trout fishery. CNHP identified 0.002 percent of the unit as potential fens, with 1.6 acres of low confidence fens, 0.3 acres of possible fens, and 0 acres of likely fens. Small potential fens are associated with springs, primarily on the west side of the unit.

Fishlake–Thousand Lake

In this unit, the Fremont River and U M Creek watersheds are within the Upper Colorado River Basin. Additional streams in this basin are in the eastern portion of the unit and on the Thousand Lake Plateau, which form the southern portion. Otter Creek and Daniel's Creek, in the Sevier River Basin, are in the western portion of the unit. This unit consists of volcanic highlands and sedimentary deposits separated by alluvial fill (fig. C.13). Nearly 2 percent of the unit is composed of carbonate bedrock with potential for karst formation (fig. C.14). These deposits are in the northern and southern portions of the unit. Volcanic rocks are extensive on the Fishlake Plateau and are at the summit of Thousand Lake Mountain. Colorado Plateaus sandstone aquifers underlie the entire unit.

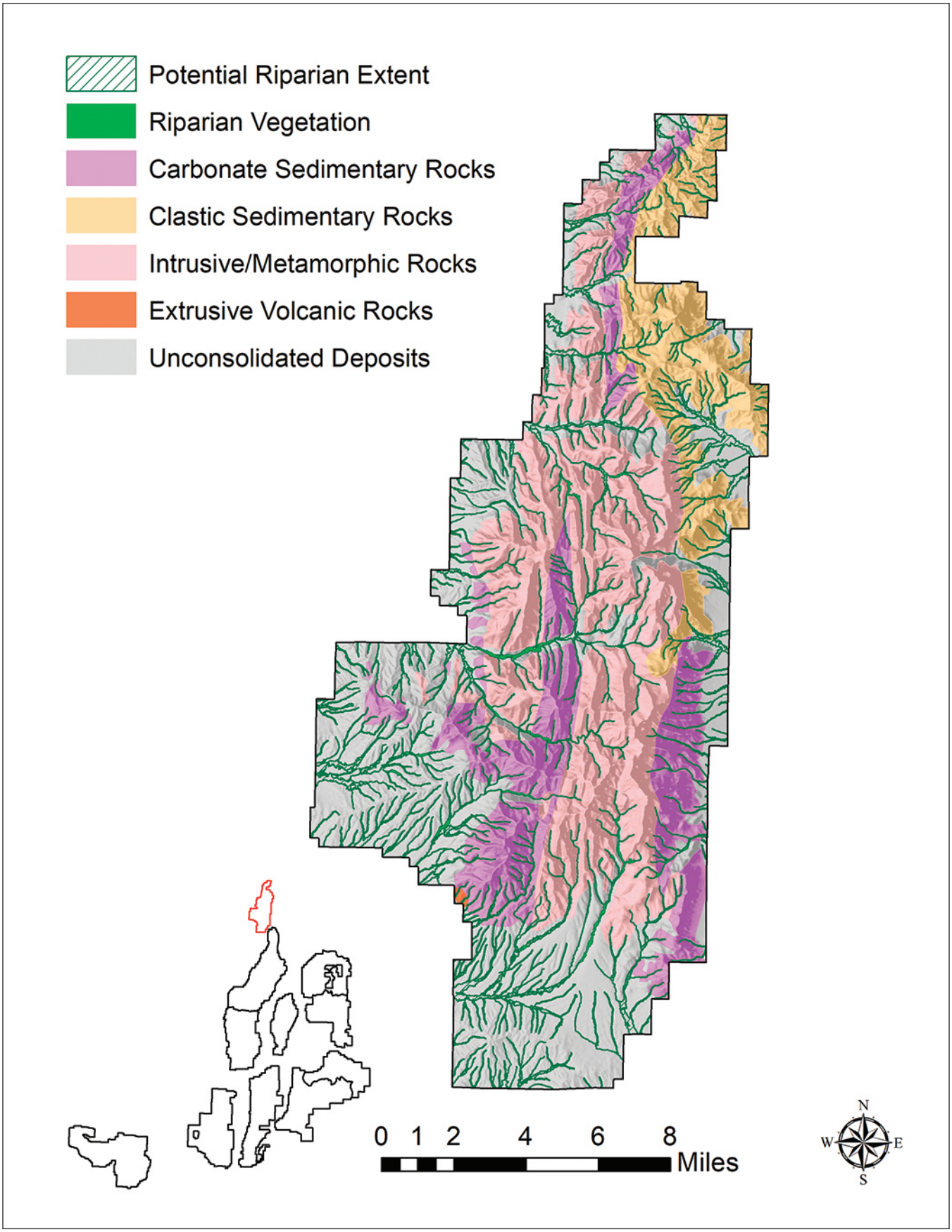


Figure C.11—Distribution of riparian ecosystems in the Canyon Mountains geographic unit.

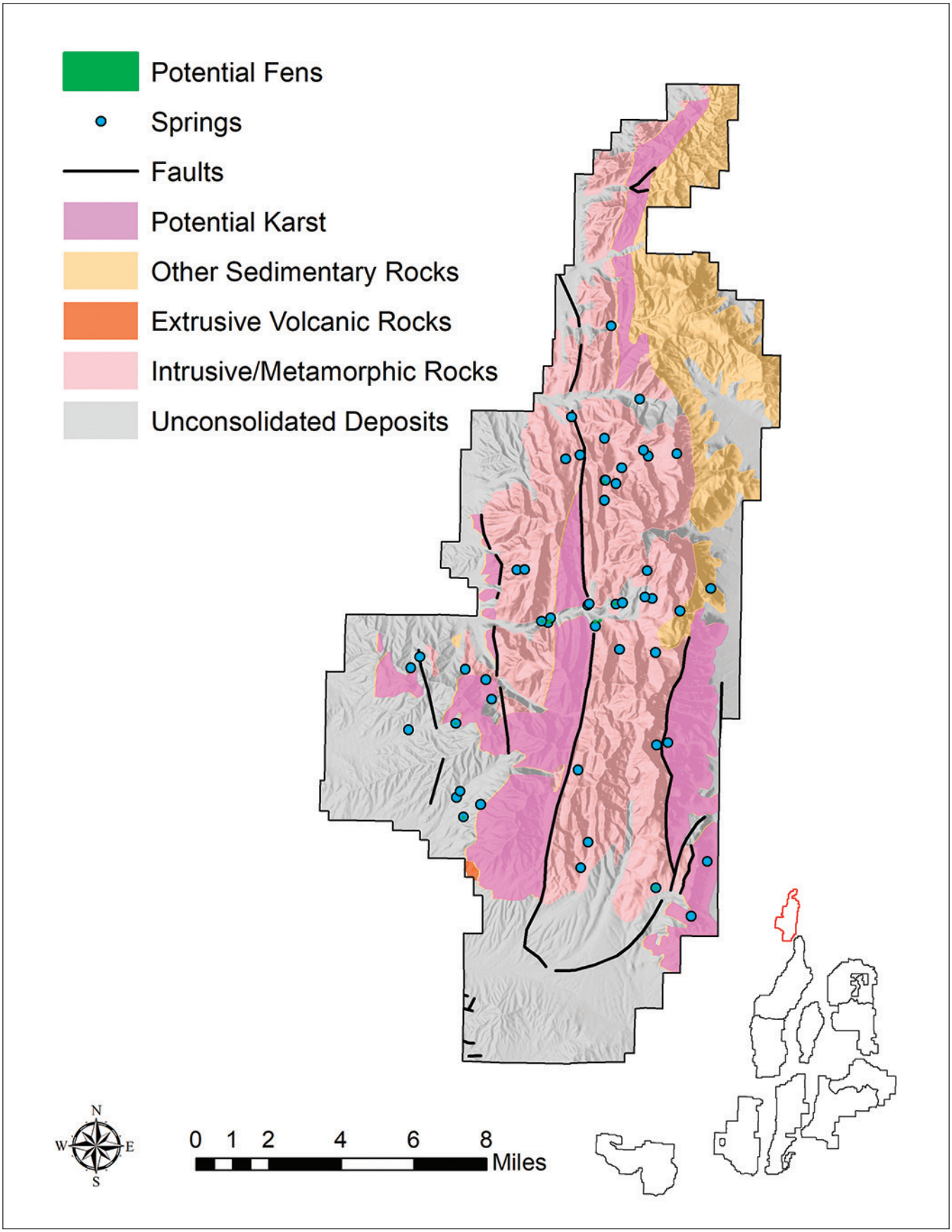


Figure C.12—Distribution of GDEs in the Canyon Mountains geographic unit.

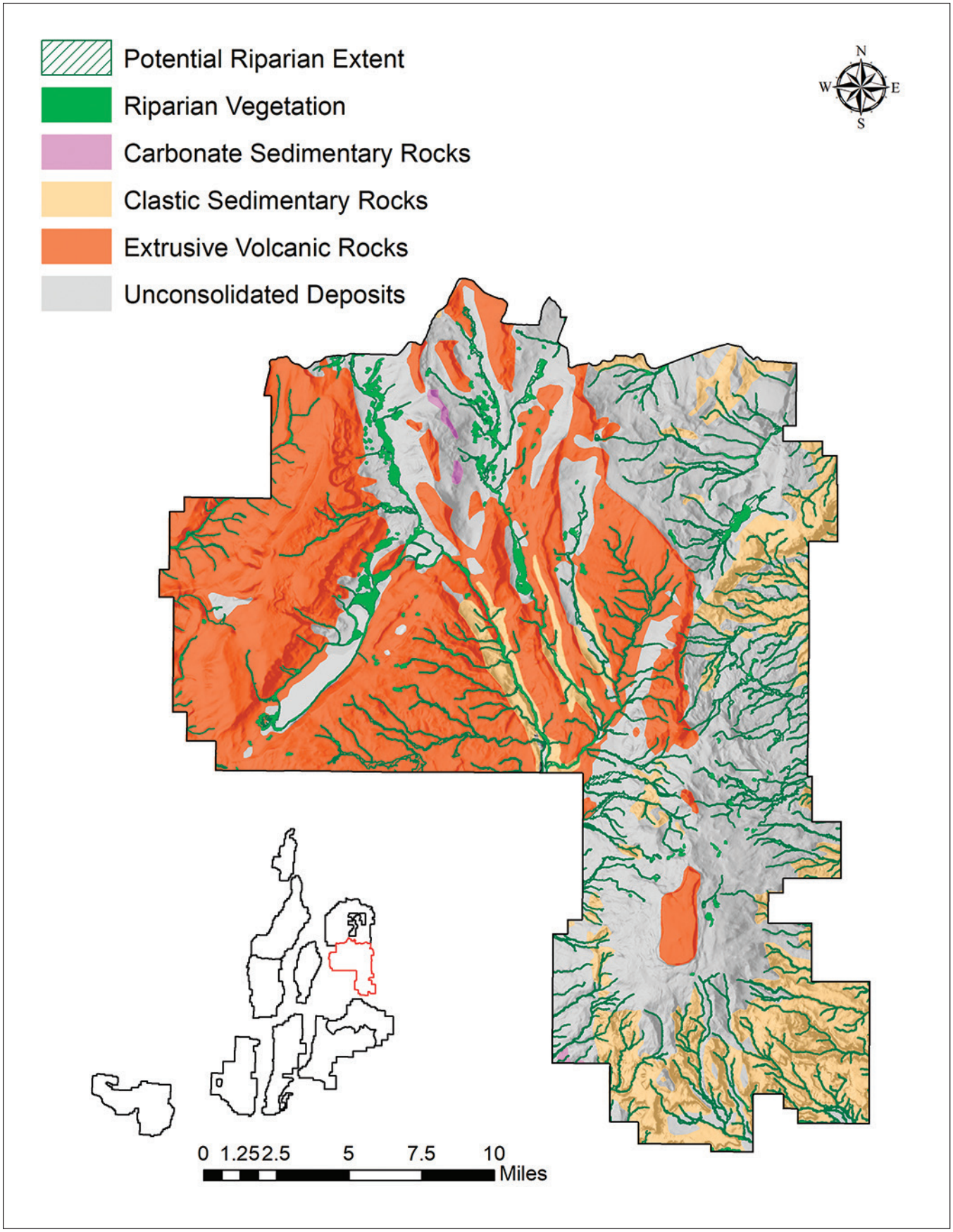


Figure C.13—Distribution of riparian ecosystems in the Fishlake–Thousand Lake geographic unit.

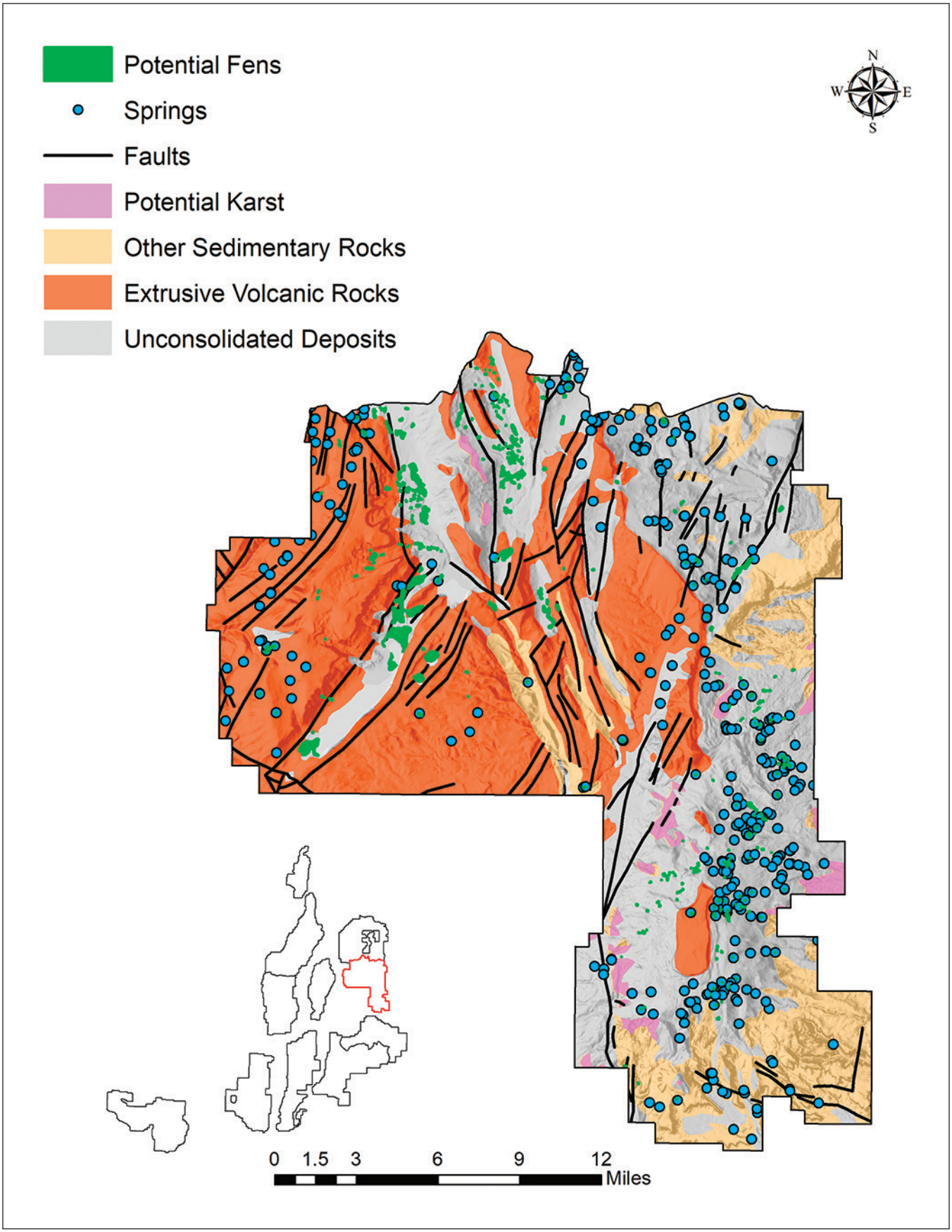


Figure C.14—Distribution of GDEs in the Fishlake–Thousand Lake geographic unit.

The most extensive riparian ecosystems are in the unconfined valley bottoms in the Fremont River and U M Creek watersheds. Narrower riparian ecosystems are present on the Thousand Lake Plateau where surface flows emerge from unconsolidated deposits below the summit. These flows support small, scattered patches of riparian vegetation. Areas with extensive riparian vegetation, as mapped by VCMQ, include Lake Creek, Sevenmile Creek, U M Creek, and the Fremont River.

There are at least 359 known springs (0.001/acre), the second greatest minimum density of any geographic unit and the greatest on the Fishlake National Forest. These springs are scattered throughout the unit, with many springs clustered around the unconsolidated deposits flanking the Thousand Lake Plateau and the mountains to its north. Clusters of springs are also associated with faults south of Thousand Lake Plateau and at northern end of the unit. Level II riparian surveys found that headwater streams of U M Creek, Sand Creek, and Tasha Creek originate at springs. Several springs also contribute flows to the Fremont River, which has economic importance because of its scenic values and trout fishery. Springs in the Sand Creek watershed contribute to the town of Torrey's water supply. CNHP identified 0.6 percent of the unit as potential fens, with 759.4 acres of low confidence fens, 390.3 acres of possible fens, and 495.9 acres of likely fens. The two largest likely fens mapped in the forest are adjacent to Fish Lake (Smith and Lemly 2020). Large complexes of mapped fens are also located in the unconsolidated deposits along Sevenmile Creek and U M Creek. Mapped fens are also scattered among the slopes of the Thousand Lake Plateau, where they are associated with spring and unconsolidated deposits.

Monroe Mountain

This unit is the northern portion of the largely volcanic Sevier Plateau, which is entirely within the Sevier River Basin (fig. C.15). There is no carbonate bedrock with potential for karst formation in the unit. Fractured volcanic rocks are extensive (fig. C.16). Colorado Plateaus sandstone aquifers underlie the entire unit.

Linear bands of riparian vegetation are present on the western and eastern slopes of the plateau. Areas with extensive riparian vegetation include Monroe Creek, Doxford Creek, Manning Creek, Box Creek, and Greenwich Creek.

There are at least 134 known springs (0.0008/acre). Springs are scattered throughout the unit. There are relatively few faults, but clusters of springs are present at faults on the eastern slope. Level II riparian surveys found Fibrist soils, indicating potential fens along Greenwich Creek. Greenwich Creek, Koosharam Creek, Box Creek, and Collins Creek originate at springs. Several of these streams contain trout fisheries and habitat for boreal toads. CNHP identified 0.3 percent of the unit as potential fens, with 417.6 acres of low confidence fens, 83.1 acres of possible fens, and 1.7 acres of likely fens. Most mapped fens are associated with volcanic bedrock in the upper elevations of the unit.

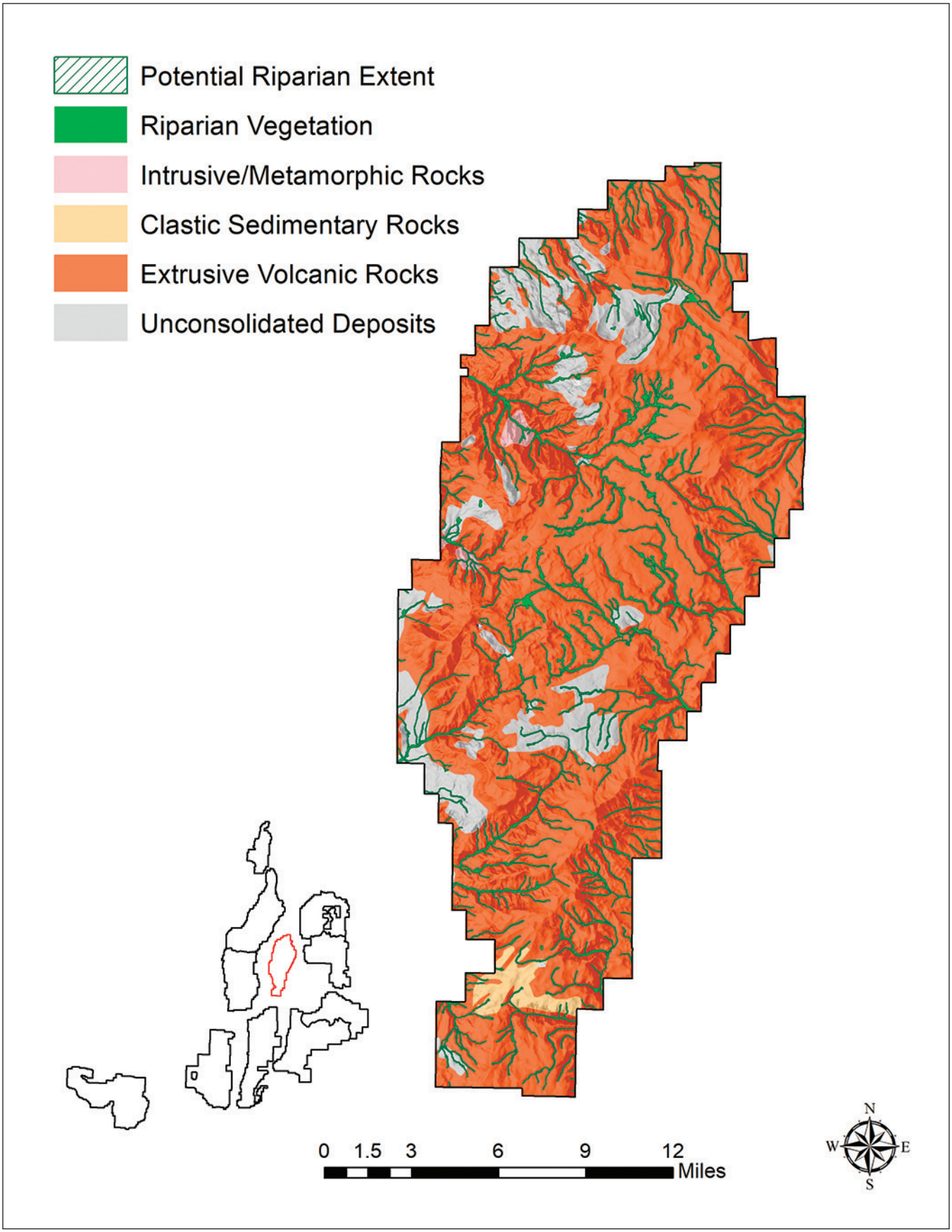


Figure C.15—Distribution of riparian ecosystems in the Monroe Mountain geographic unit.

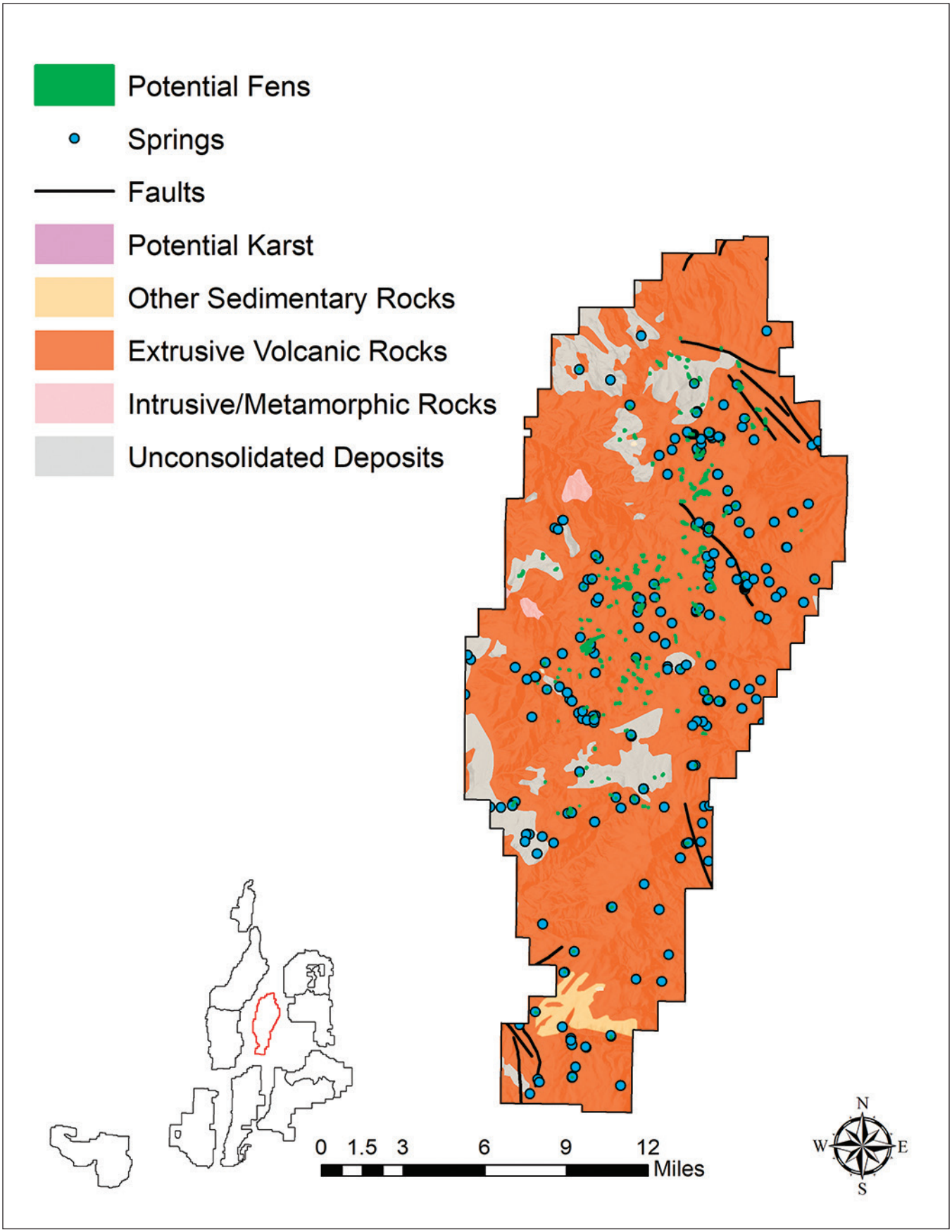


Figure C.16—Distribution of GDEs in the Monroe Mountain geographic unit.

Pavant Range

The Pavant Range, which is entirely within the Sevier River Basin, contains a mixture of sedimentary, metamorphic, and volcanic rocks (fig. C.17). Over 12 percent of the unit is composed of carbonate bedrock with potential for karst formation (fig. C.18). These deposits extend along the western slope of the range. Volcanic formations are present in the southern portion of this unit. Colorado Plateaus sandstone aquifers underlie 31 percent of the unit. Basin and Range fill and carbonate aquifers underlie 15 percent and 18 percent, respectively.

The eastern slope of the range has a high density of incised channels, but most stands of riparian vegetation are on the western slope and southern end of the unit. Areas with extensive riparian vegetation include the canyons of Corn Creek and Chalk Creek on the western slope, and Three Creeks and Grass Creek in the volcanic deposits of the Clear Creek watershed.

There are at least 119 known springs (0.0003/acre) These springs are scattered throughout the unit. There are many springs in sedimentary rocks in the central portion of the unit and in volcanic rocks in the southern portion. Several small clusters of springs are associated with faults. Level II riparian surveys found many streams to be spatially intermittent, with springs that emerge from limestone and sandstone outcrops producing perennial flows. Streams of the west slope of the range show signs of karst systems including sinkholes, travertine terraces, and calcium carbonate deposits in stream beds. The presence of bittercress and other herbaceous plants in stream channels indicates the sizable influence of springs as well. Surveys also found Fibrist soils, indicating potential fens along Clear Creek. CNHP identified 0.04 percent of the unit as potential fens, with 155.4 acres of low confidence fens, 5.4 acres of possible fens, and 2.5 acres of likely fens. The largest concentration of fens is in volcanic bedrock at the southern end of the unit.

Tushar Mountains

The Tushar Mountains, which are entirely in the Sevier River Basin, are primarily volcanic in origin (fig. C.19). There is no carbonate bedrock with potential for karst formation in the unit (fig. C.20). Colorado Plateaus sandstone aquifers underlie 75 percent of the unit. Basin and Range fill aquifers underlie 6 percent.

Narrow bands of riparian vegetation are present in the volcanic canyons of the western and eastern slopes. Areas with extensive riparian vegetation include streams in the Beaver River watershed, streams in the Clear Creek watershed, and South Fork North Creek.

There are at least 97 known springs (0.0003/acre). Springs are clustered in the northern and southern portions of the unit and many of these clusters are associated with heavy faulting. Level II riparian surveys found that many streams in the Beaver River watershed originate at springs or have springs. These springs contribute to municipal water supplies. Surveys also found Fibrist soils that indicate potential fens along the uppermost reaches of Clear Creek and Pine Creek. CNHP identified 0.1 percent of the unit as potential

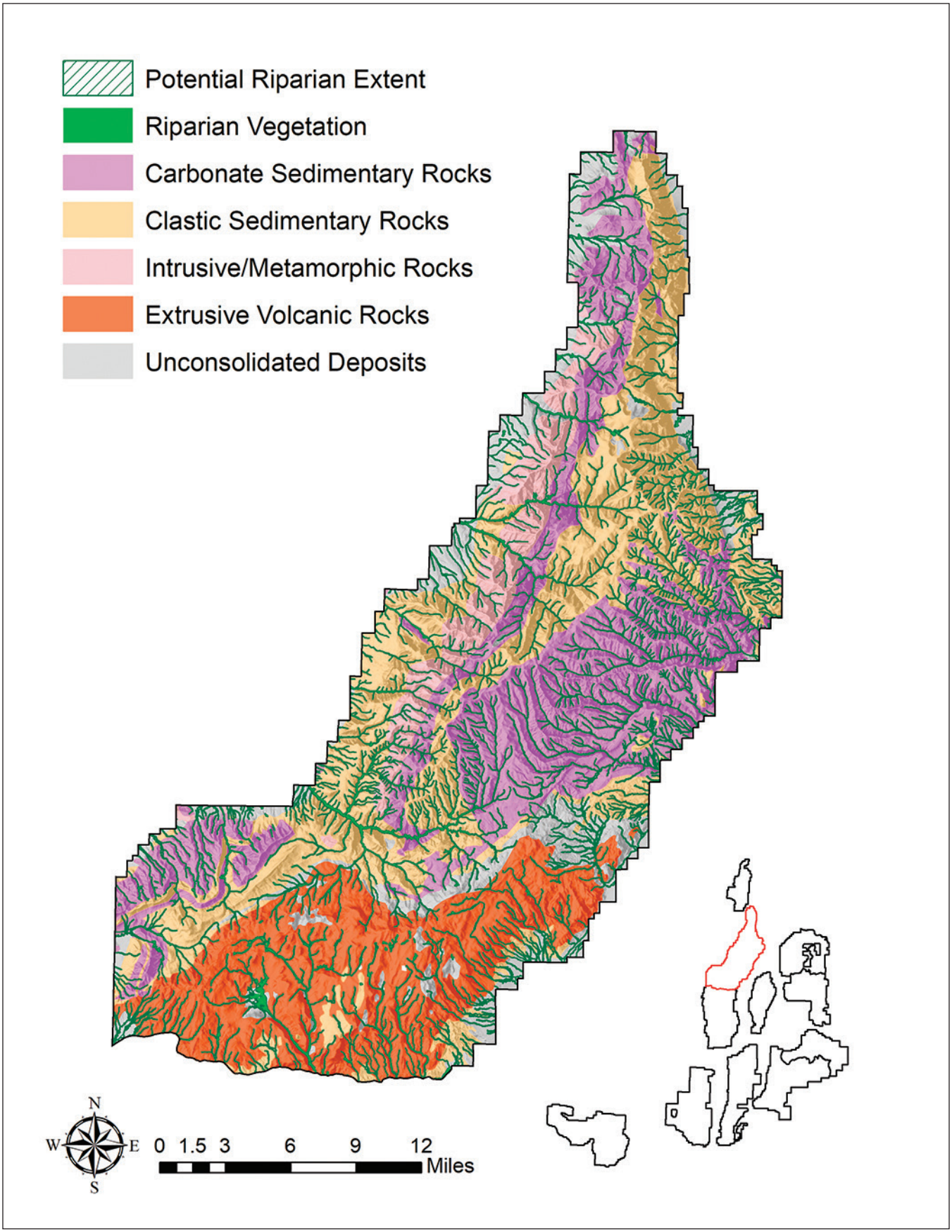


Figure C.17—Distribution of riparian ecosystems in the Pavant Range geographic unit.

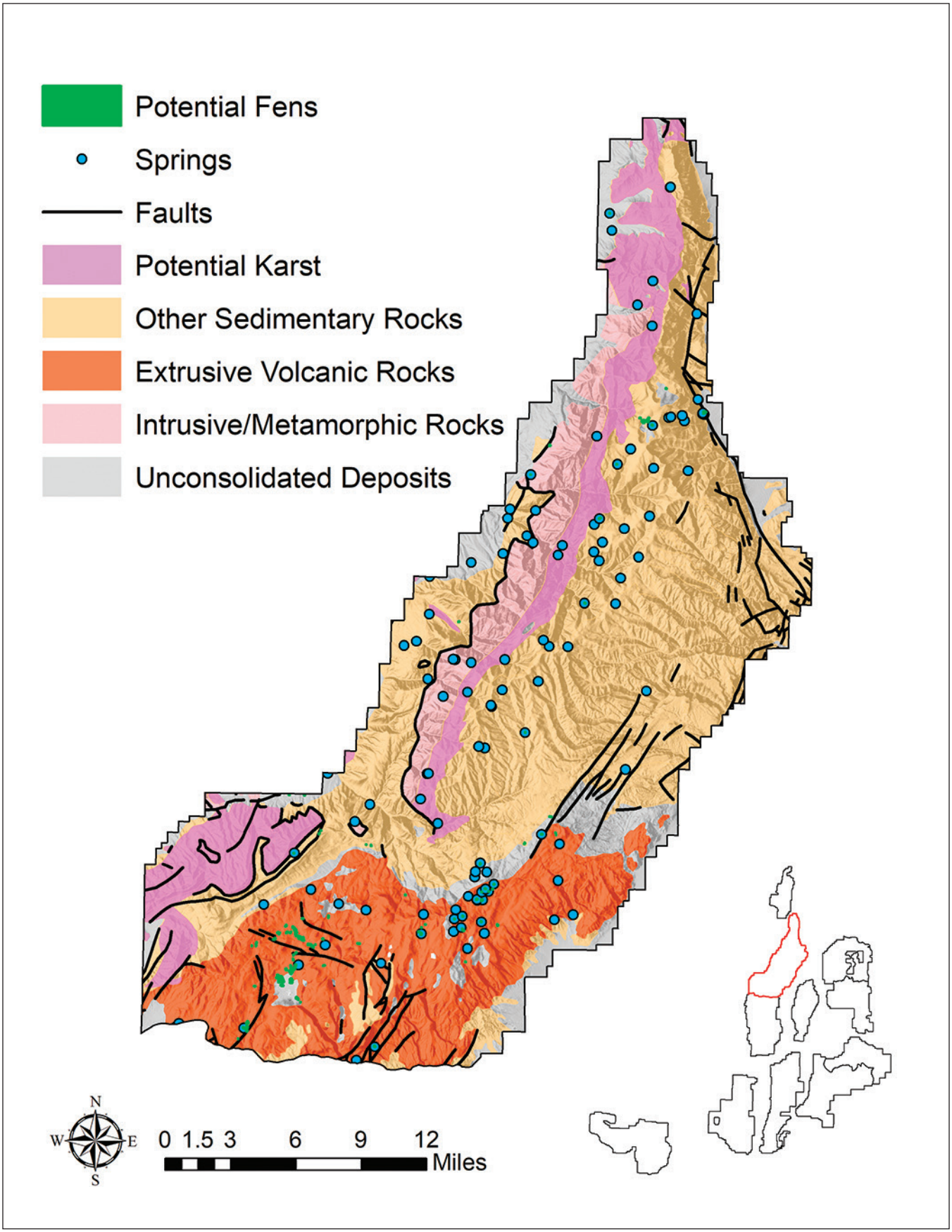


Figure C.18—Distribution of GDEs in the Pavant Range geographic unit.

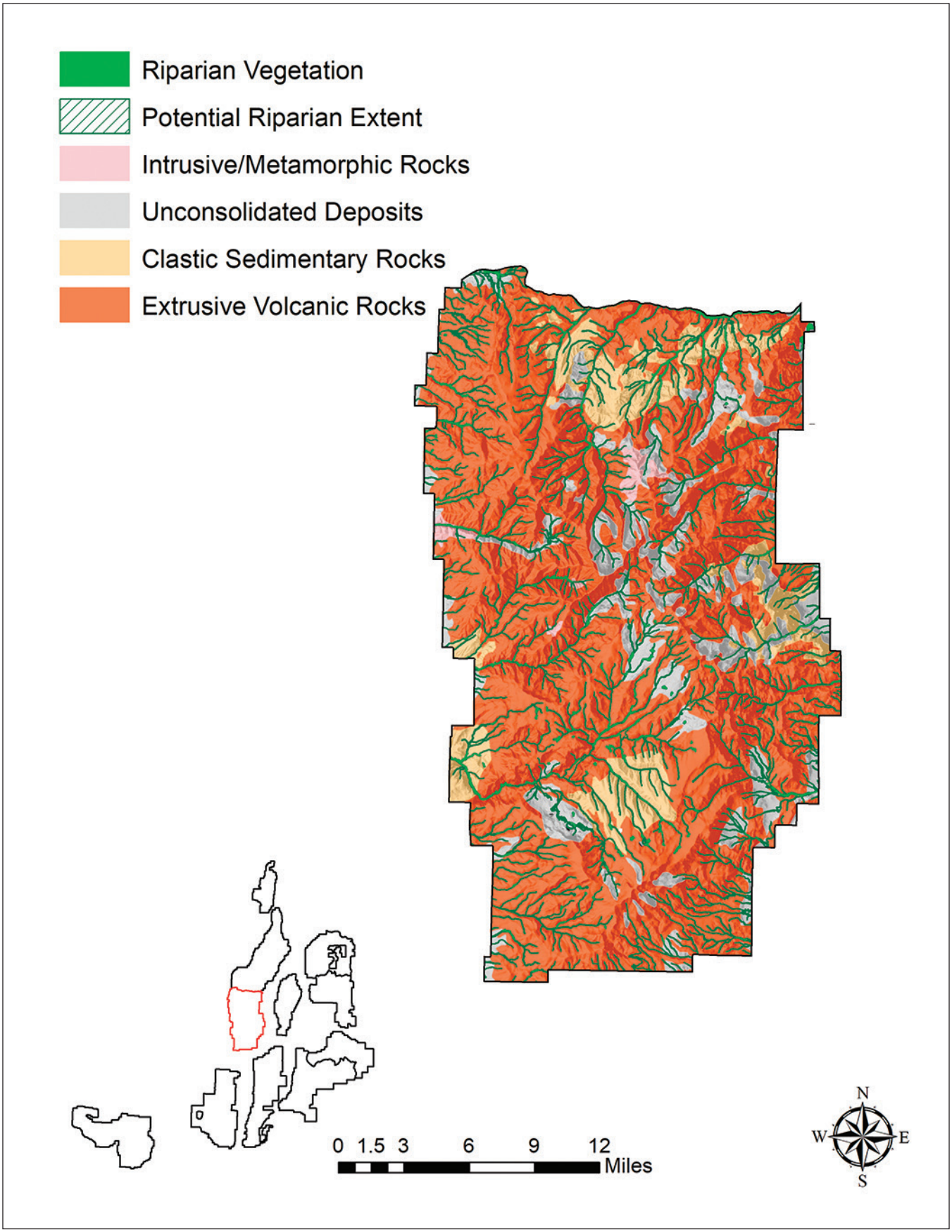


Figure C.19—Distribution of riparian ecosystems in the Tushar Mountains geographic unit.

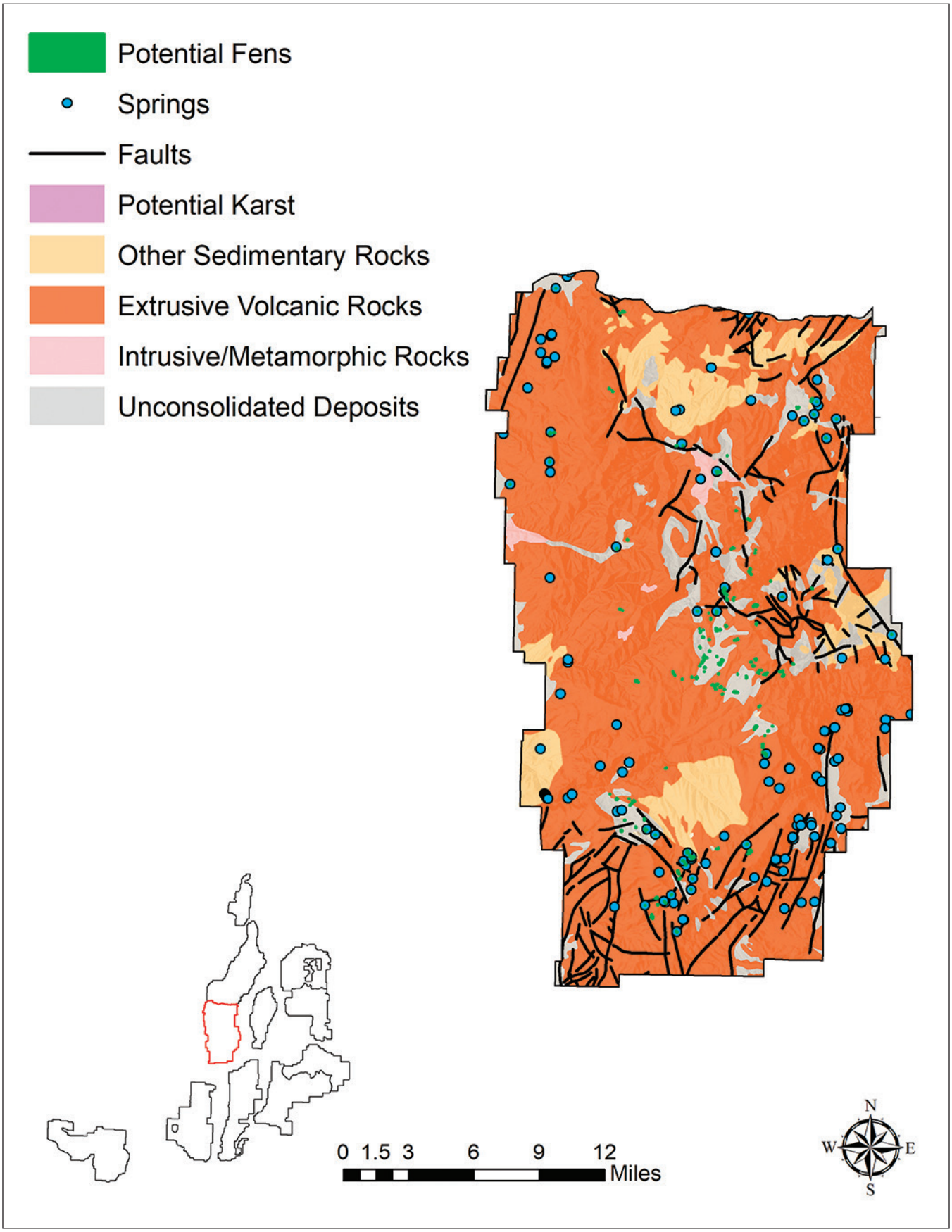


Figure C.20—Distribution of GDEs in the Tushar Mountains geographic unit.

fens, with 161.9 acres of low confidence fens, 50.5 acres of possible fens, and 13.7 acres of likely fens. Most of these fens are associated with volcanic bedrock and unconsolidated deposits at high elevations of the unit.

White Mountain

The western slope of the White Mountain unit includes streams in the Salina Creek and Lost Creek watersheds in the Sevier River Basin. Several streams in the Upper Colorado River Basin are on the eastern slope. The northern portion of the White Mountain unit is composed of sedimentary rocks of the Wasatch Plateau (fig. C.21). Volcanic rocks are present in the southwestern corner. Over 9 percent of the unit is composed of carbonate bedrock with potential for karst formation (fig. C.22). Most of these deposits are located in the northern portion of the unit. Volcanic formations are present in the southern portion of this unit. Colorado Plateau sandstone aquifers underlie the entire unit.

Stands of riparian vegetation are distributed throughout the unit. Unconsolidated deposits on the western slope contain extensive riparian ecosystems. Smaller patches of riparian vegetation are scattered along the eastern slope. Areas with extensive riparian vegetation include Lost Creek, Salina Creek, and Beaver Creek.

There are at least 154 known springs (0.0005/acre). These springs are scattered across the unit. Springs on the western slope of the unit are largely associated with faults. Level II riparian surveys found several streams originating at springs emerging from limestone or sandstone outcrops. Springs also contribute to perennial flows of larger streams. CNHP identified 0.2 percent of the unit as potential fens, with 410.1 acres of low confidence fens, 82.0 acres of possible fens, and 14.5 acres of likely fens. Most of these fens are associated with springs in the southern portion of the unit.

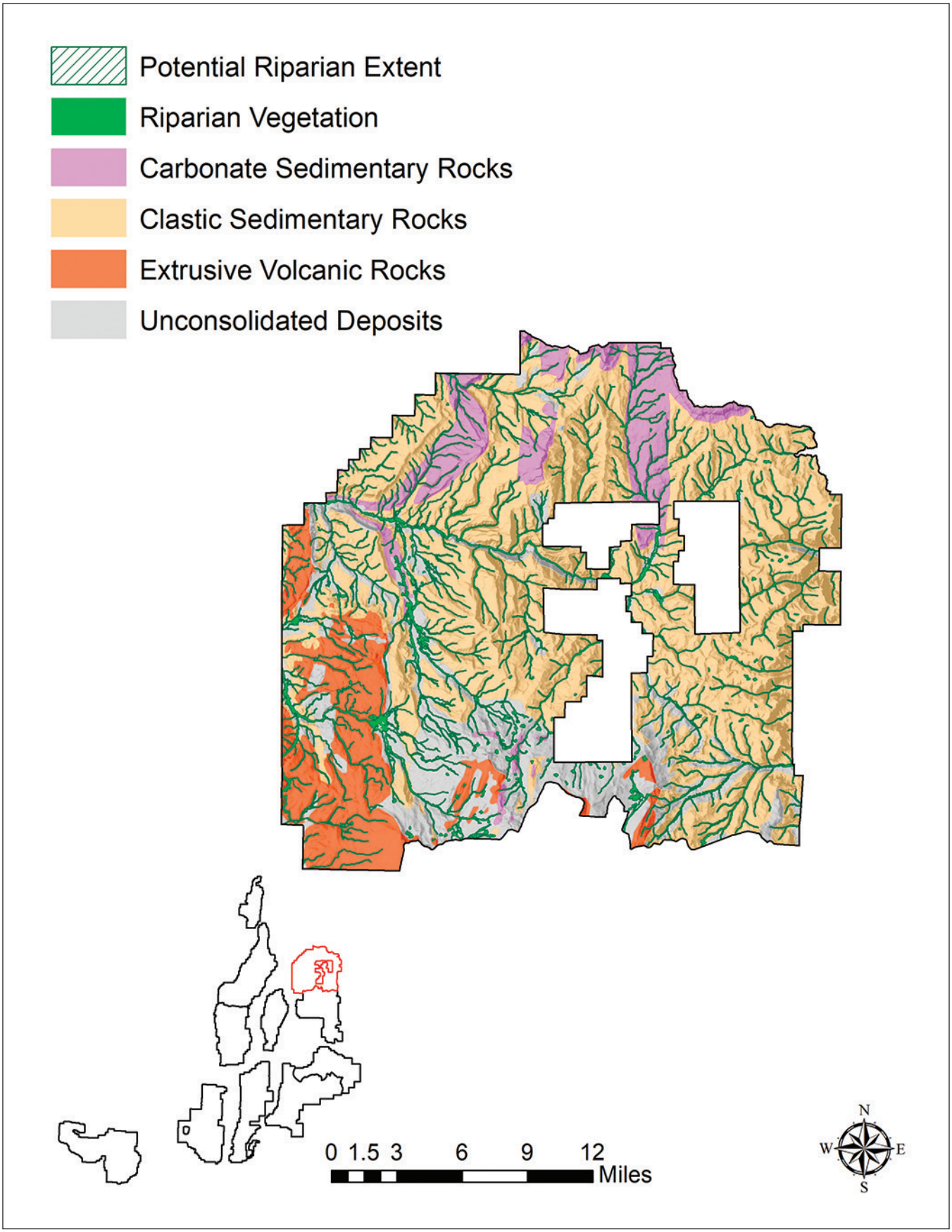


Figure C.21—Distribution of riparian ecosystems in the White Mountain geographic unit.

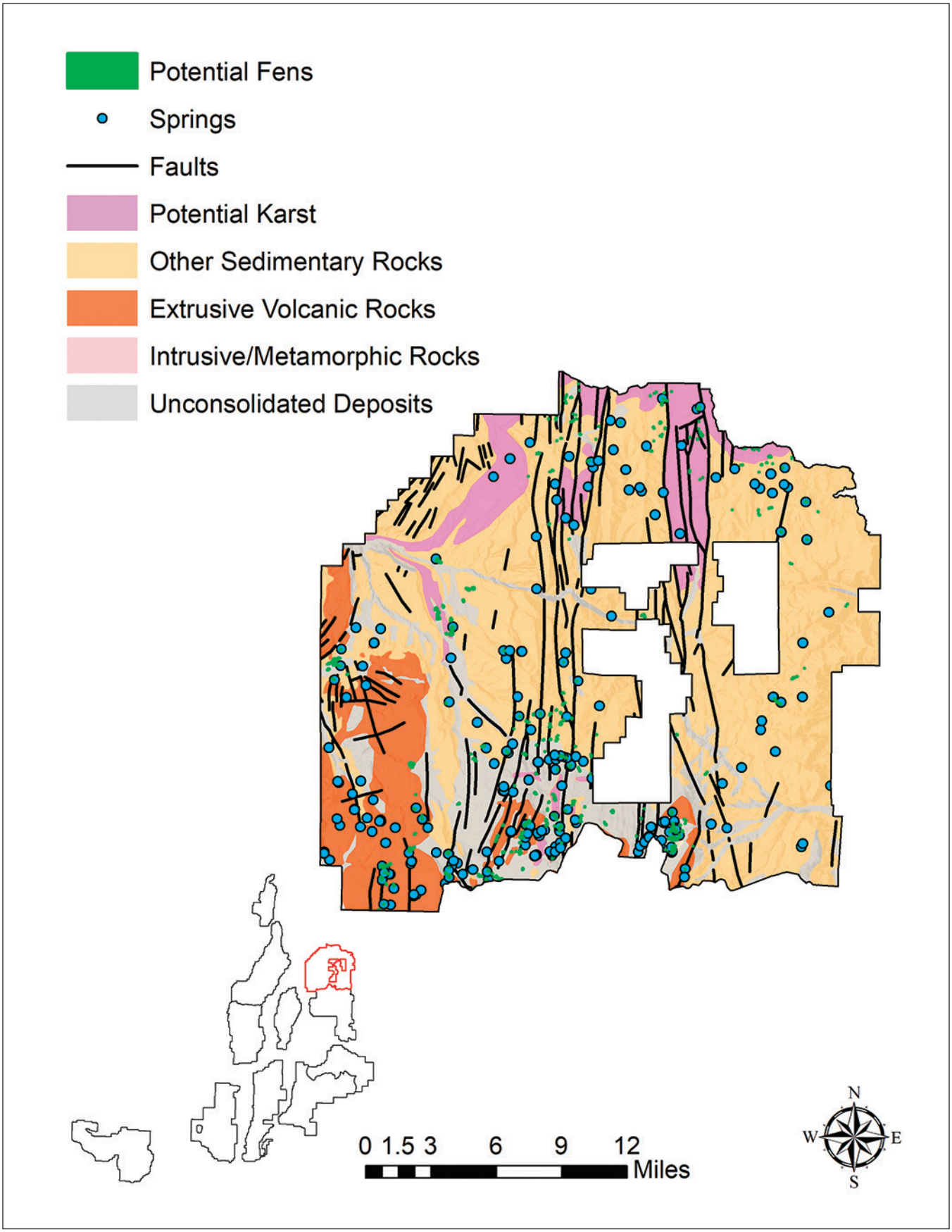


Figure C.22—Distribution of GDEs in the White Mountain geographic unit.

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Appendix D. Surface Water and Groundwater Fluctuations

Methods

We used five indicators to assess the current conditions of surface water and groundwater fluctuations: (1) conversion of riparian habitat to conifer cover, (2) conversion of riparian habitat to upland grass and shrub species, (3) water quantity, (4) deviation in winter temperature, and (5) deviation in winter precipitation (table D.1). We obtained estimates of conifer and upland encroachment from the Riparian Condition Assessment Tool (R-CAT) (Macfarlane et al. 2017). While some riparian areas can include species such as Rocky Mountain juniper, transition from riparian cover to upland species, including conifers, is associated with altered flow regimes (Macfarlane et al. 2017). This type of encroachment can initiate positive feedbacks that reduce landscape turnover, modify water yield and fluctuation timing, and eventually encourage further upland encroachment (Huxman et al. 2005; Macfarlane et al. 2017). R-CAT estimates of conifer and upland encroachment were generated using 30 meter LANDFIRE data, which can be too coarse to adequately map vegetation in some of the narrow riparian corridors that exist within the study area. In these locations, R-CAT tends to overestimate conversion of riparian habitats to alterative cover types. We used data from the USFS WCF WaterQquantity indicator (Potyondy and Geier 2011). This

Table D.1—Values of surface water and groundwater fluctuation indicators by geographic unit.

Geographic unit	Forest	Percent stream miles converted from riparian to conifer	Percent streams miles converted from riparian to grass/shrub	Water quantity score	Winter temperature deviation (°F)	Winter precipitation deviation (%)
Escalante	Dixie	28.6	4.1	2.2	2.0	-1.3
Markagunt Plateau	Dixie	32.5	17.3	2.3	2.4	-0.5
Paunsaugunt–Mt. Dutton	Dixie	15.6	34.7	1.9	2.1	-1.6
Pine Valley	Dixie	49.2	12.2	2.0	2.0	-2.7
Boulder Mountain	Fishlake	33.0	3.3	2.1	1.9	-1.3
Canyon Mountains	Fishlake	34.8	37.2	1.2	0.9	12.1
Fishlake–Thousand Lake	Fishlake	25.2	23.1	1.7	1.6	-6.2
Monroe Mountain	Fishlake	49.9	3.9	1.4	1.4	-1.8
Pavant Range	Fishlake	40.3	11.0	1.2	1.3	-1.5
Tushar Mountains	Fishlake	48.5	11.5	1.5	1.6	-5.7
White Mountain	Fishlake	24.8	8.2	1.1	1.6	-6.4

WCF indicator addresses changes in the timing, frequency, duration, or magnitude of natural flows (Potyondy and Geier 2011). Lastly, we used data related to deviation in winter temperature and precipitation from the TCA (Cleland et al. 2017). These final two indicators address climatic warming that has generally altered snowpack and contributed to altered flow regimes throughout the western United States (Safeeq et al. 2016).

We scored these five indicators for water fluctuations in surface water systems based on whether they showed evidence of no, moderate, or substantial alteration from the NRV. If the indicator had little or no alteration it was given a score of 5; moderate alteration was given a score of 3; substantial alteration was given a score of 1 (table D.2). The thresholds for moderate and substantial alteration for each indicator were determined from the literature or from the data sources. The scores for each geologic unit were summed and divided by the potential total of 30 to give a percentage rating for each. Units were considered within the NRV for fluctuations in surface water systems if the index was greater than 77 percent, moderately altered from the NRV if the index was between 50 percent and 76 percent; outside the NRV if the index was less than 50 percent.

We were unable to assess water fluctuations at GDE wetlands because we did not locate sufficient data on the condition of these systems. We used the WRU database from both Forests to evaluate the number of springs associated with a diversion and to summarize the condition of those GDEs.

Unit Summaries

Escalante

The primary stressors to groundwater and surface water fluctuations in the Escalante unit were diversions, dams, roads, and grazing. There were 0.003 diversions per acre and 0.019 dams per stream mile, which were intermediate densities relative to the other units. The WCF Flow Characteristics attribute indicated that peak and base flows are likely maintained throughout most of the unit, but that the timing, rate of change, and/or duration of mid-range discharges was altered. Additionally the WCF Habitat Fragmentation attribute indicates that dewatering had potentially contributed to fragmentation of aquatic habitats. There were 0.002 road miles

Table D.2—Thresholds of evidence for alteration from the NRV and data sources for five indicators of surface water and groundwater fluctuations condition.

Indicator	Data source	Little or no alteration (5 points)	Moderate alteration (3 points)	Substantial alteration (1 point)
Conifer encroachment	R-CAT	< 33%	33% < x < 66%	> 66%
Upland encroachment	R-CAT	< 33%	33% < x < 66%	> 66%
Water quantity score	WCF	≤ 1.6	1.7 ≤ x ≤ 2.2	≥ 2.3
Deviation in winter temperature	TCA	< 2 °F	2 °F ≤ x < 3.2 °F	≥ 3.2 °F
Deviation in winter precipitation	TCA	< 5%	5% < x < 10%	> 10%

per acre in the Escalante unit, which was relatively high within the study area. The WCF Road and Trail Condition indicator suggests that there was high probability that roads had substantially altered the hydrologic regime within this geographic unit. Best management practices for maintenance of designed drainage features had been applied to less than 50 percent of roads, trails, and water crossings with the majority of watersheds in this unit. Ninety-one percent of the Escalante unit was within a range management unit and 100 percent of those were active. The WCF indicated 55 percent of the unit is in proper functioning condition for rangeland vegetation condition, meaning these locations are capable of capturing, storing, and releasing water from rainfall, runoff, and snowmelt. Thirty-eight percent of watersheds were considered functional-at-risk for rangeland vegetation condition, with some loss of hydrologic function likely.

There were 1,289 stream miles within the Escalante unit. Of these streams, 22 percent were classified as perennial, 56 percent were intermittent, and 22 percent were ephemeral; however, these percentages naturally vary between dry and wet years. According to NHD, there are 110 springs and according to NWI there are 1,199 acres of wetlands, which is about 0.3 percent of the unit. Melting snow in the spring and summer monsoons are the largest sources of flood discharge in the Escalante unit (White 1932). The magnitude, frequency, and duration of high flows is highly variable across years. More than a dozen floods occur in some years as a result of storm water runoff and in other years flood waters are negligible (White 1932). Overall, perennial streams are relatively rare, while the numerous intermittent and ephemeral reaches in this unit can go months or even years without experiencing flow (White 1932).

Level II riparian surveys noted impacts from diversions and dams in the Deer Creek watershed. Some reaches are entirely dewatered due to earthen dams and a series of ditches that transfer all streamflow to Boulder Creek, resulting in major alterations to the flow regimes in both of these drainages. Additionally, level II riparian surveys provide evidence of several deeply incised stream reaches that are likely linked to lower water tables and reduced overbank flow. Conifer encroachment has occurred along 81.6 miles, or 28 percent, of perennial streams. An additional 11.6 miles (4 percent) of perennial stream miles have converted from riparian cover to upland grass and shrub species. This was the smallest percentage of streams converted to grass and shrub cover of units on the DNF. The average WCF water quantity score was 2.2, indicating moderate departure from natural flow regimes. Changes in climate were apparent in the Escalante unit, with increased temperature in all seasons and evidence of large shifts in precipitation patterns. Both fall and summer precipitation increased by more than 30 percent, while spring precipitation decreased by 4.0 percent. Winter temperatures increased by an average of 2.0 °F across the Escalante unit and winter precipitation decreased by 1.3 percent. Overall, these indicators suggest that water fluctuations in surface water systems of the Escalante unit were **within the NRV** with an overall score of 84 percent.

Modified level I GDE surveys were completed in the Escalante unit in 2013, 2014, and 2015. Several surveys reported impacts from culverts, regulated water flow, extraction, and diversions at the GDEs in this unit. The DNF WRU dataset indicates there are points of diversion at 36 of the 110 (33 percent) springs within the Escalante unit. No information was available on the presence of water or the condition of these springs. There was **insufficient information** to evaluate water fluctuations at GDEs in the Escalante unit.

Markagunt Plateau

The primary stressors in the Markagunt Plateau unit were diversions, dams, roads, and grazing. There were 0.008 diversions per acre, which was relatively high compared to other units in the study area. There was a moderate amount of dams compared to other units, with 0.03 dams per stream mile. The WCF Flow Characteristics attribute indicated the magnitude, duration, and/or timing of annual high and low flows generally departed from the natural hydrograph and that the timing and rate of change in flows typically were not correlated with expected seasonal changes. There were 0.004 road miles per acre and 0.002 trail miles per acre, which was a higher road density than any other unit in the study area and the highest trail density of the DNF. The WCF Road and Trail Condition indicator suggested that the density and distribution of roads and trails have a high likelihood of substantially altering the hydrologic regime of this unit. Best management practices for maintenance of drainage features had been applied to less than 50 percent of roads, trails, and water crossings in nearly all watersheds. The percent of the Markagunt unit that has been harvested for timber is relatively high for the study area (2.2 percent), however forest cover remains within proper functioning condition based on the WCF. Ninety-two percent of the Markagunt Plateau unit was located within a range management unit and 89 percent of these were active. According to the WCF, 75 percent of this geographic unit is functioning properly in terms of rangeland vegetation condition. Four percent of the unit is considered to be impaired for rangeland vegetation condition, suggesting these areas have lost the capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt. An additional 20 percent is considered functional-at-risk, meaning these areas have a reversible loss of hydrologic function and greater vulnerability to irreversible degradation.

There were 1,422 stream miles within the Markagunt Plateau unit. Of these streams, 18 percent were perennial, 8 percent were intermittent, and 74 percent were ephemeral; however, these percentages naturally vary between wet and dry years. According to NHD there were 320 springs and according to NWI there were 1,301 acres of wetland, which is 0.3 percent of the Markagunt Plateau. The geology and climate of the Markagunt Plateau make it an important source of groundwater infiltration (Thiros and Brothers 1993). Relatively large amounts of precipitation fall at high elevations and then enter the consolidated rock through fractures on the surface, which allow large amounts of precipitation to infiltrate (Brooks and Mason 2005; Gregory 1949; Thiros and Brothers 1993). Connectivity between ground and

surface water systems is particularly important in this unit, as intermittent and perennial flow in many streams is fed by springs that discharge from sedimentary rock walls at the base of lava flows (Gregory 1949). Fluctuations in flow from these major springs is highly correlated with precipitation from the preceding year and is generally tied to changes in regional climatic conditions (Gregory 1949).

Level II riparian surveys noted impacts from diversions in Deer Creek, where the flow regime has been altered by increased flow from the Castle Creek diversion. Conifer encroachment has occurred along 82.6 miles, or 32 percent, of perennial streams. An additional 43.9 miles (17 percent) of perennial streams have converted from riparian cover to upland grass and shrub species. The average WCF water quantity score for this geographic unit was 2.3, indicating moderate departures from natural flow regimes. Changes in climate were apparent in the Markagunt Plateau, with increased temperature in all seasons. Precipitation increased by 35 percent in fall months and 14 percent during the summer. Winter temperatures increased by an average of 2.4 °F across the Markagunt Plateau, but winter precipitation remained unchanged. This unit has experienced the largest increase in winter temperature of any unit considered in this assessment. Overall, these indicators suggest that water fluctuations in surface water systems of the Markagunt Plateau unit were **moderately altered from the NRV** with an overall score of 76 percent.

We did not find any data to evaluate the condition of water fluctuations at GDE wetlands. The DNF WRU dataset indicated there are points of diversion at 279 of the 320 (87 percent) springs within the Markagunt Plateau. No information was available on the presence of water or the condition of these springs. There was **insufficient information** to evaluate water fluctuations at GDEs in the Markagunt Plateau.

Paunsaugunt–Mt. Dutton

The main stressors in the Paunsaugunt–Mt. Dutton unit are diversions, dams, roads, and grazing. There were 0.0009 diversions per acre in this unit, which is the lowest diversion density of all units considered in our assessment. There were 0.004 dams per stream mile, which was the second lowest dam density of all units. While the number of dams and diversions may be limited, the WCF Flow Characteristics attribute indicated these features were impacting the timing, rate of change, or duration of mid-range discharges. There were 0.003 roads per acre in the Paunsaugunt–Mt. Dutton unit, which was the second largest road density of all units in the study area. The TCA indicated moderate condition for roads, with a large number of unimproved roads contributing to lower scores. The WCF Road and Trail Condition indicator suggested there is high probability that the density and distribution of roads has substantially altered the hydrologic regimes of this unit. Additionally, best management practices for designed drainage features had been applied to less than 50 percent of roads, trails, and water crossings in the majority of watersheds in the Paunsaugunt–Mt. Dutton

unit. One hundred percent of this unit was within range management units and 89.7 percent of those were active. According to the WCF, 39 percent of watersheds had properly functioning rangeland vegetation conditions, meaning these areas were capable of capturing, storing, and safely releasing water from rainfall, runoff, and snowmelt. Fifty percent of the unit does not meet this requirement and was considered functional-at-risk, with a reversible loss of hydrologic function.

There were 1,358 stream miles within the Paunsaugunt–Mt. Dutton unit. Of these streams, 13 percent were perennial, 21 percent were intermittent, and 66 percent were ephemeral; however, these percentages naturally vary between wet and dry years. According to NHD, there were 175 springs and according to NWI there were 64.8 acres of wetland, which comprises about 0.02 percent of the unit. Generally, the climate in the Paunsaugunt region is semiarid; however, precipitation and temperature are highly variable across time and topography (Gregory 1951). Compared to other parts of the Colorado Plateau, the Paunsaugunt region tends to have more perennial streams, but the majority of streams remain intermittent and ephemeral (Gregory 1951). Surface water flows and infiltration are highly influenced by geology and topography, with surface flow occurring where bedrock is exposed or in steep channels and infiltration more common in the foot hills and on the relatively flat Paunsaugunt Plateau (Gregory 1951). Many perennial reaches are fed by discharge from springs, highlighting the importance of connectivity between ground and surface water systems in this unit (Gregory 1951). Springs tend to occur on canyon walls along joint zones, within sandstone geologic settings, and at the contact of alluvial fill and rock surfaces (Gregory 1951).

Level II riparian surveys did not describe any impacts from dams or diversions in this unit; however, some reaches were incised and had likely experienced declines in the water table and reduced over bank flooding. These reports noted the presence of beaver in many reaches, which may contribute to stable flow regimes. Conifer encroachment had occurred along 26.6 miles, or 16 percent, of perennial streams. This was the least amount of stream miles converted to conifer cover of any geographic unit considered in our assessment. An additional 59 miles (35 percent) of perennial streams had converted from riparian cover to upland grass and shrub species. This was the largest percentage of streams converted to grass and shrub cover of any unit on the DNF. The average WCF water quantity score for this geographic unit was 2.1, indicative of moderate departures from the natural flow regime. Changes in climate were apparent in this unit, with warmer temperatures in all seasons and large shifts in precipitation patterns. Temperatures of recent years are at least 1 °F warmer and fall and summer precipitation had increased by 39 percent and 20 percent, respectively. Winter temperatures increased by 2.1 °F and winter precipitation decreased by 1.6 percent. Overall, these indicators suggest that water fluctuations in surface water systems of the Paunsaugunt–Mt. Dutton unit were **moderately altered from the NRV** with an overall score of 76 percent.

We did not find any data to evaluate the condition of water fluctuations at GDE wetlands in the Paunsaugunt–Mt. Dutton unit. The DNF WRU dataset indicated there were no points of diversion associated with springs within the Paunsaugunt–Mt. Dutton unit. There was **insufficient information** to evaluate water fluctuations at GDEs in the Paunsaugunt–Mt. Dutton unit.

Pine Valley

The main stressors in the Pine Valley unit were diversions, dams, roads, and grazing. There were 0.2 diversions per acre, more than any other unit considered in our assessment. Additionally, there were 0.05 dams per stream mile, which was also the largest dam density of all units in the study area. The WCF Flow Characteristics attribute indicated that alterations to the timing, rate of change, or duration of mid-range discharges had occurred in most watersheds in this unit. There were 0.002 road miles per acre in the Pine Valley unit, which was relatively low compared to other units in the study area. The WCF Road and Trail Condition indicator suggested the density and distribution of roads had a high probability of substantially altering the hydrologic regime of most watersheds in this unit. Best management practices for maintenance of designed drainage features were applied to less than 50 percent of roads, trails, and water crossings in nearly all watersheds. Seventy-one percent of Pine Valley was located within a range management unit, which was less than any other unit in the study area. Ninety-eight percent of these range management units were active. According to the WCF Rangeland Vegetation indicator, 3 percent of Pine Valley was impaired for rangeland vegetation condition, meaning these areas had lost the capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt. Seventy-three percent of the unit was considered functional-at-risk, meaning it had experienced reversible loss of hydrologic function. Twenty-four percent of the Pine Valley unit was in proper functioning condition for rangeland vegetation.

There were 2,027 stream miles within the Pine Valley unit. Of these, 6 percent were perennial, 7 percent were intermittent, and 86 percent were ephemeral. According to NHD there were 136 springs and according to NWI there were no wetland acres in this unit. Most streams are ephemeral, with the perennial reaches existing in upper reaches (Stephens 1975). Infiltration to groundwater systems tends to occur in the mountains, ultimately providing a runoff source to streams through spring discharge and seepage into channels (Stephens 1975). Groundwater recharge occurs from precipitation and spring flow is highly influenced by variable precipitation, with some springs flowing only in response to precipitation events and during snowmelt (Stephens 1975).

Level II riparian surveys noted impacts of diversions at Holt Canyon, Leep Creek, Leeds Creek, Shinbone Creek, Spring Creek Mountain Meadows, Wet Sandy, and the Santa Clara River. Some reaches were entirely dewatered, while others had experienced reduced flooding as a result of dams and diversions. Additionally, these reports noted some examples of incised reaches that had likely experienced declines in the water table and

reduced overbank flow. Conifer encroachment had occurred along 64.0 miles, or 49 percent, of perennial streams in the Pine Valley unit. This was the largest percentage of stream miles converted to conifer cover of all units on the DNF. An additional 15.9 miles (12 percent) of perennial streams had converted from riparian cover to upland grass and shrub species. The average WCF water quantity score for this geographic unit was 2.0, indicating moderate alterations to natural flow regimes. Changes in climate were apparent in this unit, with warmer temperatures in all seasons and large shifts in precipitation regimes. Fall and summer precipitation increased by 25 percent and 8 percent, respectively; and spring precipitation decreased by 17 percent. Winter temperatures had increased by 2.0 °F and winter precipitation had decreased by 3 percent. Overall, these indicators suggested that water fluctuations in surface water systems of the Pine Valley unit were **moderately altered from the NRV** with an overall score of 76 percent.

The NWI indicated there were no wetlands in the Pine Valley unit, and we did not find any data related to water fluctuations at GDE wetlands. The DNF WRU dataset indicated there were points of diversion associated with 16 of the 136 springs in the Pine Valley unit. No information was available on the presence of water or the condition of these springs. There was **insufficient information** to evaluate water fluctuations at GDEs in the Pine Valley unit.

Boulder Mountain

The primary stressors in the Boulder Mountain unit were diversions, dams, and roads. There were 0.003 diversions per acre and 0.2 dams per stream mile, which were both moderate densities relative to other units in the study area. The WCF Flow Characteristics attribute indicated that peak and base flows were likely maintained throughout most of the unit, but that the timing, rate of change, and/or duration of mid-range discharges was altered. Additionally, the WCF Habitat Fragmentation attribute indicated dewatering had potentially contributed to fragmentation of aquatic habitats. There were 0.002 road miles per acre, which was a moderate density compared to other units. The WCF Road and Trail Condition indicator suggested there was moderate probability that the density and distribution of roads in the Boulder Mountain unit had substantially altered hydrologic regimes. Best management practices for designed drainage features were applied to less than 50 percent of roads, trails, and water crossings in almost all watersheds in this unit.

There were 775 stream miles within the Boulder Mountain unit. Of these streams, 18 percent were perennial, 78 percent were intermittent, and 3 percent were ephemeral; however, these percentages naturally vary between dry and wet years. According to NHD there were 27 springs and according to NWI there were 1,502 acres of wetland, which is 0.6 percent of the unit. This is the largest percentage of a unit classified as wetland on both Forests. Precipitation on Boulder Mountain and the Aquarius Plateau is an important source of water for streams and GDEs in the region. The flat topography, large snow accumulation, and permeable sand and gravel

soils allow for considerable recharge to groundwater systems (Bjorklund 1969; Christiana 1991). Precipitation infiltrates through the volcanic rocks of Boulder Mountain and is transferred to springs and seeps at lower elevations (Bjorklund 1969; Christiana 1991). High rates of infiltration on the plateau limit the development of perennial streams (Bjorklund 1969; Christiana 1991); however, where they exist, their flow tends to be relatively constant from November through February, rise in response to spring snowmelt, and decline throughout the summer (Christiana 1991). Spring discharge also responds quickly to local variation in recharge rate and can cease flowing during dry periods (Bjorklund 1969; Christiana 1991).

Level II riparian surveys noted impacts from dams and/or diversions in Pleasant and Pine Creeks. Some reaches were entirely dewatered, resulting in major alterations to the flow regimes. Additionally, level II riparian surveys provided evidence of incised stream channels that are likely linked to lower water tables and reduced overbank flooding. Conifer encroachment had occurred along 46.4 miles, or 32 percent, of perennial streams. An additional 4.5 miles (3.3 percent) of perennial streams had converted from riparian cover to upland grass and shrub species. This was the smallest percentage of streams converted to grass and shrub cover of any unit. The average WCF water quantity score was 2.1, indicating moderate departure from natural flow regimes. Changes in climate were apparent in the Boulder Mountain unit, with increased temperatures in all seasons and large shifts in precipitation regimes. Fall and summer precipitation increased by more than 32 percent and summer precipitation decreased by 3.3 percent. Winter temperatures increased by 1.9 °F and winter precipitation decreased by 1.3 percent. These indicators suggested that water fluctuations in surface water systems of the Boulder Mountain unit were **within the NRV** with an overall score of 92 percent.

We did not find any data to evaluate the condition of water fluctuations at GDE wetlands. The FNF WRU dataset indicates there are no points of diversion associated with springs. There was **insufficient information** to evaluate water fluctuations at GDEs in the Boulder Mountain unit.

Canyon Mountains

The major stressor to surface and groundwater fluctuations in the Canyon Mountains was wildfire, with 11.2 percent of the unit having experienced high severity burns and 37.5 percent having experienced moderate severity burns. These were far greater percentages of land area impacted by wildfire than any other units considered in our assessment. The TCA indicated that on average the Canyon Mountains unit was in moderate condition in terms of uncharacteristic wildfire and very poor condition in terms of fire frequency. The WCF Fire Regime Condition Class indicator estimated a large percentage of watersheds in this unit had high departure from the reference fire regime. No WCF Fire Effects score had been recorded for watersheds in this unit, suggesting either less than 50 percent of watersheds were impacted by significant wildfire or wildfire occurred after completion of the WCF.

There were 537 stream miles within the Canyon Mountains unit. Of these, 2 percent were perennial, 9 percent were intermittent, and 89 percent were ephemeral. According to NHD there were 50 springs and according to NWI there were 81 acres of wetland, which is approximately 0.07 percent of the Canyon Mountains unit. The highest elevations of the Canyon Mountains receive large amounts of precipitation, which is an important source of water for both surface and groundwater systems at lower elevations (Davis 2005; Mower 1965). Streams flow into the Pavant Valley from the Canyon Mountains, but the discharge is intermittent and relatively small (Davis 2005). The major streams show strong snowmelt signatures, as well as flow during monsoon storms in the summer (Mower 1965). The rock formations of the mountains tend to be relatively impermeable and only transport small amounts of water that infiltrates through cracks, joints, and bedding planes. This groundwater emerges in canyons and valleys at lower elevations as spring discharge, which maintains baseflow of several small creeks in the region (Mower 1965).

Level II riparian surveys noted impacts from diversions in both Oak Creek and North Walker Canyon. Reaches in both streams were entirely dewatered, resulting in major alterations to the flow regime in these drainages. Additionally, level II riparian surveys provided evidence of incised channels that were likely linked to lower water tables and reduced overbank flooding. The surveys reported that the uplands of these streams were in a process of recovering from wildfire and that management actions were effectively mitigating some potential impacts. Conifer encroachment had occurred along 4.3 miles, or 34 percent, of perennial streams. An additional 4.6 miles (37 percent) of perennial streams had converted from riparian cover to upland grass and shrub species. This was the largest percentage of streams converted to grass and shrub cover of any geographic unit. The average WCF water quantity score was 1.2, indicating minor departure from natural hydrologic regimes. Changes in climate were apparent in the Canyon Mountain unit, with increased temperature in all seasons and shifts in precipitation regimes; however, the alterations in temperature and precipitation of this unit were relatively small compared to other geographic units. Precipitation has increased in all four seasons by 1.5 percent in spring to 8.5 percent in fall months. Winter temperatures increased by 0.9 °F and winter precipitation increased by 12 percent. This was the only unit that experienced an increase in winter precipitation and the increase in winter temperature was the smallest of all geographic units. These indicators suggested that water fluctuations in surface water systems of the Canyon Mountains unit were **moderately altered from the NRV** with an overall score of 68 percent.

We did not find any data to evaluate the condition of water fluctuations at GDE wetlands. The FNF WRU dataset indicated there were points of diversion associated with 2 of the 50 springs in the Canyon Mountains. Despite the diversions, both springs had abundant flowing water, with one classified in fair condition and the second classified in good condition. There was **insufficient information** to evaluate water fluctuations at GDEs in the Canyon Mountains unit.

Fishlake–Thousand Lake

The primary stressors in the Fishlake–Thousand Lake unit were tree mortality, diversions, and dams. Tree mortality and defoliation had affected 6.9 percent of this unit, which is the second highest of all units in the study area. The WCF Insects and Disease attribute suggested most watersheds were impacted by abnormally high levels of tree mortality due to insects and disease. There were 0.005 diversions per acre, which was the largest diversion density on the FNF. There were 0.02 dams per stream mile, which was a moderate density compared to other units on the Forest. The WCF Flow Characteristics attribute indicated that peak and base flows were likely maintained throughout most of the unit, but that timing, rate of change, and/or duration of mid-range discharges had been altered.

There were 643 stream miles within the Fishlake–Thousand Lake unit. Of these streams, 17 percent were perennial, 80 percent were intermittent, and 3 percent were ephemeral; however, these percentages naturally vary between dry and wet years. According to NHD, there were 93 springs and according to NWI there were 797 acres of wetlands, which is 0.3 percent of the unit. The high elevations of the Fishlake Plateau and Thousand Lake Mountain are major sources of water to lower elevation aquatic systems (Christiana 1991). More precipitation, particularly snow, falls at these altitudes, influencing a strong spring snowmelt runoff signal in surface water systems. Discharge from spring ecosystems is also highly influenced by climate, responding rapidly to change in recharge rates and even ceasing to flow during dry periods (Christiana 1991). The flat topography with limited perennial streams suggests high infiltration rates to groundwater systems (Christiana 1991). The Dry Hollow Formation is present in this unit and it contains joints and cracks that allow movement of water (Young and Carpenter 1965). Springs throughout the Fishlake Plateau discharge water from this formation and provide base flow to many streams (Young and Carpenter 1965). These springs and seeps tend to be located at the contact point between formations, along alluvial aquifers, and at the end point of basalt flows (Christiana 1991).

Level II riparian surveys did not describe any impacts from dams or diversions, but some reaches were naturally dry due to drought. Dry conditions from drought were interacting with other stressors, including grazing, and increasing the impacts of both. Additionally, level II riparian surveys provided evidence of incised channels, which are likely associated with declines in the water table and reduced overbank flooding. Conifer encroachment had occurred along 27.1 miles, or 25 percent, of perennial streams. An additional 24.8 miles (23 percent) of perennial streams had converted from riparian cover to upland grass and shrub species. The average WCF water quantity score was 1.7, indicating moderate alteration from natural flow regimes. Changes in climate were apparent in the Fishlake–Thousand Lake unit, with increased temperatures during all four seasons and shifts in the precipitation regime. Summer and fall precipitation increased by 31 percent and 8 percent, respectively. Spring precipitation decreased by

6 percent. Winter temperatures increased by 1.6 °F on average and winter precipitation decreased by 6 percent. This was among the largest decreases in winter precipitation of all units considered in our assessment. These indicators suggested that water fluctuations in surface water systems of the Fishlake–Thousand Lake unit were **within the NRV**, with an overall score of 84 percent.

We did not find any data to evaluate the condition of water fluctuations at GDE wetlands. The FNF WRU dataset indicated there were 359 points of diversion-associated springs in the Fishlake–Thousand Lake unit. Of these diverted springs, 5 were dry and unvegetated, 53 were dry and vegetated, 28 had abundant flow, and 241 had little flow. Most of the springs (45 percent) with associated diversions were in poor condition. Twenty-seven percent of diverted springs were in fair condition and 18 percent of springs with associated diversions were in good condition. There was **insufficient information** to evaluate water fluctuations at GDEs in the Fishlake–Thousand Lake unit.

Monroe Mountain

The primary stressors in the Monroe Mountain unit were tree mortality and trails. Eight percent of this geographic unit had experienced tree mortality and defoliation, which is a larger percentage than any other unit. The WCF Insects and Disease attribute indicated insects and disease induced tree mortality and likely had major impacts on the ability of the forest canopy to intercept snow and prevent excessive runoff. There were 0.002 trail miles per acre in this unit, which is a higher trail density than any other unit in the study area. While the WCF Road and Trail Condition indicator suggested the density and distribution of linear features like trails had not substantially altered the hydrology of the Monroe Mountain unit, best management practices for drainage features were only applied to between 50 and 75 percent of roads, trails, and water crossings in the majority of watersheds.

There were 514 stream miles within the Monroe Mountain unit. Of these 33 percent were perennial, 10 percent were intermittent, and 56 percent were ephemeral; however, these percentages naturally vary between dry and wet years. According to NHD, there were 134 springs and according to NWI there were 108 acres of wetlands, which is 0.06 percent of the unit. Spring snowmelt is a large source of flood discharge and infiltration to groundwater systems in the Monroe Mountain unit (Richardson 1907). Groundwater discharges at seeps and fault springs, which experience little variation in flow throughout the year (Richardson 1907). These springs convey water valleys from distant bedrock sources and are important contributors to stream base flow and alluvial water tables in lower elevation valley bottoms (Richardson 1907).

We did not find any level II riparian surveys completed in the Monroe Mountain unit, which limited our use of local data in the determination of NRV status. Conifer encroachment had occurred along 84.2 miles, or 50 percent, of perennial streams. This was the largest percentage of stream miles

converted to conifer cover across all geographic units. An additional 6.6 miles (4 percent) of perennial streams had converted from riparian cover to upland grass and shrub species. The average WCF water quantity score was 1.4, indicating little alteration to natural flow regimes. Changes in climate were apparent in the Monroe Mountain unit, with increased temperature in all four seasons and shifts in the precipitation regime. Summer and fall precipitation have increased by 29 percent and 12 percent respectively, with more minor decreases in winter and spring precipitation observed. Winter temperatures have increased by 1.4 °F on average and winter precipitation has decreased by 2 percent. These indicators suggested that water fluctuations in surface water systems of the Monroe Mountain unit were **within the NRV**, with an overall score of 92 percent.

We did not find any data to evaluate the condition of water fluctuations at GDE wetlands. The FNF WRU dataset indicated there were 119 points of diversion-associated springs in the Monroe Mountain unit. Of these diverted springs, 8 were dry and vegetated, 9 had abundant flow, and 97 had little flow. Most of the springs (47 percent) with associated diversions were in fair condition. Twenty-four percent of diverted springs were in poor condition and 25 percent of springs with associated diversions were in good condition. There was **insufficient information** to evaluate water fluctuations at GDEs in the Monroe Mountain unit.

Pavant Range

The level of stressors to groundwater and surface water fluctuations in this unit was relatively low. Indicators of stressor impacts suggested the hydrology of the Pavant Range had not been substantially altered.

There were 1,528 stream miles within the Pavant Range. Of these streams, 11 percent were perennial, 8 percent were intermittent, and 81 percent were ephemeral; however, these percentages naturally vary between dry and wet years. According to NHD there were 119 springs and according to NWI there were 428 acres of wetland, which is about 0.11 percent of the unit. The geologic formations present in the Pavant Range include the North Horn and Dry Hollow Formations, as well as Flagstaff limestone. Both the North Horn Formation and Flagstaff limestone allow for infiltration and discharge where they are fractured or contain solution channels (Young and Carpenter 1965). The Dry Hollow Formation contains joints and cracks that allow for infiltration of precipitation that falls at high elevations (Young and Carpenter 1965). Springs discharge from this formation and maintain stream base flow at lower elevations (Richardson 1907; Young and Carpenter 1965). Precipitation at high elevations, particularly snow, is the primary source of stream and spring flow (Richardson 1907). Surface water hydrographs show a strong snowmelt signal, whereas spring flow from faults is far less variable (Richardson 1907).

Level II riparian surveys noted some reaches are naturally dry due to intermittent streams. The surveys did note roads and soil compaction from livestock were contributing to increased runoff and incised channels in some

reaches. Where channels have downcut, it is likely that water table levels have declined and overbank flooding has been reduced. Nevertheless, level II riparian surveys report many reaches are in good or suitable condition. Conifer encroachment had occurred along 67.8 miles, or 40 percent, of perennial streams in the Pavant Range. An additional 18.4 miles (11 percent) of perennial streams had converted from riparian cover to upland grass and shrub species. The average WCF water quantity score was 1.2, indicating little alteration to natural flow regimes. Changes in climate were evident in this unit, with increased temperature in all four seasons and shifts in the precipitation regime. Summer and fall precipitation increased by 13 percent and 11 percent, respectively. Winter temperatures increased by 1.3 °F on average and winter precipitation decreased by 2 percent. These indicators suggested that water fluctuations in surface water systems of the Pavant Range unit were **within the NRV**, with an overall score of 92 percent.

We did not find any data to evaluate the condition of water fluctuations at GDE wetlands. The FNF WRU dataset indicated there were two points of diversion associated with springs in the Pavant Range unit. Both were dry but vegetated. One diverted spring was classified as in fair condition, while the other had not been evaluated. There was **insufficient information** to evaluate water fluctuations at GDEs in the Pavant Range.

Tushar Mountains

The primary stressors in the Tushar Mountains were wildfire, roads, trails, and grazing. Six percent of the unit had experienced high severity burns and 9.7 percent had burned at moderate severity, which was the second largest percentage impacted by high and moderate severity wildfire of all units in the study area. The TCA indicated that on average the Tushar Mountains were in moderate condition in terms of uncharacteristic wildfire and good condition in terms of fire frequency. The WCF Fire Regime Condition Class indicator indicated many watersheds had a predominant percentage of land with high departure from the reference fire regime. The WCF Fire Effects score had been recorded for some watersheds in this unit, suggesting some impacts to hydrologic impacts had occurred following a significant fire. There were 0.002 road miles per acre in the Tushar Mountains, which was moderate compared to other units. Trail density was relatively high compared to other units, with 0.002 miles per acre. The WCF Road and Trail Condition indicator suggested there was a moderate probability that these features had substantially altered the hydrologic regimes of this unit. Best management practices for maintenance of designed drainage features had been applied to less than 50 percent of roads, trails, and water crossings in the majority of watersheds in the Tushar Mountains. Ninety-nine percent of the Tushar Mountains was within a range management unit and 100 percent of those were active. According to the WCF, rangeland vegetation conditions had been impacted, with 2 percent of the Tushar Mountains having lost capacity to capture, store, and safely release water from rainfall, runoff, and snowmelt. An additional 33 percent had a reversible loss of hydrologic function and 65 percent of rangelands were functioning properly.

There were 1,022 stream miles within the Tushar Mountains. Of these streams, 35 percent were perennial, 8 percent were intermittent, and 57 percent were ephemeral. According to NHD, there were 97 springs and according to NWI there were 26 acres of wetlands, which is about 0.008 percent of the unit. Precipitation, particularly snow, that falls in the Tushar Mountains is a principal water source for both the Beaver and Sevier River systems (Mower 1978; Young and Carpenter 1965). Most of the precipitation occurs between November and April and runs off as surface flow between April and early August (Mower 1978). Magnitude of streamflows in the Tushar Mountains is temporally and spatially variable as a result of different precipitation rates, topography, and geologic material (Mower 1978). Less precipitation infiltrate in locations where the land surface is steeper and composed of consolidated rocks (Mower 1978). The Dry Hollow Formation is present in the Tushar Mountains. It contains joints and cracks that permit recharge of groundwater, transfer of water from the recharge area in the mountains to lower elevations, and discharge at springs (Young and Carpenter 1965). These springs tend to experience low flows during spring and high flows during midsummer, which maintains base flow in many streams throughout the Tushar Mountains (Mower 1978; Young and Carpenter 1965).

Level II riparian surveys noted impacts from diversions in the Beaver River drainage, including those for hydropower that dewater the channel and disrupt the natural flow regime. Some reaches are deeply incised, and these locations have likely experienced a decline in the water table level and reduced overbank flooding. Level II riparian surveys also documented beaver activity in several streams. These structures were stabilizing channels and flow regimes. Conifer encroachment had occurred along 174.9 miles, or 49 percent, of perennial streams. An additional 41.3 miles (11 percent) of perennial streams had converted from riparian cover to upland grasses and shrubs. The average WCF water quantity score was 1.5, indicating minor alterations to hydrologic regimes. Changes in climate were evident in this unit, with warmer temperatures observed in all four seasons and shifts in the precipitation regime. Summer and fall precipitation had increased by 23 percent and 17 percent, respectively, with only a small increase in spring precipitation (2 percent). Winter temperatures increased by 1.6 °F and winter precipitation had decreased by 6 percent. This was among the largest decreases in winter precipitation of all units considered in our assessment. These indicators suggested that water fluctuations in surface water systems of the Tushar Mountains were **within the NRV**, with an overall score of 84 percent.

We did not find any data to evaluate the condition of water fluctuations at GDE wetlands. The FNF WRU dataset indicated there were 50 points of diversion-associated springs in the Tushar Mountains. Of these diverted springs, 2 were dry and unvegetated, 2 were dry and vegetated, 4 had abundant flow, and 38 had little flow. Most springs associated with diversions (46 percent) in the Tushar Mountains were in fair condition. Thirty percent

of diverted springs were in good condition and 18 percent were in poor condition. There was **insufficient evidence** to evaluate water fluctuations at GDEs in the Tushar Mountains.

White Mountain

The primary stressors in the White Mountain unit were diversions, dams, and roads. There were 0.005 diversions per acre, which was a moderate diversion density relative to other units. There were 0.03 dams per stream mile, which is the second largest dam density of all units and the largest on the FNF. The WCF Flow Characteristics attribute indicated only minor alterations from natural hydrographs and the WCF Habitat Fragmentation attribute suggested more than 95 percent of historic aquatic habitats remain connected. There were 0.0002 road miles per acre in this unit, which was the largest road density of the FNF. The WCF Road and Trail Condition indicator suggested there was a moderate probability that the density and distribution of roads had resulted in substantial impacts to the unit's hydrology. Additionally, best management practices for maintenance of drainage design features had only been applied to 50–75 percent of roads, trails, and water crossings in most watersheds.

There were 850 stream miles within the White Mountain unit. Of these streams, 23 percent were perennial, 20 percent were intermittent, and 56 percent were ephemeral; however, these percentages naturally vary between dry and wet years. According to NHD, there were 154 springs and according to NWI there were 85 acres of wetland, which was 0.03 percent of the landscape. Snow accumulation at high altitudes is the primary source of runoff and recharge to groundwater systems (Danielson and Sylla 1982). Streams experience peak flow from snowmelt in spring and early summer and their base flows are supported by groundwater discharge from Flagstaff limestone and the North Horn Formation (Danielson and Sylla 1982). The amount of recharge to groundwater systems is influenced by snow water equivalent, exposure, surface relief, and permeability of the geologic setting, making it highly variable across the landscape (Danielson and Sylla 1982). Fractures and solution openings in areas with low surface relief, particularly where Flagstaff limestone is exposed, provide storage for large amounts of groundwater (Danielson and Sylla 1982). Precipitation infiltrates and moves from areas of recharge at high elevations to areas of natural discharge at springs (Danielson and Sylla 1982). There is evidence that water moves rapidly through the groundwater system, with spring discharge highly responsive to changes in recharge and a decrease in the discharge rate from the spring months through the rest of the year (Danielson and Sylla 1982).

Level II riparian surveys noted impacts from diversions and reservoirs in Lost and Skumpah Creeks. In Lost Creek, the timing of flows below reservoirs was altered and some reaches were entirely dewatered. The channel below the reservoir in Skumpha Creek was deeply incised and dry. Additionally, level II riparian surveys provided evidence of incised channels where the water table level has likely declined and overbank flooding has been reduced. These surveys also noted that some reaches naturally go dry

where streamflow sinks into alluvium. Conifer encroachment had occurred along 50.0 miles, or 25 percent, of perennial streams in the White Mountain unit. This was the least amount of stream miles converted to conifer cover of geographic units on the FNF. An additional 16.5 miles (8 percent) of perennial streams had converted from riparian cover to upland grasses and shrubs. The average WCF water quantity score was 1.1, indicating minor alterations to hydrologic regimes. Changes in climate were apparent in this unit, with warmer temperatures observed in all four seasons and shifts in the precipitation regime. Summer and fall precipitation increased by 25 percent and 9 percent, respectively, with only a small decrease in spring precipitation (2 percent). Winter temperatures increased by 1.6 °F on average and winter precipitation decreased by 6 percent. This was among the largest decreases in winter precipitation of all units considered in our assessment. These indicators suggested that water fluctuations in surface water systems of the White Mountain unit were **within the NRV**, with an overall score of 92 percent.

We did not find any data to evaluate the condition of water fluctuations at GDE wetlands. The FNF WRU dataset indicated there were 87 points of diversion associated with springs in the White Mountain unit. Of these diverted springs, 1 was dry and unvegetated, 13 were dry and vegetated, 7 had abundant flow, and 66 had little flow. Most springs associated with diversions (57 percent) were in poor condition. Twenty-eight percent of diverted springs were in fair condition and 15 percent were in poor condition. There was **insufficient information** to evaluate water fluctuations at GDEs in the White Mountain unit.

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Appendix E. Water Quality

Methods

We evaluated seven indicators of water quality: (1) condition of riparian and wetland vegetation, (2) conversion of riparian habitat to development or agriculture, (3) estimated mean August stream temperature, (4) amount of impaired waters, (5) evidence of other water quality problems, (6) substrate cementation, and (7) percent of waterbodies classified as impaired (table E.1). We used the WCF's indicator for condition of riparian and wetland vegetation, which addresses the function of native riparian vegetation and whether adequate cover exists to dissipate stream energy, reduce erosion, filter sediment, stabilize streambanks, buffer stream temperature, and improve water quality (Potyondy and Geier 2011). We estimated percent conversion of riparian habitat to development or agriculture using R-CAT (Macfarlane et al. 2017). We obtained estimated mean August stream temperature using the NorWeST stream temperature model (Isaac et al. 2017) and compared the results to Utah water quality standards for temperature. We used both the WCF Impaired Waters indicator (Potyondy and Geier 2011) and the percentage of waterbodies classified as impaired by the Utah Department of Environmental Quality (UDEQ). We only included

Table E.1—Values of water quality indicators by geographic unit.

Geographic unit	Forest	Riparian/ wetland vegetation condition	Percent stream miles converted from riparian to development or agriculture	Stream temperature	WCC impaired waters	WCC water quality problems	Embedded-ness	Percent unit impaired
Escalante	Dixie	1.8	9.6	54.7	1.0	2.0	37	8
Markagunt Plateau	Dixie	1.5	11.0	54.6	1.8	2.6	27	4
Paunsaugunt–Mt. Dutton	Dixie	1.6	4.3	56.9	1.5	2.4	20	32
Pine Valley	Dixie	1.5	10.7	62.9	1.1	2.1	60	NA
Boulder Mountain	Fishlake	1.9	4.3	53.8	1.1	1.5	50	6
Canyon Mountains	Fishlake	1.5	18.2	60.3	1.0	1.1	NA	NA
Fishlake–Thousand Lake	Fishlake	1.8	6.7	53.7	1.2	1.3	73	23
Monroe Mountain	Fishlake	1.9	4.4	52.7	1.3	1.3	NA	NA
Pavant Range	Fishlake	1.6	5.8	57.5	1.0	1.3	66	NA
Tushar Mountains	Fishlake	1.8	8.9	53.4	1.1	1.6	40	6
White Mountain	Fishlake	1.8	21.6	57.4	1.2	1.5	NA	2

UDEQ assessments as an indicator if more than 50 percent of the unit had been assessed. The WCF Water Quality problems indicator (Potyondy and Geier 2011) was used to document evidence of excessive sediment, nutrients, chemical pollution, or other water quality issues above natural or background levels. Lastly, we used level II riparian survey data documenting the cementation of pool tails, riffles, and pools. Cementation is linked to increased bank erosion and inputs of fine sediments from roads.

We scored the seven water quality indicators in surface water systems based on whether they showed evidence of no, moderate, or substantial alteration from the NRV. If the indicator showed evidence of little or no alteration, it was given a score of 5; moderate alteration was given a score of 3; substantial alteration was given a score of 1 (table E.2). The thresholds for moderate and substantial alteration for each indicator were determined from literature or from the data source. The scores for each geographic unit were summed and divided by the potential total of 35 to give a percentage rating for each. Units were considered within the NRV for fluctuations in surface water systems if the index was greater than 77 percent and moderately altered from the NRV if the index was between 50 percent and 76 percent; units were considered outside the NRV if the index was less than 50 percent. We were unable to assess water quality at GDEs because we did not locate sufficient data on the condition of these systems.

Unit Summaries

Escalante

The primary stressors to water quality in the Escalante unit included roads, recreation, diversions, and dams. There were 0.002 roads per acre in this unit and 84 percent of roads were unimproved. Additionally, there were 0.005 road miles per floodplain. There were 0.002 trail miles per acre and 0.003 recreation sites per floodplain acre. This was a relatively large

Table E.2—Thresholds of evidence for alteration from the NRV and data sources for seven indicators of water quality.

Indicator	Data source	Little or no alteration (5 points)	Moderate alteration (3 points)	Substantial alteration (1 point)
Riparian/wetland vegetation condition	WCF	≤ 1.6	1.7 ≤ x ≤ 2.2	≥ 2.3
Percent streams converted to alternative cover	R-CAT	< 33%	33% < x < 66%	> 66%
Stream temperature	NorWest	< 68	68 ≤ x < 80.6	≤ 80.6
Impaired waters	WCF	≤ 1.6	1.7 ≤ x ≤ 2.2	≥ 2.3
Water quality problems	WCF	≤ 1.6	1.7 ≤ x ≤ 2.2	≥ 2.3
Substrate cementation	Level II riparian surveys	≤ 40	40 < x ≤ 60	> 60
Percent impaired	UDEQ assessments	< 10%	10% ≤ x ≤ 30%	> 30%

floodplain recreation site density for the study area, and the highest of all units on the DNF. The WCF Proximity to Water attribute indicated roads and trails had high potential to impact water quality by contributing large sediment loads to streams and waterbodies because more than 25 percent of road and trail miles were located within 300 feet of streams and other waterbodies. Additionally, best management practices for maintenance were applied to less than 50 percent of roads, trails, and water crossings. There were 0.003 diversions per acre and 0.02 dams per stream mile in the Escalante unit. The WCF Water Quantity indicator suggested these structures have moderately altered stream hydrographs, which has potentially increased concentrations of salts, nutrients, and any pollutants in parts of the year. Ninety-one percent of the Escalante unit was grazed and 100 percent of the range management units were active. These pastures may function as nonpoint sources of pollution that can contribute excess nutrients to aquatic systems. Thirty-eight percent of watersheds in the Escalante unit show evidence of a reversible loss in the capacity to limit loss of soil resources including nutrients and organic matter. These areas are more vulnerable to irreversible degradation.

The Escalante unit contains many tributaries to the Escalante River including Pine, North, Birch, Sand, Boulder, and Deer Creeks. Stream temperature appears to be the primary water quality concern in this drainage (Adams and Judd 2005). The natural thermal regimes of these tributaries vary based on watershed characteristics and hydrologic conditions. Narrower stream channels and sections that receive spring discharge, including the headwater systems within coniferous forests, tend to provide cooler water (Adams and Judd 2005). These forests transition at lower elevations to pinyon pine and juniper, followed by sagebrush. These lower systems receive less precipitation and are warmer, with evaporation causing some reaches to dry and contributing to higher solute concentrations (Adams and Judd 2005).

Floodplains made up 5 percent of the Escalante unit and an additional 0.27 percent of the unit was wetland. The WCF indicated these areas were in adequate condition for reducing erosion, filtering sediment, buffering temperature, and improving water quality, but that existing attributes make riparian areas and wetlands susceptible to degradation. Sediment loads did not appear to be degrading water quality in the Escalante unit. Based on level II riparian surveys, the average percent of stream substrate classified as clay or silt was 19 percent. Sixty percent of pool tails, 58 percent of riffles, and 56 percent of pools showed no or slight evidence of substrate cementation. These reports noted major impacts from diversions, road, and livestock grazing, including observations that roads and livestock were increasing sediment loads. Dewatering likely contributes to concentration of pollutants and solutes in this unit and removes the ability of streams to flush sediments from the system. Water temperature did not appear to be impacted. The average estimated August stream temperature from 1993 to 2013 in this unit ranged from 52.1 °F to 56.6 °F. Riparian surveys found approximately 19 percent streambanks had overhanging vegetation. The WCF indicated there

were no State-listed impaired or threatened waterbodies in the Escalante unit, but according to the 2015 303d listed waters, 11 percent of streams were impaired. The WCF indicated that moderate water quality problems, such as excessive sediment, nutrients, or chemical pollution, existed in Escalante unit. Lastly, based on the Utah DEQ Water Quality Assessment, 55 percent of this unit was classified as fully supporting beneficial uses; 6 percent was impaired due to total dissolved solids; < 1 percent was impaired for total phosphorus and dissolved oxygen; and < 1 percent was impaired for total phosphorus. Thirty-eight percent was not assessed.

Information for all seven water quality indicators was available in the Escalante unit. Two of the seven indicators were considered moderately altered from the NRV: condition of riparian and wetland vegetation and water quality problems. The remaining five indicators showed little or no evidence of alteration from the NRV. The overall score for water quality in the Escalante unit was 89 percent and it was considered to be **within the NRV**.

Modified level I GDE surveys were completed in the Escalante unit in 2013, 2014, and 2015. Where water was present, the average water temperature was 57.7 °F; the average pH was 7.4; the specific conductance was 471; and the average dissolved oxygen was 6.5 mg/L. Pollution, including manure, trampling, and soil compaction, was noted at many GDEs in all years. There was **insufficient information** to evaluate the NRV.

Markagunt Plateau

The primary stressors to water quality in the Markagunt Plateau unit included roads, recreation, diversions, dams, loss of riparian cover, and soil conditions. There were 0.004 road miles per acre and 80 percent were classified as unimproved. Within floodplains, the road density was 0.007 road miles per acre, which is the highest of all units considered in our assessment. There were 0.003 trail miles per floodplain acre and 0.006 recreation sites per floodplain acre. The WCF indicated roads and trails have high potential to impact water quality by contributing large sediment loads to streams and waterbodies. More than 25 percent of road and trail miles were located within 300 feet of streams and other water bodies. Best management practices for maintenance of drainage features were applied to less than 50 percent of roads, trails, and water crossings in most watersheds. Additionally, mass wasting was a significant process impacting some roads constructed on unstable landforms in some watersheds within the Markagunt Plateau. There were 0.002 diversions per acre, which was the second highest diversion density of geographic units in the study area. There were 0.03 dams per stream mile. The WCF Water Quantity indicator suggested these structures have resulted in significant departure of flows from the natural hydrograph and have high potential for increasing the concentration of salts, nutrients, or pollutants. Eleven percent of perennial stream miles converted from riparian cover to development, 1 percent converted to agriculture, and 2.5 percent converted to invasive species. In addition to the loss of ecosystem services related to water quality provided by riparian systems, these areas could be nonpoint sources of pollution. The WCF Soil Contamination indicator

suggested contamination of soils impacted limited areas of the Markagunt Plateau. Ninety-two percent of the Markagunt Plateau was open to grazing, and 90 percent of range management units were active. Pastures were a potential nonpoint source of pollution that may increase nutrient loads of aquatic systems. Additionally, 20 percent of rangelands in the Markagunt Plateau unit showed evidence of a reversible loss in the capacity to limit loss of soil resources including nutrients and organic matter. These areas were vulnerable to irreversible degradation.

The Markagunt Plateau unit contains several tributaries to the Sevier River including Asay, Mammoth, Panguitch, and Bear Creeks. The headwaters of the EF Virgin River and Coal Creek are also located within this unit. The limestone and volcanic geology of the Markagunt Plateau influences the water chemistry of streams and groundwater in the area, with the dominant ions including calcium, magnesium, and bicarbonate (Thiros and Brothers 1993). Pollutants, habitat alteration, total phosphorous, and total suspended sediments have impaired coldwater fisheries throughout the Upper Sevier drainage (Harris and Judd 2004). A primary water quality concern in the upper watershed tributaries is the development and building of homes near streams and lakes (Harris and Judd 2004). Many homes use septic tanks, which may be a potential problem for surface and groundwater systems (Harris and Judd 2004). Dispersed recreational sites lacking sanitary facilities may also impact water quality in this region (Harris and Judd 2004). Lastly, some tributaries in the Upper Sevier show water quality issues related to sedimentation caused by roads and grazing (Harris and Judd 2004).

Floodplains made up 5.3 percent of the Markagunt Plateau and an additional 0.3 percent of the unit was wetland. The WCF Riparian/Wetland Vegetation indicator suggested these areas were generally in a functional condition that reduced erosion, filtered sediment, stabilized streambanks, buffered temperature, and improved water quality. Sediment loads appeared to have limited impact on water quality in the Markagunt Plateau. Based on level II riparian surveys, the average percent of stream substrate classified as clay or silt was 17 percent. Sixty-one percent of pool tails, 56 percent of riffles, and 53 percent of pools showed slight or no evidence of substrate cementation. While level II riparian surveys found only about 11 percent of streambanks had overhanging vegetation, water temperature did not appear to be impacted. The average estimated August stream temperature from 1993 to 2013 ranged from 52.2 °F to 56.4 °F. Nevertheless, the WCF Impaired Waters attribute indicated there were some waterbodies that were not supporting beneficial uses. According to 2015 303d impaired waters data, 2.5 percent of streams and 673 acres of waterbody were impaired. Based on the WCF Water Quality Problems attribute, there were extensive water quality problems, such as excessive sediment, nutrients, or chemical pollution in most of the watersheds of the Markagunt Plateau. According to Utah DEQ Water Quality Assessments, 54 percent of this unit was classified as fully supporting beneficial uses. Four percent was impaired due to total phosphorus and sediment loads and 41 percent was not assessed.

Information for all seven water quality indicators was available in the Markagunt Plateau unit. One indicator, Water Quality Problems, was substantially altered from the NRV. An additional indicator, Impaired Waters, was moderately altered from the NRV. The remaining five indicators showed little or no evidence of alteration from the NRV. The overall score for water quality was 83 percent and the Markagunt Plateau was considered to be **within the NRV**.

Paunsaugunt–Mt. Dutton

The primary stressors to water quality in the Paunsaugunt–Mt. Dutton unit included roads, dams, diversions, grazing, loss of riparian cover, wildfire, and soil contamination. There were 0.003 road miles per acre, which was the second highest road density of units considered in our assessment. Road density within floodplains in the Paunsaugunt–Mt. Dutton unit was 0.006 road miles per floodplain acre. The WCF indicated roads had high potential to impact water quality by contributing sediment to streams and other waterbodies. More than 25 percent of road miles are located within 300 feet of streams and other waterbodies in nearly all watersheds and best management practices for maintenance of design features were applied to less than 50 percent of roads, trails, and water crossings in all watersheds. Additionally, mass wasting was a significant process impacting some roads constructed on unstable landforms within some watersheds in the Paunsaugunt–Mt. Dutton unit. There were 0.0009 diversions per acre and 0.004 dams per stream mile, which was relatively low compared to other units in the study area. Nevertheless, the WCF Water Quantity indicator suggested these structures likely contributed to moderate departure of flows from the natural hydrograph and had high potential for increasing the concentration of salts, nutrients, or pollutants. One hundred percent of the Paunsaugunt–Mt. Dutton unit was open to grazing and 90 percent of range management units were active. Pastures were a nonpoint source of pollution that may contribute excess nutrients to aquatic systems. Additionally, according to the WCF, 50 percent of rangelands in the Paunsaugunt–Mt. Dutton unit showed evidence of a reversible loss in the capacity to reduce loss of soil resources including nutrients and organic matter. These areas were vulnerable to irreversible degradation. Twelve percent of riparian areas associated with perennial streams had converted to invasive species. Where these invasive species patches included tamarisk, there was high potential for increased salinity and reduced water flows. An additional 4 percent of riparian area had converted to development and less than 1 percent had converted to agriculture. Four percent of this unit had burned at high severity and the WCF indicated there may have been some significant effects including erosion from these fires. The WCF Soil Contamination attribute indicated contamination of soils impacted limited areas of the Paunsaugunt–Mt. Dutton unit.

The headwaters of the main stem and east fork of the Sevier River drain the Paunsaugunt Plateau, including Limekiln, Sanford, Pine, Deep, Cottonwood, and Hunt Creeks (Thiros and Brothers 1993). The water that

drains this area is influenced by the limestone geology, making the dominant ions calcium, magnesium, and bicarbonate (Thiros and Brothers 1993). Much of the EF Sevier River and its tributaries are designated for cold water fisheries (Cirrus Ecological Solutions 2006). The primary water quality concern appears to be phosphorus loading, the concentration of which often exceeds water quality standards throughout the EF Sevier River drainage (Cirrus Ecological Solutions 2006). Management efforts in this region aim to reduce impacts from livestock grazing and improving maintenance of septic tanks (Cirrus Ecological Solutions 2006).

Floodplains made up 4.7 percent of the Paunsaugunt–Mt. Dutton unit and < 1 percent of the unit was wetland. The WCF Riparian/Wetland Vegetation Condition indicator suggested these areas were in a functional condition that reduced erosion, filtered sediment, stabilized streambanks, buffered stream temperature, and improved water. Sediment loads appeared to be impacting water quality in the Paunsaugunt–Mt. Dutton unit. Based on level II riparian surveys, the average percent of stream substrate was 41 percent clay and silt. Fifty-four percent of pool tails, 54 percent of riffles, and 46 percent of pools showed slight or no evidence of substrate cementation. Water temperature did not appear to be impacted in this geographic unit. The average estimated August stream temperature from 1993 to 2013 ranged from 54.4 °F to 58.8 °F. Level II riparian surveys found only approximately 10 percent of banks had overhanging vegetation. The WCF Impaired Waters attribute indicated there were some aquatic systems not supporting beneficial uses, but that it was less than 10 percent of water bodies. According to 2015 303d listed waters, 18 percent of streams and 52 acres of waterbody were impaired. Based on the WCF Water Quality Problems attribute, there were extensive additional water quality problems, such as excessive sediment, nutrients, or chemical pollution in most watersheds. Based on Utah DEQ Water Quality Assessments, 61 percent of this unit was fully supporting beneficial uses. Twenty-five percent was impaired due to total phosphorus and sediment; 6 percent was impaired only for total phosphorus; and < 1 percent was impaired due to total dissolved solids. Eight percent of the unit was not assessed.

Information for all seven water quality indicators was available in the Paunsaugunt–Mt. Dutton unit. Two indicators showed evidence of substantial alteration from the NRV: Percent of Landscape Classified as Impaired by Utah DEQ and Water Quality Problems. The remaining five indicators showed little or no evidence of alteration from the NRV. The overall score for water quality was 77 percent and the Paunsaugunt–Mt. Dutton unit was considered to be **within the NRV**.

Pine Valley

The primary stressors to water quality in the Pine Valley unit included roads, diversions, dams, loss of riparian cover, grazing, and soil contamination. There were 0.002 road miles per acre in this unit. These roads tended to be concentrated in the floodplain, with 0.005 road miles per floodplain acre. Even though these were relatively low road densities

compared to other units, the WCF indicated they had a high potential for degrading water quality. More than 25 percent of road miles were located within 300 feet of streams and other water bodies and best management practices for maintenance were applied to less than 50 percent of roads, trails, and water crossings in nearly all watersheds. There were 0.02 diversions per acre in Pine Valley, a higher diversion density than any other unit. There were 0.05 dams per stream mile, which was also more than any other unit. According to the WCF Water Quantity indicator, there was a high likelihood that these structures had contributed to moderate departures of flow from the natural hydrograph, potentially increasing the concentration of salts, nutrients, or pollutants. Four percent of floodplains had converted to invasive species, including 1 percent to tamarisk. Patches of tamarisk can increase salinity and diminish flows. An additional 6 percent of riparian areas had converted to development and 4 percent had converted to agriculture, which was more than any other unit on the Forest. These areas had high potential for increasing nutrient loads of adjacent water bodies. Seventy-one percent of the Pine Valley unit was open to grazing and 98 percent of range management units were active. Pastures are a nonpoint source of pollution that may contribute excess nutrients and sediment to aquatic systems. Additionally, according to the WCF, 73 percent of watersheds in the Paunsaugunt–Mt. Dutton unit showed evidence of a reversible loss in the capacity of rangelands to limit loss of soil resources including nutrients and organic matter. These areas were vulnerable to irreversible degradation. An additional 3 percent of rangelands in this unit were impaired and had lost the ecological processes that provide this service. According to the WCF Soil Contamination attribute, contamination of soils has impacted limited areas of most watersheds in the Pine Valley unit.

The chemical composition of waters in the Pine Valley unit is influenced by the composition of precipitation that falls in the area and the mineral matter of the rocks and soils (Stephens 1975). Quartz tends to dominate the mineral content of rocks and, because it is comparatively insoluble, the concentration of dissolved solids in groundwater tends to be low (Stephens 1975). In contrast, springs that discharge from igneous formations in the area have high concentrations of dissolved solids (Stephens 1975). Surface water and groundwater generally have similar chemical signatures due to the maintenance of base flows by discharge from groundwater systems (Stephens 1975).

Floodplains made up 5.0 percent of the Pine Valley unit and there were no documented wetlands. The WCF Riparian and Wetland Vegetation Condition indicator suggested these areas were in a functional condition that reduced erosion, filtered sediment, stabilized streambanks, buffered stream temperature, and improved water quality. Sediment loads may have contributed to reduced water quality in the Pine Valley unit. Based on level II riparian surveys, the average percent of stream substrate classified as clay or silt was 23 percent. Thirteen percent of pool tails, 18 percent of riffles, and 29 percent of pools showed evidence of heavy substrate cementation.

Water temperature did not appear to be impacted. The average estimated August stream temperature from 1993 to 2013 ranged from 61.5 °F to 63.8 °F and level II riparian surveys found 15 percent of streambanks to have overhanging vegetation. The WCF Impaired Waters attribute indicated there were very few waterbodies not supporting beneficial uses and, according to 2015 303d listed waters, 6 percent of streams were impaired. Based on the WCF Water Quality Problems attribute, there were moderate water quality problems, such as excessive sediment, nutrients, or chemical pollution. Based on Utah DEQ Water Quality Assessments, 41 percent of this unit was fully supporting beneficial uses. Six percent was impaired due to total dissolved solids. Fifty-four percent was not assessed.

Information for six of the seven water quality indicators was available in the Pine Valley unit. We did not incorporate percent classified as impaired by Utah DEQ because less than 50 percent of the unit had been assessed. One indicator, embeddedness, showed evidence of substantial alteration from the NRV. An additional indicator, water quality problems, was moderately altered from the NRV. The remaining four indicators showed little or no evidence of alteration from the NRV. The overall score for water quality was 80 percent and the Pine Valley unit was considered to be **within the NRV**.

Boulder Mountain

The primary stressors to water quality in the Boulder Mountain unit were roads, diversions, dams, and soil erosion. There were 0.002 road miles per acre and 0.004 road miles per acre within the floodplain. Even though these were relatively low road densities compared to other units, the WCF indicated they have high potential for degrading water quality. More than 25 percent of road miles were located within 300 feet of streams and other water bodies and best management practices for maintenance were applied to less than 50 percent of roads, trails, and water crossings in nearly all watersheds. Additionally, mass wasting was a significant process impacting some roads constructed on unstable landforms within some watersheds. There were 0.003 diversions per acre and 0.02 dams per stream mile in this unit, which were relatively low densities compared to other units in the study area. Nevertheless, according to the WCF Water Quantity indicator, these structures had contributed to moderate departure of flows from the natural hydrograph and have high potential for increasing the concentration of salts, nutrients, or pollutants by removing water from the system. According to the WCF Soil Erosion attribute, there was evidence of accelerated surface erosion over less than 10 percent of the Boulder Mountain unit, with generally small and disconnected rills and gullies present. This erosion may contribute sediment and nutrients to the aquatic systems of the unit.

The headwaters of the Fremont and Escalante Rivers originate within the Boulder Mountain unit. As water moves through this unit, either as surface or groundwater, the type of rock it is in contact with strongly influences the chemical composition (Thiros and Brothers 1993), with water discharging from the volcanic rocks that are present in this unit have calcium bicarbonate concentrations (Christiana 1991; Thiros and Brothers 1993). The Boulder

Mountain unit is an important groundwater recharge location, and the spring-fed tributaries that originate in the unit tend to have cool temperatures and low levels of total dissolved solids that support beneficial uses (Adams and Judd 2005; Christiana 1991). In fact, the high water quality of Pine, Oak, and Pleasant Creeks as well as springs that discharge water that has recharged through Boulder Mountain improve water quality of downstream systems like the Fremont River (Christiana 1991).

The Boulder Mountain unit had a greater percentage of land classified as floodplain (6.1 percent) and wetland (0.6 percent) than any other unit in the study area. The WCF Riparian/Wetland Vegetation condition indicator suggested these areas were capable of reducing erosion, filtering sediment, stabilizing streambanks, buffering water temperature, and improving water quality, but that existing attributes have made some riparian areas more susceptible to degradation. Level II riparian surveys indicated 24 percent of stream substrates are clay or silt. Additionally, 17 percent of pool tails, 8 percent of riffles, and 25 percent of pools showed evidence of heavy cementation. The average estimated August stream temperature from 1993 to 2013 ranged from 51.2 °F to 55.7 °F. Level II riparian surveys found that 14 percent of streambanks had overhanging vegetation. The WCF Impaired Waters attribute indicated there were very few water bodies not supporting beneficial uses. According to 2015 303d listed waters, 1 percent of streams and 61 acres of waterbody were impaired. Based on the WCF Water Quality Problems attribute, there were minor water quality problems such as excessive sediment, nutrients, or chemical pollution in the Boulder Mountain unit. Based on Utah DEQ Water Quality Assessments, 55 percent of this unit was fully supporting beneficial uses and 6 percent was impaired due to total phosphorus and dissolved oxygen. Thirty-nine percent was not assessed.

Information for all seven water quality indicators was available in the Boulder Mountain unit. Two indicators showed evidence of moderate alteration from the NRV: condition of riparian and wetland vegetation and substrate embeddedness. The remaining five indicators showed little or no evidence of alteration from the NRV. The overall score for water quality was 89 percent and the Boulder Mountain unit was considered to be **within the NRV**.

Canyon Mountains

The primary stressors to water quality in the Canyon Mountains unit included roads, invasive species, and loss of riparian cover. There were 0.001 road miles per acre and 0.002 road miles per acre within the floodplain. Even though according to the WCF, less than 10 percent of road miles were located within 300 feet of water bodies, best management practices for maintenance had only been applied to 50 to 75 percent of roads, trails, and water crossings throughout the unit. Additionally, mass wasting was a significant process impacting some roads constructed on unstable landforms within some watersheds in the Canyon Mountains unit. Eighteen percent of floodplains had been converted from riparian cover to development, generating a loss in the ecosystem services related to water quality provided by riparian areas

as well as a potential source of pollution and excess nutrients. This was the second largest percentage of stream miles converted to development within the study area. An additional 2 percent of perennial streams and 4 percent of overall floodplains have converted to invasive species, including tamarisk. Where tamarisk is present, there was potential for high salinity and reduced flows that concentrate pollutants.

The geology of the Canyon Mountains is primarily composed of quartzite, shale, conglomerate, limestone, and dolomite (Bjorklund and Robinson 1968). Water draining the Canyon Mountains tends to have good quality, with low salinity and dissolved solid concentrations (Bjorklund and Robinson 1968).

Floodplains made up 4.7 percent of the Canyon Mountains unit and 0.07 percent of the unit was classified as wetland. The WCF Riparian/Wetland Vegetation Condition indicator suggested that, in most watersheds, these areas were in a functional condition that reduced erosion, filtered sediment, stabilized streambanks, buffered stream temperature, and improved water quality. A report on level II riparian surveys conducted in Oak Creek and North Walker Canyon noted recent incision of the channel, likely caused by very high discharges that moved bedload sediments. The report described successful efforts to stabilize streambanks, reduce erosion, and stop incision. The average estimated August stream temperature from 1993 to 2013 ranged from 57.7 °F to 62.2 °F. The WCF Impaired Waters attribute indicated there were very few waterbodies not supporting beneficial uses and, according to 2015 303d listed waters, there were no impaired streams or waterbodies. Based on the WCF Water Quality Problems attribute, there were minor water quality problems such as excessive sediment, nutrients, or chemical pollution in the Canyon Mountains unit. Based on Utah DEQ Water Quality Assessments, 1 percent of this unit was impaired due to total dissolved solids, sediment, and total phosphorus. The other 99 percent of the unit was not assessed.

Information was not available for two indicators in the Canyon Mountain unit: substrate embeddedness and percent classified as impaired by Utah DEQ. The remaining five indicators showed little or no evidence of alteration from the NRV. We did not assess water quality in the Canyon Mountain unit because there was **insufficient information**.

Fishlake–Thousand Lake

The primary stressors to water quality in the Fishlake–Thousand Lake unit were dams and diversions, recreation, timber harvest, and degraded soil conditions. There were 0.005 diversions per acre, which was relatively high compared to other units within the study area. The WCF water quantity indicator suggested these structures had contributed to moderate departures of intermediate flows from natural conditions. There were 0.02 recreation sites per floodplain acre, which was the second largest density of all units considered in this assessment. Approximately 1.6 percent of the Fishlake–Thousand Lake unit was located within a timber harvest project and nearly half of those projects had been clearcuts, which was the most of any unit on

the Forest. Nevertheless, the WCF Loss of Forest Cover attribute indicated loss of forest cover due to timber harvest and other stressors such as fire, insects and disease, or weather events was minor and that watersheds in the Fishlake–Thousand Lake unit remained in proper functioning condition for forest cover. Soil conditions were degraded at some locations within this unit. According to the WCF Soil Erosion attribute, accelerated erosion occurred over extensive areas in nearly all watersheds, with evidence of expanding rills and gullies. Additionally, the WCF Soil Productivity attribute indicated soil nutrient and hydrologic cycling processes were impaired in several watersheds. However, based on the WCF Soil Contamination attribute, no substantial areas of soil contamination were evident throughout the Fishlake–Thousand Lake unit.

The Fishlake–Thousand Lake unit contains the headwaters of the Fremont River. The geology of this area is dominated by volcanic rocks that influences the chemical composition of waters draining the unit (Fremont River Watershed Water Quality Management Plan 2002). The water quality of Fish Lake has generally been good, with past impacts from excessive phosphorus due to cabin septic tanks. This issue has been improved since cabins on the lake connected to centralized sewer (Fremont River Watershed Water Quality Management Plan 2002). Nonpoint sources of pollution within the unit include natural background, animal waste, and recreation (Fremont River Watershed Water Quality Management Plan 2002).

Floodplains made up 4.2 percent of the Fishlake–Thousand Lake unit and 0.3 percent of the unit was classified as wetland. The WCF Riparian/Wetland Vegetation Condition indicator suggested that the native vegetation of these areas was in a functional condition that dissipated stream energy, reduced erosion, filtered sediment, stabilized streambanks, buffered stream temperature, and improved water quality, but that some attributes made them susceptible to degradation. Based on level II riparian surveys, the average percent of stream substrate classified as sand and silt was 17 percent and coarse fines made up 10 percent of stream substrates. Twenty-one percent of pool tails, 20 percent of riffles, and 32 percent of pools show evidence of cementation. Additionally, several surveys noted impacts from large amounts of silt, mass wasting, road cuts, overgrazing, and turbid water. The average estimated August stream temperature from 1993 to 2013 ranged from 51.1 °F to 55.6 °F. Level II riparian surveys found 57 percent of streambanks had overhanging vegetation. The WCF Impaired Waters attribute indicated there were few waterbodies not supporting beneficial uses and, according to 2015 303d listed waters, 22 percent of streams were impaired. Based on the WCF Water Quality Problems attribute, the watershed only had minor water quality problems such as excessive sediment, nutrients, or chemical pollution. Based on Utah DEQ Assessments, 56 percent of the Fishlake–Thousand Lake unit was fully supporting beneficial uses. Thirteen percent was impaired due to total phosphorus and dissolved oxygen. Eight percent was impaired due to total phosphorus and sediment. Two percent was impaired due to dissolved oxygen. Twenty-two percent of the unit was not assessed.

Information for all seven water quality indicators was available in the Fishlake–Thousand Lake unit. One indicator, substrate embeddedness, showed evidence of substantial alteration from the NRV. Two additional indicators showed evidence of moderate alteration from the NRV: condition of riparian and wetland vegetation and percent classified as impaired by Utah DEQ. The remaining four indicators showed little or no evidence of alteration from the NRV. The overall score for water quality was 77 percent and the Fishlake–Thousand Lake unit was considered to be **within the NRV**.

Monroe Mountain

The primary stressors to water quality in the Monroe Mountain unit included roads and trails, timber harvest, and degraded soil conditions. There were 0.002 road miles per acre and 61 percent of these are unimproved. Within floodplains, the road density was 0.005 road miles per acre and the trail density was 0.007 trail miles per acre, which was the highest floodplain trail density of all units considered in this assessment. The WCF indicated roads and trails had high potential to impact water quality by contributing large sediment loads to streams and waterbodies. While less than 10 percent of road and trail miles are located within 300 feet of streams and other, best management practices for maintenance were applied to between 50–75 percent of roads, trails, and water crossings in many watersheds. Additionally, mass wasting was a significant process impacting some roads constructed on unstable landforms in some watersheds within the Monroe Mountain unit. About 1.6 percent of this unit was located within a timber harvest project and 28 percent of these projects had been clearcuts. Nevertheless, the WCF Loss of Forest Cover attribute indicated loss of forest cover due to timber harvest and other stressors such as fire, insects and disease, or weather events was minor and that watersheds in the Monroe Mountain unit remain in proper functioning condition for forest cover. According to the WCF Soil Erosion attribute, accelerated soil erosion occurred across about 10 percent of the landscape. Based on the WCF Soil Productivity attribute, soil nutrient and hydrologic cycling processes were impaired. However, no substantial areas of soil contamination were evident throughout the Monroe Mountain unit.

The local geology of the Monroe Mountain unit is highly influential on the chemical composition of surface and groundwaters (Richardson 1907). Much of the unit is composed of igneous rocks that contribute relatively little mineral matter (Richardson 1907), with streams showing evidence of relatively low concentrations of calcium, bicarbonate, sulfate, or chlorine (Richardson 1907). Generally water quality is naturally high throughout the unit, but hot springs can contribute highly mineralized water to surface water systems (Young and Carpenter 1965)

Floodplains made up 2.6 percent of the Monroe Mountain unit and 0.06 percent was classified as wetland. The WCF Riparian/Wetland Vegetation Condition indicator suggested that the native vegetation of riparian areas and wetlands were in a functional condition that dissipated stream energy, reduced erosion, filtered sediment, stabilized streambanks, buffered stream

temperature, and improved water quality, but that some attributes made them susceptible to degradation. Level II riparian surveys had been completed in Koosharem Creek, Manning Creek, and Box Creek Watersheds. The data we found for these reports did not contain information about substrate, cementation, or overhanging vegetation, so we were only able to summarize the final reports for each watershed. Based on these reports, it appeared erosion and increased sediment loads due to livestock grazing may have affected water quality in the Monroe Mountain unit. Impacts from grazing to water quality were specifically noted in Greenwich Creek, Straight Canyon, and Box Creek. The average estimated August stream temperature from 1993 to 2013 ranged from 50.1 °F to 54.6 °F. The WCF Impaired Waters attribute indicated there were few waterbodies not supporting beneficial uses and, according to 2015 303d listed waters, 14 percent of streams and 52 acres of waterbody were impaired. Based on the WCF Water Quality Problems attribute, watersheds in the Monroe Mountain unit tended to only have minor water quality problems such as excessive sediment, nutrients, or chemical pollution. Based on Utah DEQ Assessments, less than 1 percent of this unit was fully supporting beneficial uses. One percent was impaired due to total dissolved solids. One percent was impaired due to total phosphorus. Forty percent was impaired due to total phosphorus and sediment. Fifty-nine percent was not assessed.

Information was not available for two indicators in the Monroe Mountain unit: Substrate Embeddedness and percent classified as Impaired by Utah DEQ. One of the remaining four indicators, Condition of Riparian and Wetland Vegetation, showed evidence of moderate alteration from the NRV. The remaining three indicators showed little or no evidence of alteration from the NRV. We did not assess water quality in the Monroe Mountain unit because there was **insufficient information**.

Pavant Range

The primary stressors to water quality in the Pavant Range unit included roads, invasive species, wildfire, loss of riparian cover, and degraded soil conditions. There were 0.001 road miles per acre and 76 percent of roads were unimproved. Within floodplains, the road density was 0.005 miles per acre. The WCF indicated roads had high potential to impact water quality by contributing sediment loads to streams and other waterbodies. Best management practices for maintenance were applied to between 50 and 75 percent of roads, trails, and water crossings across the unit and mass wasting was a significant process impacting some roads constructed on unstable landforms within some watersheds. About 6.5 percent of floodplains had converted from riparian cover to invasive species, and at least some of these patches included tamarisk. Where tamarisk is established, there is higher potential for increased salinity and lower flows. The WCF indicated terrestrial invasive species infest significant portions of watersheds throughout the Pavant Range with widespread impacts to soil and water resources. Approximately 1.8 percent of this unit had burned at high severity and, according to the WCF, at least some watersheds showed evidence of

postfire runoff and erosion. Approximately 3.3 percent of riparian areas associated with perennial streams had converted from riparian cover to development and 2.6 percent had converted to agriculture. Riparian surveys also noted heavy cattle use and turbid waters in some reaches. In addition to the loss of ecosystem services related to water quality provided by riparian systems, these areas were also potential nonpoint sources of pollution. Soil conditions were degraded at some locations within this unit. According to the WCF Soil Erosion attribute, there was evidence of accelerated erosion occurring on about 10 percent of the landscape, with small and disconnected rills and gullies present. Based on the WCF Soil Productivity attribute, soil nutrient and hydrologic cycling processes were impaired in some watersheds. However, no substantial areas of soil contamination were evident throughout the Pavant Range.

Streams that flow from the Pavant Range are important sources of water for irrigation at lower elevations (Dennis et al. 1946). The chemical composition of streams in this unit are influenced by the limestone and dolomite geological formations that make up a large part of the Pavant Range (Dennis et al. 1946). These streams carry low concentrations of calcium, magnesium, and bicarbonate and were generally good sources of high quality surface water (Richardson 1907).

Floodplains made up 3.0 percent of the Pavant Range unit and 0.1 percent of the unit was classified as wetland. The WCF Riparian/Wetland Vegetation Condition indicator suggested that native vegetation in these areas is in a functional condition that dissipated stream energy, reduced erosion, filtered sediment, stabilized streambanks, buffered stream temperature, and improved water quality. Based on level II riparian surveys, the average percent of stream substrate classified as sand and silt was 24 percent and an additional 8 percent was coarse fines. Nineteen percent of pool tails, 17 percent of riffles, and 30 percent of pools showed evidence of substrate cementation. The average estimated August stream temperature from 1993 to 2013 ranged from 54.9 °F to 59.4 °F. Level II riparian surveys found 43 percent of banks had overhanging vegetation. The WCF Impaired Waters attribute indicated all waterbodies were supporting beneficial uses and, according to 2015 303d listed waters, 18 percent of streams and 52 acres of waterbody were impaired. Based on the WCF Water Quality Problems attribute, most watersheds in the Pavant Range had minor water quality problems such as excessive sediment, nutrients, and chemical. Based on Utah DEQ Assessments, 44 percent of this unit was fully supporting beneficial uses and 56 percent was not assessed.

Information for six of the seven water quality indicators was available in the Pavant Range unit. We did not include the percent classified as impaired by Utah DEQ because less than 50 percent of the unit had been assessed. One indicator, embeddedness, showed evidence of substantial alteration from the NRV. The remaining five indicators showed little or no evidence of alteration from the NRV. The overall score for water quality was 87 percent and the Pavant Range unit was considered to be **within the NRV**.

Tushar Mountains

The primary stressors to water quality in the Tushar Mountains included roads and recreation, invasive species, livestock grazing, wildfire, and degraded soil conditions. There were 0.002 road miles per acre and 69 percent of roads were unimproved. Road density within floodplains was 0.007 miles per acre, which was the largest floodplain road density of units on the FNF. There were 0.02 recreation sites per floodplain acre, which was a higher density than any other unit in the study area. The WCF indicated roads had high potential to impact water quality by contributing sediment loads to streams and other water bodies. Between 10 and 25 percent of road length was within 300 feet of streams and water bodies and best management practices for maintenance were applied to less than 50 percent of roads, trails, and water crossings. Additionally, mass wasting was a significant process impacting some roads constructed on unstable landforms within some watersheds. About 3.4 percent of floodplains had converted from riparian cover to invasive species, and at least some of these patches included tamarisk. Where tamarisk occurs, there is higher potential for increased salinity and lower flows. The WCF indicated terrestrial invasive species infested less than 10 percent of watersheds on average and the rate of spread was minimal. Ninety-nine percent of the Tushar Mountains unit was open to grazing and 100 percent of range management units were active. These pastures were a potential nonpoint source of pollution that may contribute excess nutrients to aquatic systems. Additionally, 33 percent of watersheds in the Tushar Mountains showed evidence of a reversible loss in the capacity of rangelands to limit loss of soil resources including nutrients and organic matter. These areas were more vulnerable to irreversible degradation. Two percent of the unit was in impaired function and had lost this capacity. Approximately 6.3 percent of this unit had burned at high severity and, according to the WCF, at least some watersheds showed evidence of postfire runoff and erosion. Approximately 8.8 percent of riparian areas associated with perennial streams had converted from riparian cover to development. In addition to the loss of ecosystem services related to water quality provided by riparian systems, these areas were potential nonpoint sources of pollution. Soil conditions were degraded at some locations within this unit. According to the WCF Soil Erosion attribute, there was evidence of accelerated erosion occurring on more than 10 percent of the landscape, with actively expanding rills and gullies present. Additionally, the WCF Soil Productivity attribute indicated soil nutrient and hydrologic cycling processes were impaired. However, based on the WCF Soil Contamination attribute, no substantial areas of soil contamination were evident throughout the Tushar Mountains.

The water quality of the Tushar Mountains is influenced by the volcanic geology that increases the concentration of sodium (Thiros and Brothers 1993). Surface- and groundwater discharged from or within this unit tend to be of good chemical quality (Mower 1978). Water pumped from groundwater systems recharged by precipitation that falls in this unit are generally free of silt, weed seeds, and organic contamination (Young and Carpenter 1965). Furthermore, water temperature and chemical composition tend to remain

constant throughout the year (Young and Carpenter 1965). Uranium and alunite mining that occurs in and near the Tushar Mountains have been identified by other studies as potential threats to water quality (Young and Carpenter 1965).

Floodplains made up 2.5 percent of the Tushar Mountains and 0.01 percent of the unit was classified as wetland. The WCF Riparian/Wetland Vegetation Condition indicator suggested that native vegetation in these areas was in functional condition that dissipated stream energy, reduced erosion, filtered sediment, stabilized streambanks, buffered stream temperature, and improved water quality, but that some attributes made riparian areas and wetlands more susceptible to degradation. Based on level II riparian surveys, the average percent of stream substrate classified as sand and silt was 9 percent and an additional 10 percent was coarse fines. Eleven percent of pool tails, 10 percent of riffles, and 19 percent of pools showed evidence of substrate cementation. Additionally, surveys noted some impacts from failing banks and road cuts. The average estimated August stream temperature from 1993 to 2013 ranged from 50.8 °F to 55.3 °F. Level II riparian surveys found 40 percent of banks had overhanging vegetation. The WCF Impaired Waters attribute indicated nearly all waterbodies were supporting beneficial uses. According to the WCF Water Quality Problems attribute, watersheds in the Pavant Range had minor water quality problems such as excessive sediment, nutrients, and chemical pollution. Based on Utah DEQ Assessments, 81 percent of this unit was fully supporting beneficial uses. One percent was impaired due to temperature. One percent was impaired due to total phosphorus. Four percent was impaired due to total phosphorus and sediment.

Information for all seven water quality indicators was available in the Tushar Mountain unit. One indicator, condition of riparian and wetland vegetation, showed evidence of moderate alteration from the NRV. The remaining six indicators showed little or no evidence of alteration from the NRV. The overall score for water quality was 94 percent and the Tushar Mountain unit was considered to be **within the NRV**.

White Mountain

The primary stressors to water quality in the White Mountain unit included roads, recreation, invasive species, loss of riparian cover, and degraded soil conditions. There were 0.002 road miles per acre and 73 percent of roads were unimproved. Road density within floodplains was 0.006 miles per acre. There were 0.01 recreation sites per floodplain acre, which was relatively high compared to other units in the study area. The WCF indicated roads had high potential to impact water quality by contributing sediment loads to streams and other water bodies. Best management practices for maintenance were applied to between 50 and 75 percent of roads, trails, and water crossings and mass wasting was a significant process impacting some roads constructed on unstable landforms within some watersheds. About 8.0 percent of floodplains had converted from riparian cover to invasive species, with 2 percent of floodplains characterized

by tamarisk. Where tamarisk occurs, there is higher potential for increased salinity and lower flows. However, the WCF indicated terrestrial invasive species infested less than 10 percent of watersheds on average and the rate of spread was minimal. Twenty-one percent of perennial stream miles had converted from riparian cover to development, which was more than any other unit. In addition to the loss of ecosystem services related to water quality provided by riparian systems, these areas were also potential nonpoint sources of pollution. Soil conditions were degraded at some locations within this unit. According to the WCF Soil Erosion attribute, there was evidence of accelerated erosion occurring on more than 10 percent of the landscape in most watersheds, with actively expanding rills and gullies present. Additionally, the WCF Soil Productivity attribute indicated soil nutrient and hydrologic cycling processes were impaired in some watersheds. However, based on the WCF Soil Contamination attribute, no substantial areas of soil contamination were evident throughout the White Mountain unit.

The composition of water draining the White Mountain unit is influenced by the presence of Flagstaff limestone and North Horn Formation (Danielson and Sylla 1982). Groundwater that has been in contact with limestone geologies tends to contain calcium, magnesium, bicarbonate, and sulfate (Danielson and Sylla 1982). Chemistry of groundwater that contacts the North Horn Formation is far more variable (Danielson and Sylla 1982). The water quality of surface water systems in the area is highly influenced by the chemical composition of the groundwater that discharges into streams (Danielson and Sylla 1982). Surface water in the region tends to be suitable for most uses, with the predominate chemical constituents including calcium, magnesium, and bicarbonate (Danielson and Sylla 1982). Coal mining in this region is a potential threat to water quality (Danielson and Sylla 1982).

Floodplains made up 3.3 percent of the White Mountain unit and 0.03 percent of the unit was classified as wetland. The WCF Riparian/Wetland Vegetation Condition indicator suggested that native vegetation in these areas was in a functional condition that dissipated stream energy, reduced erosion, filtered sediment, stabilized streambanks, buffered stream temperature, and improved water quality, but that some attributes made them susceptible to degradation. Level II riparian surveys had been completed in Lower Salina, Upper Salina, West Slope Salina, and Lost Creek Watersheds. The data we found for these reports did not contain information about substrate, cementation, or overhanging vegetation, so we were only able to summarize the final reports for each watershed. Based on these reports, it appeared erosion and increased sediment loads may have impacted water quality. Drought and overgrazing were specifically noted to be contributing to excessive erosion, channel incision, and turbid waters. The average estimated August stream temperature from 1993 to 2013 ranged from 54.8 °F to 59.3 °F. The WCF Impaired Waters attribute indicated most waterbodies were supporting beneficial uses. According to the WCF Water Quality Problems attribute, most watersheds in the White Mountain unit had minor or no water quality problems such as excessive sediment, nutrients, and chemical

pollution. Based on Utah DEQ Assessments, 83 percent of this unit was fully supporting beneficial uses. One percent was impaired due to total dissolved solids. One percent was impaired due to total phosphorus and sediment. Sixteen percent was not assessed.

Information for six of the seven water quality indicators was available in the White Mountain unit. One indicator, condition of riparian and wetland vegetation, showed evidence of moderate alteration from the NRV. The remaining five indicators showed little or no evidence of alteration from the NRV. The overall score for water quality was 93 percent and the White Mountain unit was considered to be **within the NRV**.

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Appendix F. Channel and Floodplain Dynamics

Methods

We evaluated five indicators that provide information related to the current condition of channel and floodplain dynamics: (1) channel shape and function, (2) percent of perennial streams with no change in riparian cover, (3) percent of confined perennial streams classified as impacted, (4) percent of unconfined perennial streams in good or intact condition, and (5) percent of streambanks classified as stable (table F.1). We obtained data on channel shape and function from the WCF, which considers whether width-to-depth ratios are within an expected range, whether channels are vertically stable, and whether channels remain connected to their floodplains (Potyondy and Geier 2011). We used R-CAT to estimate the percent of perennial stream segments with no change in riparian cover, percent of confined streams classified as impacted, and percent of unconfined reaches that were intact or in good condition (Macfarlane et al. 2017). Finally, we used level II riparian survey data to determine the average percent of streambanks classified as stable.

We scored these five indicators of channel and floodplain dynamics based on whether they showed evidence of no, moderate, or substantial alteration from the NRV. If the indicator had little or no alteration from the NRV, it was

Table F.1—Values of channel and floodplain dynamics indicators by geographic unit.

Geographic unit	Forest	Channel shape and function	Percent stream miles with no change in riparian cover	Percent confined impacted	Percent unconfined very poor to moderate	Percent reaches—good stability
Escalante	Dixie	2.0	46.3	24.4	53.3	67
Markagunt Plateau	Dixie	2.5	33.2	33	60.5	63
Paunsaugunt–Mt. Dutton	Dixie	2.2	29.7	37.7	66.8	36
Pine Valley	Dixie	2.2	25.9	20.5	66.1	33
Boulder Mountain	Fishlake	1.7	55.6	15.3	18.7	73
Canyon Mountains	Fishlake	1.1	4.4	62.2	61.3	-
Fishlake–Thousand Lake	Fishlake	1.6	46.1	20.7	37.5	55
Monroe Mountain	Fishlake	1.3	40.1	16.4	27.2	-
Pavant Range	Fishlake	1.3	39.4	13.4	88	64
Tushar Mountains	Fishlake	1.9	28.0	18.6	70.8	79
White Mountain	Fishlake	1.6	38.9	33.7	72.3	-

given a score of 5; moderate alteration was given a score of 3; substantial alteration was given a score of 1 (table F.2). The thresholds for moderate and substantial alteration for each indicator were determined from literature or from the data source's methods. The scores for each geographic unit were summed and divided by the potential total of 25 to give a percentage rating for each. Level II riparian surveys were not completed in all units, resulting in a lack of data on bank stability in some geographic units considered in our assessment. These units were divided by the potential total of 20. More information on the completed level II riparian surveys can be found in the descriptions of each unit contained within this appendix. Units were considered within the NRV for fluctuations in surface water systems if the index was greater than 77 percent; moderately altered from the NRV if the index was between 50 percent and 76 percent; and outside the NRV if the index was less than 50 percent. We were unable to assess the condition of spring runout channels because we did not locate any data for these systems.

Unit Summaries

Escalante

The primary stressors to channel and floodplain dynamics in the Escalante unit included roads, dams, diversions, and grazing. There were 0.005 road miles per floodplain acre, which was a moderate floodplain road density compared to other geographic units. The WCF indicated nearly all watersheds had more than 25 percent of roads or trails within 300 feet or otherwise hydrologically connected to streams and other water bodies. Additionally, level II riparian surveys noted impacts from roads at West Fork (WF) Deer, Birch, Center, East Fork (EF) Boulder, and Boulder Creeks. There were 0.003 diversions per acre and 0.02 dams per stream mile. These densities were relatively low compared to other geographic units; however, the WCF indicated that changes to the timing, rate of change, and/or duration of mid-range discharge had occurred in most watersheds. Level II riparian surveys provided examples of dewatering and incision as impacts from diversions in WF and EF Deer Creek. Ninety-one percent of the Escalante unit is within range management units. The WCF indicated 38 percent

Table F.2—Thresholds of evidence for alteration from the NRV and data sources for five indicators of channel and floodplain dynamics.

Indicator	Data source	Little or no alteration	Moderate alteration	Substantial alteration
Channel shape and function	WCF	≤ 1.6	1.7 ≤ x ≤ 2.2	≥ 2.3
% streams no change in riparian cover	R-CAT	< 3 3%	34% < x < 66%	> 66%
% confined–impacted	R-CAT	< 24%	25% < x < 49%	> 50%
% unconfined–very poor to moderate	R-CAT	< 24%	25% < x < 49%	> 50%
% reaches–good condition bank stability	Level II riparian surveys	> 50%	25% < x < 49%	> 50%

watersheds contain rangelands in functional-at-risk condition. These areas have moderate probability of soil compaction, increased overland flow, and incised channels. Impacts from grazing, including incised channels, were noted in riparian surveys at Birch, Cedar, and EF Boulder Creeks.

There were 17.4 floodplain acres per stream mile, which was the largest floodplain to stream mile ratio of units on the DNF and second largest ratio in the study area. Level II riparian survey data identified most surveyed streams to be single-thread channels that were moderately or entirely entrenched. Some stream reaches in wet meadows were only slightly entrenched and were highly sinuous with low gradients. There was variation in the shape of valley bottoms, generally due to gradient and geology. Trough-like and v-shaped valleys were the most common channel types, many with moderate to extremely steep gradients and narrow widths. The average stream gradient in the Escalante unit was 6.4 percent. On average, 27 percent of streams consisted of pool habitat types and 12 percent of banks were undercut. The average width-to-depth ratio of streams in the Escalante unit was 9.6. Level II riparian surveys indicated that roads, grazing, and flow diversions had negatively impacted stream channels and their floodplains, with additional noted impacts from past upland timber harvests.

There were 271 miles of perennial streams in the Escalante unit. Of these perennial streams, R-CAT estimated 219 miles were confined and 52 miles were unconfined. Twenty-four percent of confined reaches were classified as impacted. Of the unconfined reaches, 39 percent were in moderate condition, 24 percent were intact, 23 percent were in good condition, and 14 percent were in poor condition. Nearly half (46 percent) of perennial streams displayed no change in riparian cover, with 28 percent converting to conifer and 9 percent converting to development. These results suggested reduced dynamism and less connectivity between channels and floodplains. The WCF indicated less than 25 percent of historic aquatic habitats were still connected and habitat fragmentation due to temperature, blockages, or dewatering was a serious concern in nearly all watersheds. Large woody debris was present and continues to be recruited into aquatic and riparian systems that evolved with wood near the stream in most of the Escalante unit. Only one watershed had large wood lacking such that riparian and aquatic habitats were in poor condition. An additional four watersheds had a reduced rate of large wood recruitment. There was limited degradation to channels and floodplains in most watersheds and some incised stream channels had lost connectivity with their floodplains.

Information was available for all five channel and floodplain dynamic indicators in the Escalante unit. Two of the five indicators showed evidence of moderate alteration from the NRV: channel shape and function and percent of perennial streams with no change in riparian cover. The percentage of perennial streams in very poor to moderate condition provided evidence of substantial alteration from the NRV. The percentage of confined perennial streams classified as impacted and the percentage of reaches considered in good condition with regard to bank stability both supplied no evidence

of alteration from the NRV. The overall score for channel and floodplain dynamics in the Escalante unit was 68 percent and it was considered to be **moderately altered from the NRV**.

Markagunt Plateau

The primary stressors to channel and floodplain dynamics in the Markagunt Plateau included roads, dams, diversions, and grazing. There were 0.007 road miles per floodplain acre, which was a higher floodplain road density than any other unit in the study area. Overall, the WCF indicated nearly all watersheds had more than 25 percent of roads and trails within 300 feet or otherwise hydrologically connected to streams and water bodies. Additionally, level II riparian surveys noted impacts from roads at Deer, Caddy, and Tommy Creeks, as well as road that runs the length of Bunker Creek. There were 0.008 diversions per acre and 0.03 dams per stream mile in the Markagunt Plateau. These densities were relatively low compared to other geographic units; however, the WCF indicated the magnitude, duration, and timing of yearly peak and low flows were significantly departed from the natural hydrograph in most watersheds. Level II riparian surveys provided at least one example of a stream channel and floodplain negatively impacted by diversions in Deer Creek, where these structures were increasing flow in Deer Creek, resulting in movement of large amounts of substrate and an incised channel. Ninety-two percent of the Markagunt Plateau was within range management units. The WCF indicated 20 percent watersheds had rangelands in functional-at-risk condition and 4 percent were impaired. These areas have higher likelihood of soil compaction, increased overland flow, and incised channels. Livestock grazing was noted as a major resource use in all level II riparian surveys completed within the Markagunt Plateau unit.

There were 15.1 floodplain acres per stream mile, which was a moderate amount compared to other geographic units. Level II riparian survey data that identified most streams to be single-thread channels that were moderately or entirely entrenched. Most valley bottoms were trough-like with moderate or low gradients and narrow widths, resulting in generally low to moderate sinuosity. Diverse geologic settings drive high variation in valley bottom characteristics in some streams, including Bunker and Mammoth Creeks. The average stream gradient in the Markagunt Plateau was 4.3 percent. On average, 27 percent of streams consisted of pool habitats and 8 percent of banks were undercut. The average width-to-depth ratio of streams was 9.7. Level II riparian surveys suggested decline in stability of several reaches due to livestock grazing and roads, with limited impacts from upland activities such as fire and timber harvest also noted.

There were 253 miles of perennial streams in the Markagunt Plateau. Of these perennial streams, R-CAT estimated 187 miles were confined and 66 miles were unconfined. Thirty-three percent of confined reaches were classified as impacted. Of the unconfined reaches, 29 percent were in good condition, 10 percent were intact, 44 percent were in moderate condition, and 17 percent were in poor condition. Only 33 percent of perennial streams displayed no change in riparian cover, with 32 percent converting to conifer

cover, 11 percent converting to development, and 17 percent converted to grass and shrub cover. These results suggested reduced connectivity, and fewer dynamic floodplains are present in the Markagunt Plateau. Nevertheless, the WCF indicated between 25 and 95 percent of historic aquatic habitats remain connected. Of the 35 watersheds in the Markagunt Plateau unit, 11 had large woody debris present with continued recruitment at rates expected for the system. An additional 13 watersheds had large woody debris present, but it failed to be recruited at the expected rate. Finally, one watershed lacked large wood such that riparian and aquatic habitat conditions were impaired. Most watersheds provided evidence of impaired channels. In these watersheds, more than 25 percent of channels had width-to-depth ratios greater than expected under natural conditions, incised channels were common and increasing, and more than 50 percent of stream channels were disconnected from their floodplain.

Information was available for all five channel and floodplain indicators in the Markagunt Plateau. Three of the five indicators showed evidence of being outside the NRV: channel shape and function, percent of perennial streams with no change in riparian cover, and percent of perennial streams in very poor to moderate condition. The percentage of confined perennial streams classified as impacted was considered moderately altered from the NRV. One indicator, percentage of reaches in good condition with regard to streambank stability, showed little evidence of alteration from the NRV. The overall score for channel and floodplain dynamics in the Markagunt Plateau unit was 44 percent and it was considered **outside the NRV**.

Paunsaugunt–Mt. Dutton

The primary stressors to channel and floodplain dynamics in the Paunsaugunt–Mt. Dutton unit included roads, diversions, and grazing. There were 0.006 road miles per floodplain acre, which was a moderate density compared to other units in the study area. The WCF indicated nearly all watersheds had more than 25 percent of roads and trails within 300 feet or otherwise hydrologically connected to streams and water bodies. Additionally, level II riparian surveys noted impacts from roads at Podunk, Pole Canyon, and Deep Creek, as well as a road that parallels WF Hunt Creek. There were 0.0009 diversions per acre and 0.004 dams per stream mile, which were relatively low densities compared to other units; however, the WCF indicated these structures had contributed to alterations in the timing, rate of change, and/or duration of mid-range discharges. Level II riparian surveys did not note any impacts from diversions or dewatering. All of Paunsaugunt–Mt. Dutton was within a range management unit and the WCF indicated 50 percent of watersheds had high probability of rangelands with compacted soils, increased overland flow, and incised channels. Impacts from livestock grazing, including incised channels and cattle trails were noted in all level II riparian surveys completed within this unit.

There were 13.4 floodplain acres per stream mile in the Paunsaugunt–Mt. Dutton unit, which was moderate compared to other geographic units. There was wide variation in stream channel types. Many valley bottoms

were trough-like with low gradients and narrow widths. Streams tended to have moderate or high sinuosity and ranged from slightly entrenched to entirely entrenched. The average stream gradient was 2.9 percent. On average 21 percent of streams were in pools and 13 percent of banks were undercut. The average width-to-depth ratio of streams in this unit was 7.5. Level II riparian surveys suggested degradation to channels including severe channel downcutting in several reaches. These conditions were generally attributed to livestock grazing, roads, and trails. Beavers were present and restoration activities in some streams had contributed to improved channel and floodplain conditions.

There were 170 miles of perennial streams in the Paunsaugunt–Mt. Dutton unit. Of these perennial streams, R-CAT estimated 108 miles were confined and 63 miles were unconfined. Thirty-eight percent of confined channels were classified as impacted. Of the unconfined reaches, 44 percent were in moderate condition, 26 percent were in good condition, 23 percent were in poor condition, and 7 percent were intact. Only 30 percent of perennial streams displayed no change in riparian cover, with 35 percent having converted to grasses and shrubs, 16 percent converted to conifers, and 12 percent converted to invasive species. The WCF indicated less than 25 percent of historic aquatic habitats were still connected in most watersheds. The presence of large woody debris was not an important component for riparian and aquatic systems in most watersheds in this unit. Of the 14 watersheds with systems that evolved with large woody debris, 8 had it present and recruited at an appropriate rate. Five watersheds had large woody debris present, but recruitment occurred at a rate less than what was expected. One watershed had systems where wood was lacking, resulting in poor riparian or aquatic condition. There was evidence of impaired channels in most watersheds, including large width-to-depth ratios, extensive and increasing channel incision, and more than 50 percent of channels disconnected from their floodplain.

Information was available for all five channel and floodplain indicators in the Paunsaugunt–Mt. Dutton unit. Two of the five indicators showed evidence of substantial alteration from the NRV: percentage of perennial streams with no change in riparian cover and the percentage of unconfined perennial streams in very poor to moderate condition. The remaining three indicators showed evidence of moderate alteration from the NRV. The overall score for channel and floodplain dynamics in the Paunsaugunt–Mt. Dutton unit was 44 percent and it was considered **outside the NRV**.

Pine Valley

The primary stressors to channel and floodplain dynamics in the Pine Valley unit included roads, recreation, dams, diversions, and grazing. There were 0.005 road miles per floodplain acre, 0.001 trail miles per floodplain acre, and 0.004 recreation sites per floodplain acre. The WCF indicated most watersheds had more than 25 percent of roads and trails within 300 feet or otherwise hydrologically connected to streams and water bodies. Additionally, level II riparian surveys noted impacts from roads in Holt

Canyon, Leeds, Pine Park, Santa Clara, Shinbone, Ox Valley, and Wet Sandy drainages. While the densities of trails and recreation sites within the floodplain were relatively low, recreation had major impacts to channel and floodplain dynamics in this unit. Level II riparian surveys noted recreation as the most significant use and noted impacts such as litter, soil compaction, erosion, trampled streambanks, and downcut streams at popular campgrounds. There were 0.02 diversions per acre and 0.05 dams per stream mile in the Pine Valley unit. These were the largest diversion and dam densities of all units in the study area. The WCF indicated these structures had contributed to departure in the timing, rate of change, and/or duration of mid-range discharges. Level II riparian surveys noted impacts for diversions and dewatering in Holt Canyon, Leeds Creek, Shinbone Creek, Spring Creek Mountain Meadows, and Wet Sandy. Seventy-one percent of Pine Valley was within a range management unit and the WCF indicated 76 percent of watersheds had high probability of compacted soils, increased overland flow, and incised channels as a result of impaired or functional-at-risk rangeland vegetation conditions. Impacts from livestock grazing, including incised channels and cattle trails, were noted in nearly all level II riparian surveys completed for the Pine Valley unit. Level II riparian surveys also noted major impacts to channels and floodplains due to poor upland conditions related to extreme impacts from grazing and wildfire.

There were 11.8 floodplain acres per stream mile in the Pine Valley unit, which was moderate compared to other geographic units. Streams frequently had moderate or entirely entrenched single-thread channels with low to moderate sinuosity. However, there was wide variation in stream type, with some examples of multiple channels or slightly entrenched reaches present in the unit. Similarly, there was wide variation in valley bottom characteristics, with valleys ranging from very low gradient to very steep, generally with trough-like shapes and narrow widths. The average stream gradient was 4.9 percent, but gradients were highly variable. On average, 33 percent of streams were in pools and 9 percent of banks were undercut. The average width-to-depth ratio was 11.4. Level II riparian surveys suggested degradation to channels including dewatered reaches, eroding streambanks, and incised channels. These conditions were generally attributed to diversions, poor upland conditions, livestock use, roads, and recreation. Beaver dams were noted in Leeds Creek and were generally having a stabilizing effect.

There were 131 miles of perennial streams in the Pine Valley unit. Of these perennial streams, R-CAT estimated 104 miles were confined and 27 miles were unconfined. R-CAT results indicated 20 percent of confined reaches were impacted. Of the unconfined reaches, 44 percent were in moderate condition, 26 percent were in good condition, 22 percent were in poor condition, and 8 percent were intact. Only 26 percent of perennial streams displayed no change in riparian cover, with 49 percent converting to conifers and 12 percent converting to grasses and shrubs. The WCF indicated between 25 and 95 percent of historic aquatic habitats were still connected in most watersheds. Only two watersheds in the Pine Valley unit evolved

with large woody debris as an important component for riparian and aquatic structure and function. One of these watersheds had large wood present and an appropriate recruitment rate. One watershed had large wood present, but a recruitment rate less than what was expected for the system. There was evidence of impaired channels in most watersheds, including large width-to-depth ratios, extensive and increasing channel incision, and more than 50 percent of channels disconnected from their floodplain.

Information was available for all five channel and floodplain dynamic indicators in the Pine Valley unit. Two indicators provided evidence of substantial alteration from the NRV: the percentage of perennial streams with no change in riparian cover and the percentage of unconfined perennial reaches in very poor to moderate condition. Two additional indicators showed evidence of moderate alteration from the NRV: channel shape and function and the percentage of reaches in good condition with regards to streambank stability. Lastly, the percentage of confined perennial reaches that were impacted provided little or no evidence of alteration from the NRV. The overall score for channel and floodplain dynamics in the Pine Valley unit was 52 percent and it was considered **moderately altered from the NRV**.

Boulder Mountain

The primary stressors to channel and floodplain dynamics in the Boulder Mountain unit were roads, recreation, dams, diversions, and grazing. There were 0.0004 road miles per floodplain acre, 0.001 trail miles per floodplain acre, and 0.007 recreation sites per floodplain acre. Floodplain road and trail densities were relatively low compared to other units, but recreation site density was moderate. The WCF indicated most watersheds in this unit had more than 25 percent of roads within 300 feet or otherwise hydrologically connected to streams and water bodies. Additionally, level II riparian surveys noted impacts from roads, trails, and recreation sites in Fish, Pleasant, Spring, and Pine Creeks. There were 0.003 diversions per acre and 0.02 dams per stream mile, which were moderate to low densities compared to other units in the study area. Nevertheless, the WCF indicated these structures had contributed to departure in the timing, rate of change, and/or duration of mid-range discharges. Level II riparian surveys noted impacts from diversions and dewatering in Pleasant and Pine Creeks. One hundred percent of the Boulder Mountain unit was within a range management unit. While the WCF indicated 86 percent of watersheds had rangelands that were in proper functioning condition, level II riparian surveys described impacts from livestock grazing that included trailing, trampled banks, streambank erosion, and incised channels at all assessed sites. Some level II riparian surveys also noted impacts to channels and floodplains from upland activities including timber harvest.

There were 20.0 floodplain acres per stream mile in the Boulder Mountain unit, which was more than any other unit in the assessment area. This high ratio was despite many narrow trough-like or v-shaped valleys with very high gradients. Most streams were single-thread channels that were moderately or entirely entrenched with low or moderate sinuosity, although

some reaches were composed of multiple channels with low sinuosity. The average stream gradient was 6.7 percent. On average, 22 percent of streams were in pools and 10 percent of banks were undercut. The average width-to-depth ratio was 7.7. Level II riparian surveys suggested degradation to channels including slight to moderate erosion, trampled banks, and incised channels. These conditions were generally attributed to diversions, livestock use, roads, and recreation. Beaver dams were present in some drainages and were generally having a stabilizing effect.

There were 140 miles of perennial streams in the Boulder Mountain unit. Of these perennial streams, R-CAT estimated 129 miles were confined and 11 miles were unconfined. R-CAT results indicated 15 percent of confined reaches were impacted. Of the unconfined reaches, 43 percent were in good condition, 38 percent were intact, 15 percent were in moderate condition, and 4 percent were in poor condition. Fifty-six percent of perennial streams displayed no change in riparian cover, with 32 percent converted to conifers. The WCF indicated less than 25 percent of historic aquatic habitats were still connected in most watersheds. All watersheds where large woody debris is an important component of riparian and aquatic systems have woody debris present and recruited at appropriate rates. Most watersheds provided evidence of increased width-to-depth ratios at 5 to 25 percent of channels and evident but limited degradation including downcutting at some reaches.

Information was available for all five channel and floodplain dynamic indicators in the Boulder Mountain unit. Two of the five indicators showed evidence of moderate alteration from the NRV: channel shape and function and percent of perennial streams with no change in riparian cover. The remaining three indicators showed little or no evidence of alteration. The overall score for channel and floodplain dynamics in the Boulder Mountain unit was 84 percent and it was considered to be **within the NRV**.

Canyon Mountains

The level of stressors to channel and floodplain dynamics in the Canyon Mountains was low. The WCF indicated that, on average, less than 10 percent of roads and trails were located within 300 feet or otherwise hydrologically connected to streams and water bodies. Streams in this unit were generally free-flowing with only minor or no alterations to natural flow regimes. While 94 percent of the unit was within a range management unit, the WCF indicated all watersheds had rangelands that were in proper functioning condition. Two riparian surveys indicated watersheds in the Canyon Mountains were impacted by past stressors, as well as some downcutting and trailing at campgrounds.

There were 10.6 floodplain acres per stream mile in the Canyon Mountains unit, which was relatively low compared to other units in the study area. There were only 13 miles of perennial streams in this unit. Of these streams, 11 miles were confined and 2 miles were unconfined. R-CAT results indicated 7 miles of the confined reaches were impacted. Of the unconfined reaches, 0.6 miles were in good condition and 1 mile was

in moderate condition. Only 4 percent of perennial streams displayed no change in riparian cover, with 37 percent converted to grasses and shrubs, 35 percent converted to conifers, and 18 percent converted to development. Habitat fragmentation was not a serious concern, with more than 95 percent of historic aquatic habitats still connected. Every watershed in this unit evolved with large wood near the streams. Large woody debris was present and continues to be recruited at natural rates throughout the unit. Lastly, on average, less than 5 percent of streams showed signs of widening. Channels tended to be vertically stable and remained connected to their floodplains.

Information was not available for the percentage of reaches in good condition with regard to streambank stability. Therefore, the overall index score for the Canyon Mountains was only based on four indicators. One indicator, channel shape and function, provided evidence of little or no alteration from the NRV. The remaining three indicators were all considered to be outside the NRV. The overall index score for the Canyon Mountains unit was 40 percent and it was considered to be **outside the NRV**.

Fishlake–Thousand Lake

The primary stressors to channel and floodplain dynamics in the Fishlake–Thousand Lake unit were recreation, diversions, dams, and grazing. There were 0.004 road miles per floodplain acre, which was relatively low compared to other units in the study area. There were 0.004 trail miles per floodplain acre, which was a moderate floodplain trail density compared to other units. There were 0.02 recreation sites per floodplain acre, which was high compared to other units. While the WCF indicated less than 10 percent of roads and trails were within 300 feet or otherwise hydrologically connected to streams and waterbodies, level II riparian surveys noted major impacts from ATV trails throughout this unit. Camping areas and ATV use were linked to degraded stream conditions in Right Fork U M, Sawmill, Sevennmile, Tasha, and U M Creeks. There were 0.005 diversions per acre, which was relatively high compared to other units. There were 0.02 dams per stream mile, which was a moderate dam density compared to other units in the study area. The WCF indicated these structures had contributed to departure in the timing, rate of change, and/or duration of mid-range discharges. Level II riparian surveys noted impacts from reservoir-altered flow regimes in Sevenmile and U M creek that included channel downcutting. Beavers were present throughout this unit and were contributing to more complex channels and stabilization in some locations. One hundred percent of the Fishlake¬–Thousand Lake unit was within a range management unit. While the WCF indicated 86 percent of watersheds had rangelands that were in proper functioning condition, level II riparian surveys noted impacts from livestock grazing including trailing, trampled banks, streambank erosion, and downcutting channels at nearly all assessed sites.

There were 77.4 floodplain acres per stream mile in the Fishlake–Thousand Lake unit, which was relatively high compared to other units in the assessment area. This high ratio reflected the presence of diverse channel

types throughout this unit. Many channels were moderately or entirely entrenched single-thread channels with moderate or low sinuosity; however, slightly entrenched highly sinuous reaches were present throughout the unit as well. Stream gradients tended to be relatively shallow, with some examples of steep sections present. On average, 24 percent of streams consisted of pool habitats and 36 percent of banks were undercut. Level II riparian surveys suggested degradation to channels include erosion, trampled banks, and incised channels. These conditions were generally attributed to livestock use and recreation including camping and ATV trails.

There were 116 miles of perennial streams in the Fishlake–Thousand Lake unit. Of these streams, R-CAT estimated 93 miles were confined and 23 miles were unconfined. R-CAT results indicated 21 percent of confined reaches were impacted. Of the unconfined reaches, 35 percent were in good condition, 30 percent were in moderate condition, 27 percent were intact, and 7 percent were in poor condition. Forty-six percent of perennial streams displayed no change in riparian cover, with 25 percent converted to conifers, 23 percent converted to grasses and shrubs, and 6 percent converted to development. The WCF indicated more than 95 percent of historic aquatic habitats were still connected. Of the 24 watersheds in the Fishlake–Thousand Lake unit, 19 evolved with large wood as a component of riparian and aquatic systems. Eighteen of these watersheds continued to have large wood present and recruited at natural rates and one watershed had large woody debris present but recruited at less than the natural rate. Lastly, according to the WCF, channels were generally vertically stable, with only isolated locations of degradation. Channels were generally connected to their floodplains where expected based on geology.

Information was available for all five channel and floodplain dynamic indicators in the Fishlake–Thousand Lake unit. Two indicators provided evidence of moderate alteration from the NRV: percentage of perennial streams with no change in riparian cover, and the percent of unconfined perennial reaches in very poor to moderate condition. The remaining three indicators provided evidence of little or no alteration from the NRV. The overall index score for channel and floodplain dynamics in the Fishlake–Thousand Lake unit was 84 percent and it was considered **within the NRV**.

Monroe Mountain

The level of stressors to channel and floodplain dynamics in the Monroe Mountain unit was low. The WCF indicated on average less than 10 percent of roads and trails are located within 300 feet or otherwise hydrologically connected to streams and water bodies. Streams in this unit were generally free-flowing with only minor or no alterations from natural flow regimes. While 91 percent of the unit was within a range management unit, the WCF indicated 91 percent of watersheds had rangelands that were in proper functioning condition. No level II riparian surveys had been completed in this unit and therefore information about local stressors was not available.

There were 8.8 floodplain acres per stream mile in the Monroe Mountain unit, which was relatively low compared to other units in the study area. Of the 169 miles of perennial streams in the unit, R-CAT estimated 162 miles were confined and 6 miles were unconfined. R-CAT results indicated 16 percent of the confined reaches were impacted. Of the unconfined reaches, 40 percent were in good condition, 32 percent were intact, 22 percent were in moderate condition, and 5 percent were in poor condition. Forty percent of perennial streams displayed no change in riparian cover, with 50 percent converted to conifers. Habitat fragmentation was not a serious concern, with more than 95 percent of historic aquatic habitats still connected. Of the 12 watersheds in the Monroe Mountain unit, 10 evolved with wood present near the stream. All but one of those watersheds had large wood present and recruited at natural rates. The remaining watershed had large wood present, but recruited at a rate less than what is expected for the system. Lastly, on average, less than 5 percent of streams showed signs of widening, channels tended to be vertically stable and remain connected to their floodplains.

Information was not available for the percentage of reaches in good condition with regard to streambank stability. Therefore the overall index score for the Monroe Mountain unit is based on four indicators. Two indicators provided evidence of moderate alteration from the NRV: the percentage of perennial streams with no change in riparian cover and the percentage of unconfined reaches in very poor to moderate condition. The remaining two indicators, channel shape and function and the percent of confined perennial streams in impacted condition, provided little or no evidence of alteration from the NRV. The overall index score for the Monroe Mountain unit was 80 percent and it was considered **within the NRV**.

Pavant Range

The primary stressors to channel and floodplain dynamics in the Pavant Range were roads and grazing. There were 0.005 road miles per floodplain acre in this unit, which was relatively low compared to other units in the study area. The WCF indicated less than 10 percent of roads were located within 300 feet or otherwise hydrologically connected to streams and waterbodies. The WCF also indicated 90 percent of watersheds have rangeland vegetation in proper functioning condition. However, riparian level II surveys indicated impacts from grazing and roads in some reaches. Livestock grazing had resulted in compacted soils, frequent headcuts, streambank erosion, and incised channels in several streams including Leavitt's Canyon, NF Corn, Middle Canyon, Pine Hollow, Second, and WF Corn Creeks. Degradation due to roads was described in the Second Creek drainage.

There were 7.3 floodplain acres per stream mile in the Pavant Range, which was less than any other unit in the assessment area. This low ratio was due to many narrow trough-like or v-shaped valleys with very high gradients. Most creeks were moderately or entirely entrenched single-thread channels with low to moderate sinuosity; however, some examples of slightly entrenched, highly sinuous reaches existed within this unit. Stream gradients

in the Pavant Range were highly variable, ranging from gently to very steep. On average 19 percent of streams consisted of pool habitats and 12 percent of banks were undercut. Level II riparian surveys suggested degradation to channels including erosion, trampled banks, and incised channels. These conditions were generally attributed to livestock use and natural reestablishment of channels following large floods.

There were 169 miles of perennial streams in the Pavant Range. Of these streams, R-CAT estimated 161 miles were confined and 7 miles were unconfined. R-CAT results indicated 13 percent of the confined reaches were impacted. Of the unconfined reaches, 51 percent were in moderate condition, 36 percent were in poor condition, 8 percent were in good condition, and 4 percent were intact. Thirty-nine percent of perennial streams displayed no change in riparian cover, with 40 percent converted to conifers and 11 percent converted to grasses and shrubs. The WCF indicated more than 95 percent of historic aquatic habitats were still connected. Of the 33 watersheds in the Pavant Range unit, 30 evolved with large wood as a component of riparian and aquatic systems. Twenty-eight of these watersheds continue to have large wood present and recruited at natural rates; two watersheds had large woody debris present but recruited at a rate less than what is natural. Lastly, according to the WCF, channels were generally vertically stable, with only isolated locations of degradation. Channels are generally connected to their floodplains as expected based on geology.

There was information available for all five indicators of channel and floodplain dynamics in the Pavant Range. One indicator, the percent of unconfined reaches in very poor to moderate condition, provided evidence of substantial alteration from the NRV. An additional indicator, percentage of perennial streams with no change in riparian cover, provided evidence of moderate alteration from the NRV. The remaining three indicators provided little or no evidence of alteration from the NRV. The overall score for channel and floodplain dynamics in the Pavant Range was 76 percent and it was considered **moderately altered from the NRV.**

Tushar Mountains

The primary stressors to channel and floodplain dynamics in the Tushar Mountains were roads, recreation, dams, diversions, and grazing. There were 0.0007 road miles per floodplain acre in this unit, which was the largest floodplain road density on the FNF and second largest of all units evaluated in this assessment. There were 0.006 trail miles per floodplain acre, which was the second largest floodplain trail density on the FNF and in this study. Finally, there were 0.02 recreation sites per floodplain acre, which was the largest floodplain recreation site density of all units in this assessment. The WCF indicated most watersheds had between 10 and 25 percent of road and trail length within 300 feet or otherwise hydrologically connected to streams and water bodies. Additionally, level II riparian surveys noted impacts from roads, trails, and recreation sites in Beaver, Dry Hollow, Jim Reed, Lousy Jim, Lower Kents, Merchant, North Fork (NF) Three, South Fork (SF) Three, Three, WF Merchant, and Wilson Canyon Creeks. Specific

issues described in level II riparian surveys included inappropriate use of ATVs, increased sedimentation from road crossings, and increased flows from roads and parking lots that were contributing to channel incision. There were 0.004 diversions per acre, which was a moderate diversion density compared to other units. There were 0.03 dams per stream mile, which was a relatively high dam density compared to other units in the study area. The WCF indicated these structures have had only minor impacts to natural flow regimes in most watersheds. However, level II riparian surveys noted impacts from diversions, dewatering, and reservoir-altered flow regimes in Beaver, Dry Hollow, Lower Kents, SF Beaver, and Three Creeks. These surveys also noted the presence of beavers in some reaches, but an overall loss in beaver had contributed to incision and bank failure in many watersheds. Ninety-nine percent of the Tushar Mountains was within a range management unit. The WCF indicated 35 percent of watersheds in the unit had rangelands with compacted soils, increased overland flow, and incised channels. Additionally, level II riparian surveys noted impacts from livestock grazing including trailing, trampled banks, streambank erosion, and incised channels in Dry Hollow, Hi Hunt, Jim Reed, Lousy Jim, Merchant, SF Beaver, SF Baker Canyon, WF Merchant, and Wilson Canyon Creeks.

There were 7.8 floodplain acres per stream mile in the Tushar Mountains, which was relatively low compared to other units in the assessment area. Most streams were entirely or moderately entrenched single-thread channels with low or moderate sinuosity. Gradients were variable, ranging from gently sloping to very steep reaches with slopes over 20 percent. Many reaches were well armored with bedrock, boulder, and cobble substrates in narrow canyon valleys. These settings resulted in several streams that were resistant to stressors such as roads and grazing. On average, 21 percent of streams were in pools and 19 percent of banks were undercut. In locations where the stream was less protected by bedrock channels and steep narrow canyons, level II riparian surveys suggested degradation to channels including narrowing and straightening for roads, dewatered reaches, deep incision, eroding banks, and active head cutting. These conditions were generally attributed to roads, ATV trails, diversions, and livestock use.

There were 359 miles of perennial streams in the Tushar Mountains. Of these streams, R-CAT estimated 321 miles were confined and 38 miles were unconfined. R-CAT results indicated 18 percent of the confined reaches were impacted. Of the unconfined reaches, 55 percent were in moderate condition, 20 percent were in good condition, 13 percent were in poor condition, 9 percent were intact, and 2 percent were in very poor condition. Only 28 percent of perennial streams displayed no change in riparian cover, with 48 percent converted to conifers, 11 percent converted to grasses and shrubs, and 9 percent converted to development. The WCF indicated more than 95 percent of historic aquatic habitats were still connected. Of the 31 watersheds in the Tushar Mountains, the WCF showed 26 evolved with large wood as a component of riparian and aquatic systems. Twenty of these watersheds continued to have large wood present and recruited at natural rates; and six

watersheds had large woody debris present but recruited at a rate less than what is natural. The WCF may underrepresent the number of watersheds that evolved with large wood, as some FNF staff believe large wood is an important component within all watersheds in the Tushar Mountains unit (Jim Whelan, USDA Forest Service, Richfield, UT, personal communication, May 20, 2020). Lastly, according to the WCF, channel degradation had occurred in limited reaches and downcutting in some locations had disconnected channels from their floodplains.

Information was available for all five indicators of channel and floodplain dynamics in the Tushar Mountains. Two of the five indicators provided evidence of substantial alteration from the NRV: the percentage of perennial streams with no change in riparian cover and the percent of unconfined perennial reaches in very poor to moderate condition. One indicator, channel shape and function, provided evidence of moderate alteration from the NRV. Lastly, two indicators showed little or no evidence of alteration from the NRV: the percentage of confined perennial streams impacted and the percentage of reaches in good condition with regard to streambank stability. The overall index score for channel and floodplain dynamics in the Tushar Mountains was 60 percent and it was considered **moderately altered from the NRV**.

White Mountain

The primary stressors to channel and floodplain dynamics in the White Mountain unit were roads and recreation. There were 0.0055 road miles per floodplain acre and 0.002 trail miles per floodplain acre. These densities were moderate compared to other units in the study area. There were 0.01 recreation sites per floodplain acre in the White Mountain unit, which was relatively high for the study area. The WCF indicated most watersheds had less than 10 percent of road and trail length within 300 feet or otherwise hydrologically connected to streams and water bodies; however, best management practices for maintenance of these features were only applied at 50 to 75 percent of roads, trails, and water crossings; mass wasting was a significant process in many watersheds. Level II riparian surveys noted impacts from drought, livestock grazing, and recreation in reaches across the White Mountain unit. Roads parallel several streams in this unit, constricting their lateral movement. Riparian surveys also described limited sediment movement due to altered flow regimes in the Lost Creek drainage, and drought throughout the unit.

There were 10.9 floodplain acres per stream mile in the White Mountain unit, which was moderate compared to other units in the assessment area. While most reaches were single-thread channels that were entirely or moderately entrenched with low to moderate sinuosity, channel forms were highly diverse throughout this unit. Many channels were steep, narrow canyons with trough-like or v-shaped valleys; however, there were reaches in the White Mountain that meandered through meadows in broad valleys. Level II riparian surveys noted wide ranges in condition, with reaches that were vulnerable to excessive erosion incised up to 40 feet. While some

streams are highly impacted by roads, reaches located within the roadless areas are generally in good condition.

There were 201 miles of perennial streams in the White Mountain unit. Of these streams, R-CAT estimated 167 miles were confined and 33 miles were unconfined. R-CAT results indicated 34 percent of the confined reaches were impacted. Of the unconfined reaches, 45 percent were in moderate condition, 25 percent were in poor condition, 20 percent were in good condition, 7 percent were intact, and 2 percent were in very poor condition. Thirty-eight percent of perennial streams displayed no change in riparian cover, with 25 percent converted to conifers, 21 percent converted to development, and 8 percent converted to grasses and shrubs. Habitat fragmentation was not a serious concern, with more than 95 percent of historic aquatic habitats remaining connected. Of the 23 watersheds in the White Mountain unit, 17 evolved with wood present near the stream. Eleven watersheds had large wood present and recruited at natural rates. Six watersheds had large wood present but recruited at a rate less than what is expected for the system. Lastly, on average, less than 5 percent of streams showed signs of widening, and channels tended to be vertically stable and remain connected to their floodplains.

Information was not available for the percentage of reaches in good condition with regard to streambank stability. Therefore the overall index score for the White Mountain unit was based on four indicators. One indicator, the percentage of unconfined perennial reaches in very poor to moderate condition, provided evidence of substantial alteration from the NRV. Two indicators, the percentage of confined perennial streams impacted and the percentage of perennial streams with no change in riparian cover, provided evidence of moderate alteration from the NRV. Lastly, channel shape and function provided little or no evidence of alteration from the NRV. The overall index score for the White Mountain unit was 60 percent and it was considered to be **moderately altered from the NRV**.

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Appendix G. Composition and Structure of Riparian and Groundwater-Dependent Ecosystems

In this section we present results for each geographic unit of the DNF and FNF. We combined spatial data and plot-level data to describe the settings of riparian ecosystems and GDEs, which largely determine the expected vegetation types. We also quantified stressors and indicators of composition and structure in each unit. We used the VCMQ existing vegetation data to categorize riparian and GDE vegetation. We clipped the VCMQ shapefile to the boundaries of the 50-year floodplain and potential fens. We also mapped VCMQ vegetation classified as riparian woody or riparian herbaceous. We combined these shapefiles to map riparian and wetland dominance groups throughout each geographic unit. We also compiled a list of riparian communities identified in level II and level III surveys for each unit.

We used results from level II and level III vegetation data collected to evaluate compositional ratings in the geographic units. Protocols differed between level II surveys conducted in the DNF and FNF. We used the forage trend variable from the FNF surveys and the seral stage variable from the DNF surveys to represent desired condition. We interpreted an upward forage trend and a late seral or potential natural community (PNC) rating as indicators that stream segments were in desired condition. Whether or not a site was in desired condition was determined during level III surveys in both Forests, based on the percentage of greenline vegetation classified as late seral. In most cases, level II surveys were recorded on one occasion at each study reach. Level III sites are remeasured every 5 years, with dates of initial measurement and subsequent measurements varying among the sites. For this analysis, we examined desired condition status during the most recent measurement and the previous measurement.

To determine whether conditions are within the NRV, moderately altered, or outside of the NRV in each unit, we examined the data described above and then considered the following:

1. Are expected riparian vegetation dominance groups present?
2. Do the ratings of riparian plant composition reflect desired functioning conditions?
3. Does remotely sensed riparian vegetation match the expected natural conditions along most stream segments?
4. Are stressors few, local, and reversible?
5. Is there evidence that anthropogenic effects are improving?

We used these questions to calculate a composition and structure index score. We gave "yes" answers a score of 1 and "no" answers a score of 0. If the total score was 4 to 5, we determined that the composition and structure of riparian vegetation is **within** the NRV; if the score was 3 to 2, we determined that composition and structure is **moderately altered**; and if the score was 0 to 1, we determined that composition and structure is **outside** of the NRV.

Unit Summaries

Escalante

Settings

Perennial streams are present throughout the Escalante unit. An estimated 82 percent of perennial reaches are confined. Vegetation was measured at 43 level II survey reaches in 1994 and 1995 and at 71 level III survey sites from 2005 to 2018. There was some beaver activity, but no active dams observed during level II surveys. Beaver activity was noted at Durfey Creek during level III surveys. This unit contains numerous springs and groundwater-fed wetlands, including several likely fens.

Dominance Groups

Within the 50-year floodplain, 32 percent of VCMQ-mapped vegetation is dominated by conifers, 22 percent by upland shrubs, 20 percent by upland woodland species, 16 percent by woody riparian species, and 5 percent by herbaceous plants (fig. G.1). Level II and level III surveys indicated that community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, nonwillow shrubs, tall deciduous trees, and tall willows (table G.1). GDEs were surveyed in 2013, 2014, and 2015, using a modified version of the level I methodology. Graminoids were ranked as the dominant vegetation at 85 percent of the GDEs, followed by forbs (7 percent), shrubs (6 percent), aquatic plants (3 percent), bryophytes (2 percent), and trees (2 percent). Score: 1

Vegetation Ratings

During level II surveys, 47 percent of reaches were rated as late seral or potential natural community, a moderate percentage. During the most recent level III surveys, 64 percent of sites were in desired condition, also a moderate percentage. Score: 1

Conversion

According to R-CAT results, vegetation along most (54 percent) perennial stream miles has departed from the expected composition and structure. Conifer encroachment is the most frequent cause of conversion. Score: 0

Stressors

During level II surveys, noted stressors were dams, diversions, roads, road crossings, ATVs, eroding trails, timber harvest, and livestock grazing, beaver removal, and invasive species including *Cirsium arvense*. Density of diversions is moderate, at 0.003 per acre. Floodplain road density is relatively high, at 0.01 miles per acre. Wildfire hazard potential is high or very high within 26 percent of the 50-year floodplain, a moderate percentage.

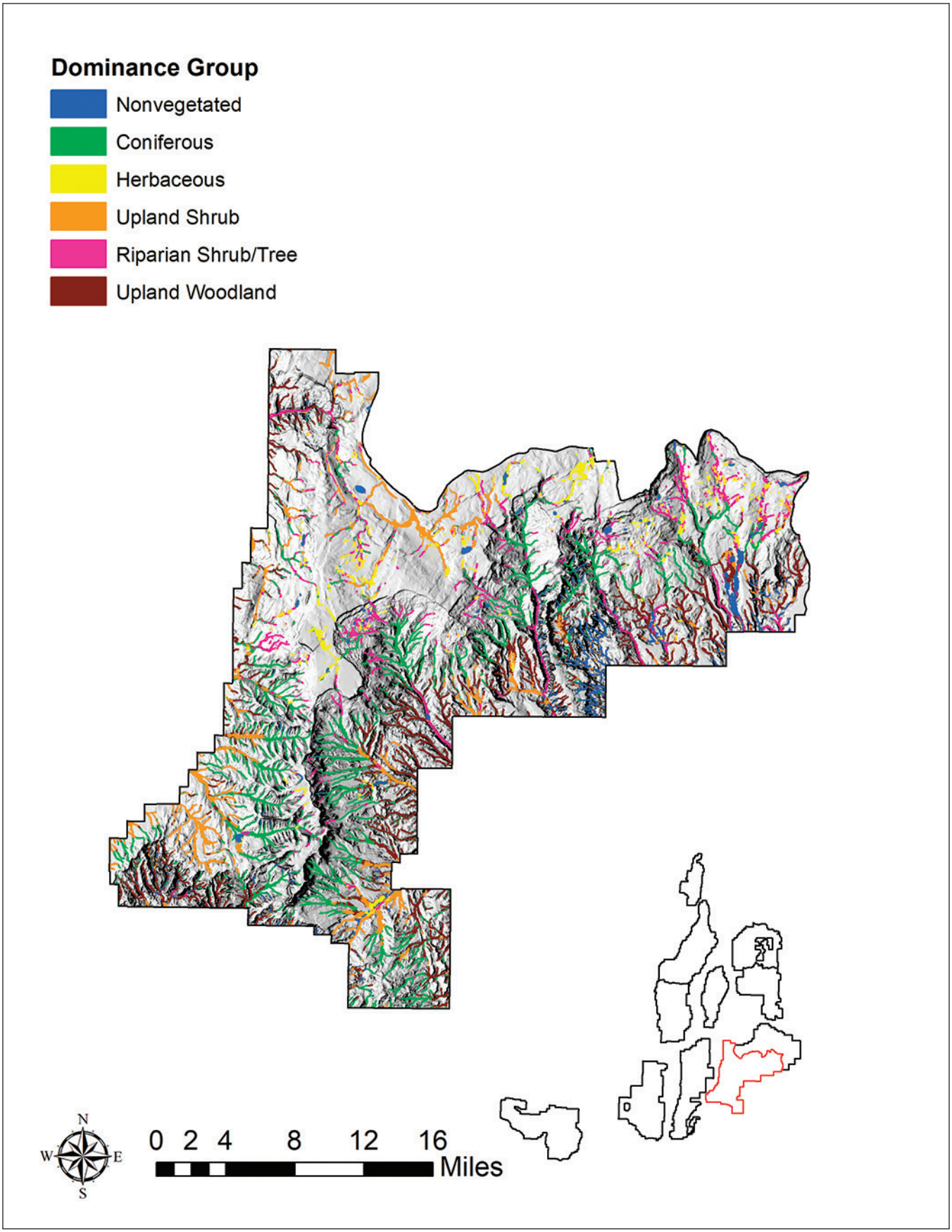


Figure G.1— Riparian dominance groups in the Escalante geographic unit.

Table G.1—Vegetation communities within the riparian dominance groups observed during level II and level III measurements in the Escalante geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Aconitum columbianum*
	Conifer/*Betula occidentalis*
	Conifer/*Equisetum arvense,*
	Conifer/Mesic Forb
	Conifer/*Poa pratensis*
	Conifer/Tall Forb
	Misc. Conifer
Tall deciduous tree	*Populus angustifolia/ Betula occidentalis*
	Populus angustifolia/Cornus sericea
	*Populus angustifolia/*Herbaceous
	Populus tremuloides/ Betula occidentalis
	*Populus tremuloides/*Mesic Forb
	Populus tremuloides/Rosa spp.
	Populus tremuloides/Salix spp.
Low deciduous tree	*Betula occidentalis/*Bench
	Betula occidentalis/Cornus sericea
	Betula occidentalis/ Equisetum arvense
	Betula occidentalis/ Mesic Graminoid
	Betula occidentalis/Poa pratensis
	Betula occidentalis/Salix lutea

Dominance group	Communities
Tall willow	*Salix boothii/*Mesic Forb
	*Salix Boothii/*Mesic Graminoid
	Salix boothii/Poa pratensis
	Salix drummondiana
	Salix drummondiana/Poa pratensis
	*Salix geyeriana/*Mesic Graminoid
	Salix exigua /Mesic Forb
	Salix exigua/ Poa pratensis
	Salix exigua/Rosa woodsii
	Salix monticola/Carex aquatilis
Nonwillow shrub	Upland Shrubs/Grasses
	Rosa woodsii
Herbaceous	*Agrostis stolonifera*
	Carex aquatilis
	Carex microptera
	Carex nebrascensis
	Carex pellita
	Catabrosa aquatica
	Deschampsia cespitosa
	Equisetum spp.
	Equisetum arvense
	Juncus arcticus
	Juncus ensifolius
	Misc. Graminoid
	Poa pratensis

Between 1984 and 2014, 1 percent of 50-year floodplain area was affected by moderate to high severity wildfire, also a moderate percentage. Several of the community types observed (Conifer/*Poa pratensis*, *Betula occidentalis*/*Poa pratensis*, *Salix boothii*/*Poa pratensis*, *Salix exigua*/*Poa pratensis*, *Salix exigua*/*Rosa woodsia*, *Rosa woodsii*, *Agrostis stolonifera*, *Carex nebrascensis*, *Juncus arcticus*, *Poa pratensis*) are indicative of heavy livestock use (Hansen et al. 1995).

Diversions were present at 10 percent of the GDEs surveyed from 2013 to 2015. Pollution (primarily livestock manure) was observed at 20 percent of the sites. Forms of soil alteration, such as channel erosion, compaction, ground disturbance, pedestals, and soil mixing, were observed at 93 percent of the sites. Impacts of recreation were observed at 3 percent. Soil integrity was maintained at 68 percent of sites and vegetation was considered healthy at 79 percent. Animal effects (wild ungulates, beavers, livestock) were observed at 98 percent; livestock effects were observed at 81 percent.
Score: 0

Improvement

There are numerous stressors affecting riparian ecosystems and GDEs in this geographic unit. Among level III sites that have been remeasured, conditions improved to desired at 7 of 58 sites and declined from desired at 3 sites. These results suggest that there has been improvement in conditions brought upon by these stressors. Score: 1

The composition and structure score is 3, indicating that the Escalante geographic unit is **moderately altered** from the NRV.

Markagunt Plateau

Settings

Perennial stream segments are present throughout the Markagunt Plateau. An estimated 75 percent of perennial stream reaches are confined. Riparian vegetation was measured at 59 level II survey reaches in 1994 and 1995 and at 111 level III survey sites from 2004 to 2018. During recent level III surveys, beaver activity was noted at Panguitch Creek, Duck Creek, and Caddy Creek. This unit contains numerous springs and groundwater-fed wetlands, including several likely fens.

Dominance Groups

Within the 50-year floodplain, 28 percent of VCMQ-mapped vegetation is dominated by conifers, 26 percent by upland shrubs, 22 percent by herbaceous plants, 8 percent by woody riparian species, and 7 percent by upland woodland species (fig. G.2). Level II and level III surveys indicated that community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, low willows, nonwillow shrubs, tall deciduous trees, and tall willows (table G.2). Score: 1

Vegetation Ratings

During level II surveys, 46 percent of reaches were rated as late seral or PNC, a moderate percentage. During the most recent level III surveys, 73 percent of sites were in desired condition, a relatively high percentage. Score: 1

Conversion

According to R-CAT results, vegetation along most (67 percent) perennial stream miles has departed from the expected composition and structure. Conifer encroachment, upland encroachment, and development are the most frequent causes of conversion. Score: 0

Stressors

Diversion density is relatively high, at 0.01 per acre. Floodplain road density is high as well, at 0.007 miles per acre. Wildfire hazard potential is high or very high within 26 percent of the 50-year floodplain, a moderate percentage. Between 1984 and 2014, 1 percent of 50-year floodplain area was affected by moderate to high severity wildfire, a relatively low percentage. During level II, surveys noted stressors were diversions, dams, water pollution, livestock use, wildfire, campsites, and other forms of recreation. Invasive species include *Cynoglossum officinale*, *Carduus nutans*, and *Sonchus arvenis*. Several of the community types observed (Conifer/

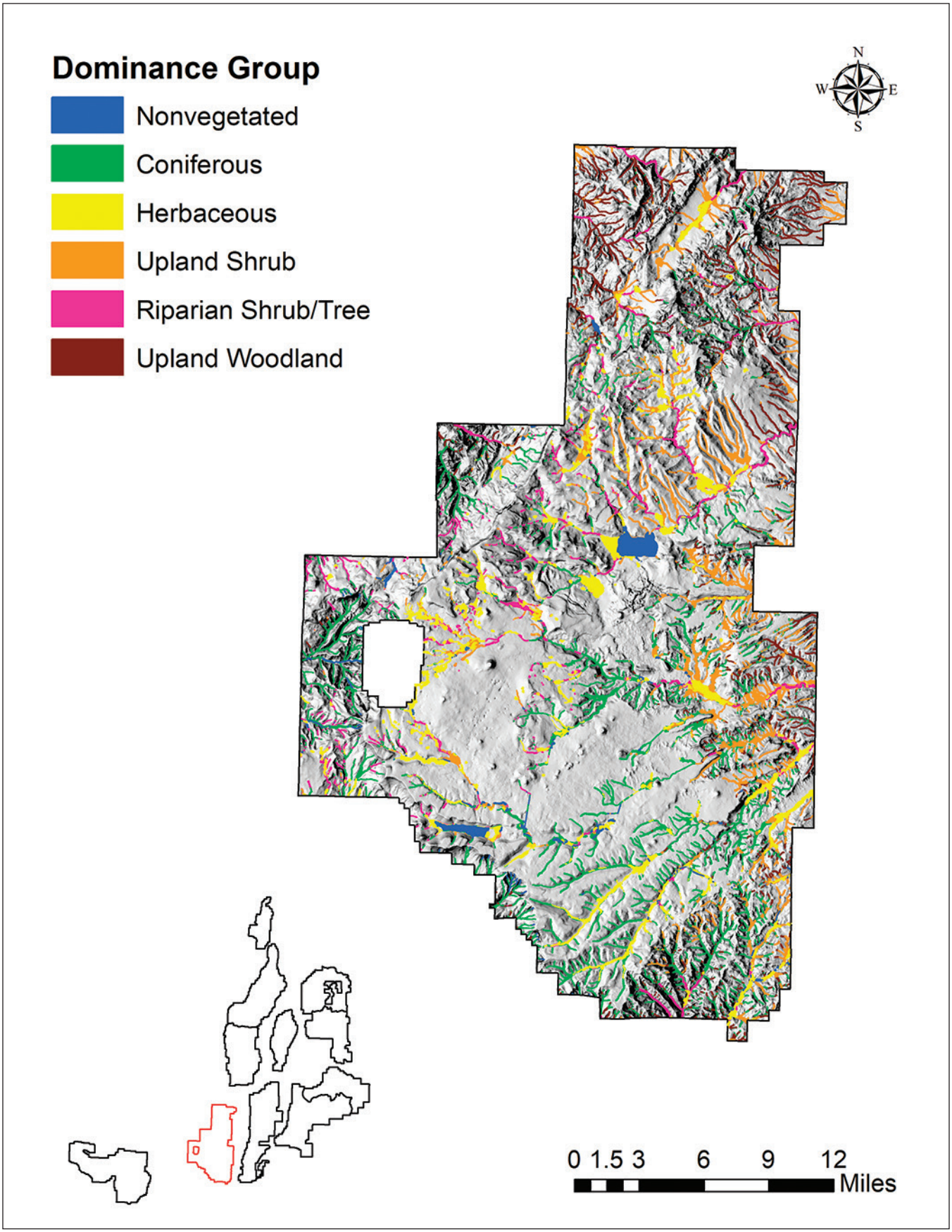


Figure G.2—Riparian dominance groups in the Markagunt Plateau geographic unit.

Table G.2—Vegetation communities within the riparian dominance groups observed during level II and level III measurements in the Markagunt Plateau geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Aconitum columbianum*
	Conifer/*Cornus sericea*
	Conifer/*Equisetum arvense*
	Conifer/Mesic Forb
	Conifer/*Poa pratensis*
	Misc. Conifer
Tall deciduous tree	*Populus angustifolia*
	Populus angustifolia/Cornus sericea
	*Populus angustifolia/*Herbaceous
	Populus angustifolia/Poa pratensis
	Populus tremuloides/Poa pratensis
	Populus tremuloides/Rosa woodsii
	Populus tremuloides/Salix spp.
	*Populus tremuloides/*Tall Shrub
Low deciduous tree	*Betula occidentalis/ Equisetum arvense*
	*Betula occidentalis/*Mesic Graminoid
Tall willow	*Salix boothii/Carex aquatilis*
	*Salix boothii/*Mesic Forb
	*Salix boothii/*Mesic Graminoid
	*Salix exigua/*Mesic Graminoid
	Salix spp./*Mesic Graminoid*
Low willow	Low willow/Unclassified

Dominance group	Communities
Nonwillow shrub	*Artemisia cana/Festuca ovina*
	Artemisia tridentata
	Dasiphora fruticosa/ Deschampsia cespitosa
	Shrub/Unclassified
	Upland Shrubs/Grasses
Herbaceous	*Aconitum columbianum*
	Agrostis stolonifera
	Bromus inermis
	Carex aquatilis
	Carex aquatilis-Carex nebrascensis
	Carex microptera
	Carex pellita
	Carex utriculata
	Cardamine cordifolia
	Deschampsia cespitosa
	Equisetum spp.
	Equisetum arvense
	Juncus arcticus
	Misc Graminoid
	Phleum pratense
	Poa pratensis
	Tall Forb

Poa pratensis, *Populus angustifolia*/*Poa pratensis*, *Populus tremuloides*/*Poa pratensis*, *Populus tremuloides*/*Rosa woodsia*, *Agrostis stolonifera*, *Bromus inermis*, *Juncus arcticus*, *Poa pratensis*) are indicative of heavy livestock use (Hansen et al. 1995). Score: 0

Improvement

There are numerous stressors affecting riparian ecosystems in this geographic unit. Among level III sites that have been remeasured, conditions improved to desired at 6 of 76 sites remeasured but declined from desired at 7 sites. Overall, there is little evidence for improvement in conditions brought upon by stressors. Score: 0

The composition and structure score is 2, indicating that the Markagunt Plateau geographic unit is **moderately altered** from the NRV.

Paunsaugunt–Mt. Dutton

Settings

Perennial stream segments are present throughout the unit. An estimated 66 percent of perennial stream reaches are confined. Riparian vegetation was measured at 65 level II survey reaches in 1994 and 1995 and 64 at level III survey sites from 2004 to 2018. During recent level III surveys, beaver activity, including large ponds, was noted at Sieler Meadows on the Paunsaugunt Plateau. Activity was also noted at Deer Creek on the Sevier Plateau. There are springs throughout the unit and groundwater-fed wetlands in the southern portion, including some likely fens.

Dominance Groups

Within the 50-year floodplain, 45 percent of VCMQ-mapped vegetation is dominated by upland shrubs, 24 percent by conifers, 12 percent by upland woodland species, 10 percent by herbaceous plants, and 8 percent by woody riparian species (fig. G.3). Level II and level III surveys indicated that community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, low willows, nonwillow shrubs, tall deciduous trees, and tall willows (table G.3). Score: 1

Vegetation Ratings

During level II surveys, 32 percent of reaches were rated as late seral or PNC, a relatively low percentage. However, during recent level III measurements, 70 percent of sites were in desired condition, a moderate percentage. Score: 1

Conversion

According to R-CAT results, vegetation along most (70 percent) perennial stream miles has departed from the expected composition and structure. Upland encroachment, conifer encroachment, and invasive species are the most frequent causes of conversion. Score: 0

Stressors

Density of diversions is 0.001, among the lowest of the geographic units. Floodplain road density is relatively high, at 0.006 miles per acre. Wildfire hazard potential is high or very high within 27.3 percent of the 50-year floodplain, a moderate percentage. Between 1984 and 2014, 6.2 percent of 50-year floodplain area was affected by moderate to high severity wildfire, also a moderate percentage. Noted stressors were diversions, earthen dams, livestock grazing, campsites, roads, road crossings, willow browsing, and eroding trails. On the Paunsaugunt Plateau, willows have been replaced by nonnative forage grass in areas along East Fork Sevier River, perhaps for range improvement. Robinson et al. (1998) also note loss of willows in this area. Invasive species included *Cirsium vulgare* and *Cirsium arvense*. Several of the community types observed (*Populus angustifolia*/*Poa pratensis*, *Populus tremuloides*/*Poa pratensis*, *Populus tremuloides*/*Rosa woodsia*, *Rosa woodsia*, *Agrostis stolonifera*, *Carex nebrascensis*, *Juncus arcticus*, *Poa pratensis*) are indicative of heavy livestock use (Hansen et al. 1995). Score: 0

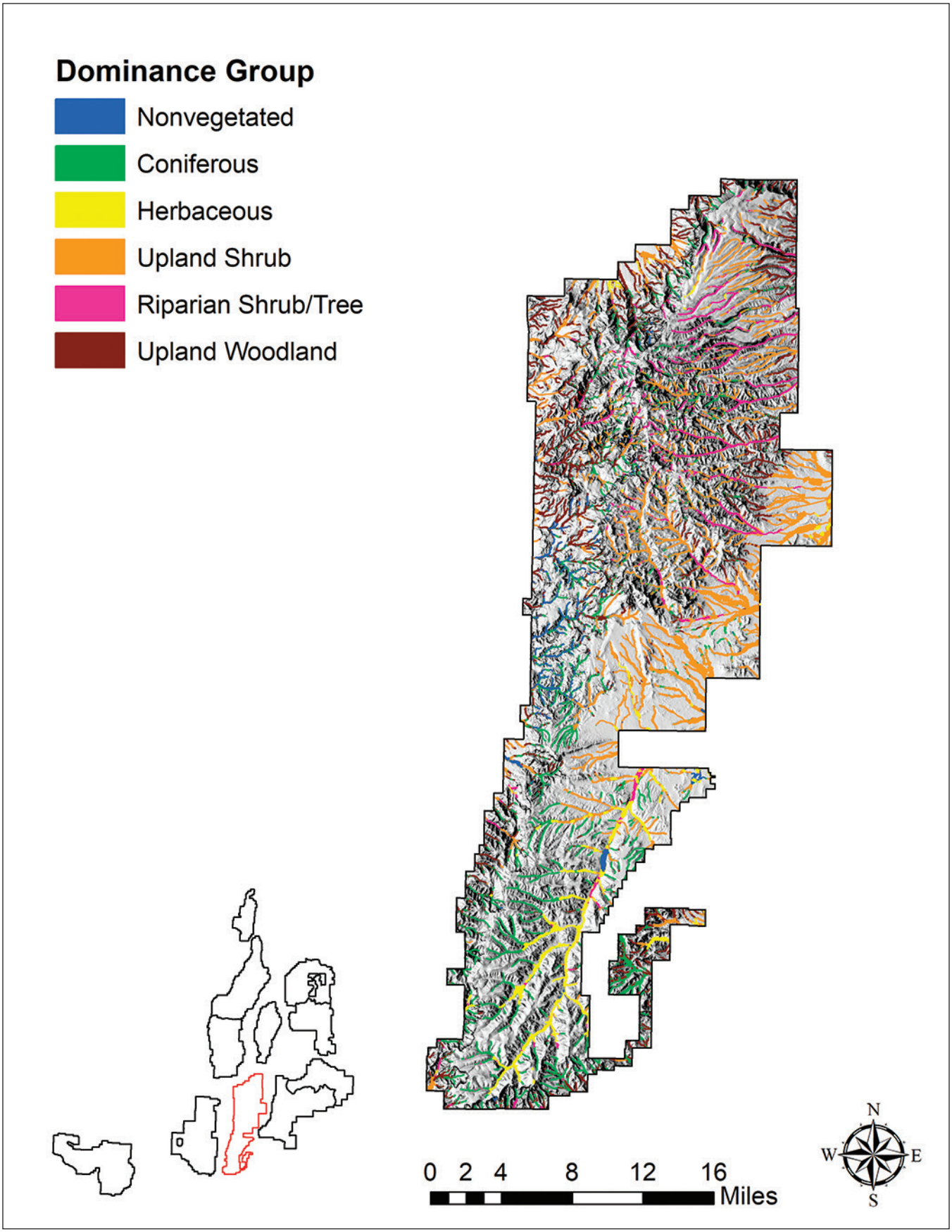


Figure G.3—Riparian dominance groups in the Paunsaugunt–Mt. Dutton geographic unit.

Table G.3—Vegetation communities within the riparian dominance groups observed during level II and level III measurements in the Paunsaugunt–Mt. Dutton geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Equisetum arvense*
	Conifer/*Mesic Forb*
	Conifer/*Tall Forb*
	Misc. Conifer
	Juniperus scopulorum
Tall deciduous tree	*Populus angustifolia/ Betula occidentalis*
	Populus angustifolia/ Cornus sericea
	Populus angustifolia/ Herbaceous
	Populus angustifolia/Poa pratensis
	*Populus tremuloides/*Dry Graminoid
	*Populus tremuloides/*Mesic Forb
	Populus tremuloides/Poa pratensis
	Populus tremuloides/Rosa woodsii
Low deciduous tree	*Betula occidentalis/*Bench
Tall willow	*Salix boothii/*Mesic Forb
	*Salix boothii/*Mesic Graminoid
	*Salix exigua/*Mesic Graminoid
	*Salix lutea/*Mesic Graminoid
Low willow	*Low Salix* spp./Mesic Graminoid
Nonwillow shrub	*Chrysothamus/Rosa* spp.
	Rosa woodsii
Herbaceous	*Agrostis stolonifera*
	Carex aquatilis
	Carex nebrascensis
	Carex pellita
	Carex utriculata
	Deschampsia cespitosa
	Festuca pratensis
	Juncus arcticus
	Misc. Forb
	Phalaris arundinacea
	Poa pratensis
	Tall Forb

Improvement

There are numerous stressors affecting riparian ecosystems in this geographic unit. Among level III sites that have been remeasured, conditions improved to desired at 3 of 40 sites remeasured and declined from desired at 2. Overall, there is some evidence for improvement in conditions brought upon by stressors. Score: 1

The composition and structure score is 3, indicating that the Paunsaugunt–Mt. Dutton geographic unit is **moderately altered** from the NRV.

Pine Valley

Settings

An estimated 79 percent of perennial stream reaches are confined. Perennial stream segments are most abundant on the western portion of the unit. Riparian vegetation was measured at 99 level II survey reaches in 1994 and 1995 and at 63 level III surveys from 2004 to 2018. Active beaver dams were observed at Leeds Creek and the Santa Clara River during level II surveys in 1994 and 1995. Beaver activity was noted as prevalent during a recent level III survey at Pine Park Canyon. This unit contains numerous springs, but few groundwater-fed wetlands.

Dominance Groups

Within the 50-year floodplain, 49 percent of VCMQ-mapped vegetation is dominated by upland woodland species, 26 percent by upland shrubs, 9 percent by herbaceous plants, 8 percent by woody riparian species, and 3 percent by conifers (fig. G.4). Level II and level III surveys indicated that community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, nonwillow shrubs, tall deciduous trees, and tall willows (table G.4). Score: 1

Vegetation Ratings

During level II surveys, 39 percent of reaches were rated as late seral or PNC, a relatively low percentage. During the most recent level III surveys, 52 percent of sites were in desired condition, also a low percentage. Score: 0

Conversion

According to R-CAT results, vegetation along most (74 percent) perennial stream miles has departed from the expected composition and structure. Conifer encroachment and upland encroachment are the most frequent causes of conversion. Score: 0

Stressors

Pine Valley has the highest density of diversions of any unit (0.019 per acre). Diversions are scattered across the unit and most dams are in the northern portion. Floodplain road density is moderate, at 0.005 miles per acre. Wildfire hazard potential is high or very high within 81 percent of the 50-year floodplain, a relatively high percentage. Between 1984 and 2014, 7.4 percent of 50-year floodplain area was affected by moderate to high severity wildfire, also a high percentage. Noted stressors include numerous dams and diversions, water pollution, roads, livestock grazing, fences crossing streams, eroding trails, wildfire, grazing and fire interactions, willow decline, campsites, and other forms of recreation. Invasive species include *Bromus tectorum*, *Onopordum acanthium*, *Arctium minus*, *Cirsium arvense*, and *Cirsium vulgare*. Several of the community types observed (Conifer/*Poa pratensis*, *Populus angustifolia*/*Rosa woodsia*, *Betula occidentalis*/*Poa pratensis*, *Salix* spp./*Juncus arcticus*, *Rosa woodsii*, *Carex nebrascensis*, *Juncus arcticus*, *Poa pratensis*) are indicative of heavy livestock use (Hansen et al. 1995). Score: 0

Improvement

There are numerous stressors affecting riparian ecosystems in this geographic unit. Among level III sites that have been remeasured. Conditions improved to desired at 5 of 55 sites remeasured but declined from desired at 6. Overall, there is little evidence for improvement in conditions brought upon by stressors. Score: 0

The composition and structure score is 1, indicating that the Pine Valley geographic unit is **outside** of the NRV.

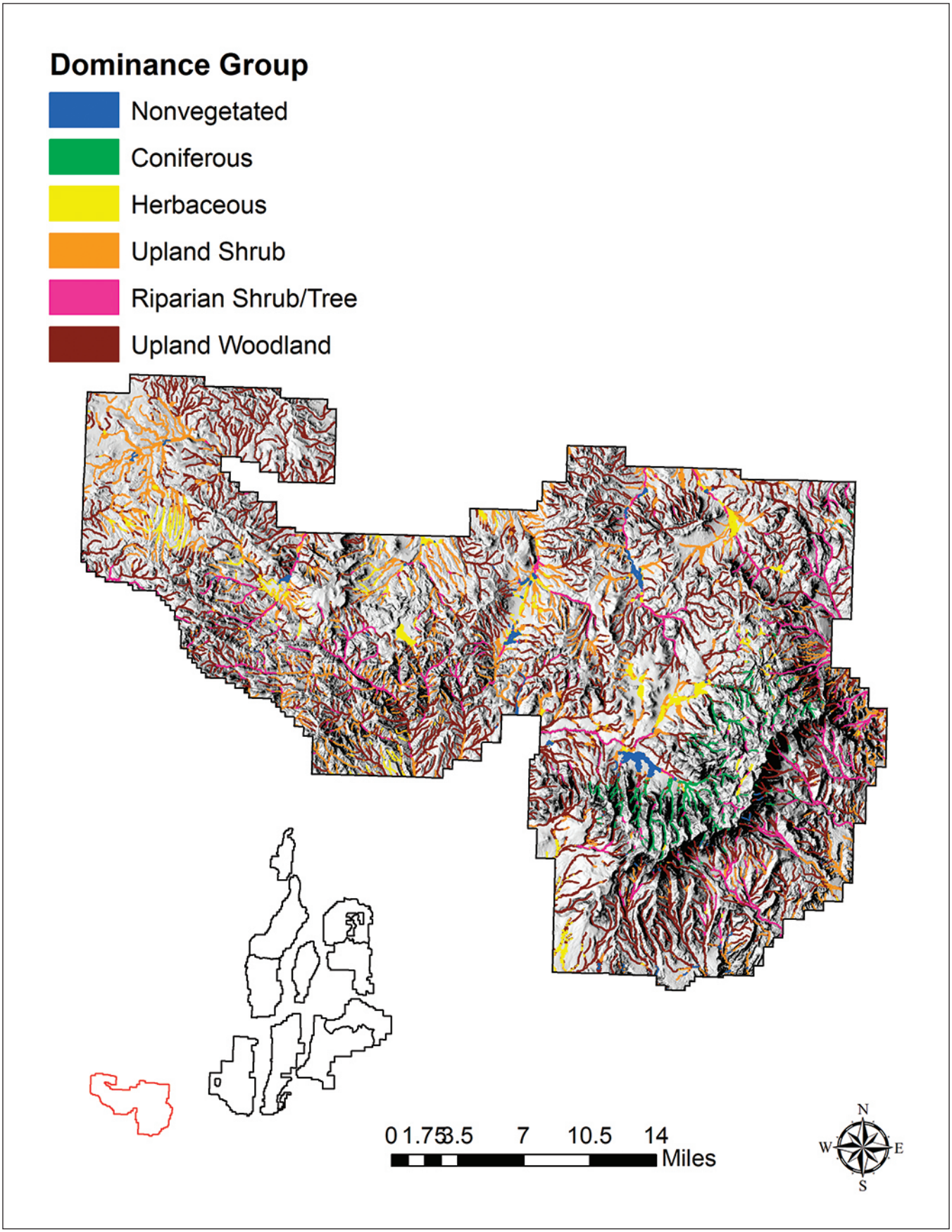


Figure G.4—Riparian dominance groups in the Pine Valley geographic unit.

Table G.4—Vegetation communities within the riparian dominance groups observed during level II and level III measurements in the Pine Valley geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Aconitum columbianum*
	Conifer/*Betula occidentalis*
	Conifer/*Poa pratensis*
Tall deciduous tree	*Acer negundo/Cornus sericea*
	Acer negundo/Equisetum arvense
	Misc. Tall Deciduous Tree
	Populus angustifolia/ Betula occidentalis
	Populus angustifolia/Cornus sericea
	*Populus angustifolia/*Herbaceous
	Populus angustifolia/Rosa woodsii
	Populus fremontii/ Salix drummondiana
	Populus tremuloides/ Betula occidentalis
	Populus tremuloides/Cornus sericea
	Populus spp./*Salix* spp.
Low deciduous tree	*Alnus incana/Cornus sericea*
	Betula occidentalis/Cornus sericea
	Betula occidentalis/ Equisetum arvense
	*Betula occidentalis/*Mesic Forb
	*Betula occidentalis/*Mesic Graminoid
	Betula occidentalis/Poa pratensis
	Salix boothii/Equisetum arvense
Tall willow	*Salix drummondiana*
	*Salix exigua/*Barren
	*Salix exigua/*Mesic Graminoid
	Salix spp./*Juncus arcticus*
	*Salix lucida/*Barren
	*Salix lutea /*Bench
	*Salix lutea/*Barren
	*Salix lutea/*Mesic Graminoid
	Salix lutea/Rosa woodsii
Nonwillow shrub	*Chilopsis linearis*
	Prunus virginiana
	Rosa woodsii
	Upland Shrubs/Grasses
Herbaceous	*Carex aquatilis*
	Carex nebrascensis
	Deschampsia cespitosa
	Equisetum
	Festuca pratensis
	Hordeum jubatum
	Juncus arcticus
	Mertensia arizonica
	Misc. Graminoid
	Poa pratensis

Boulder Mountain

Settings

An estimated 92 percent of perennial stream reaches are confined. Perennial stream segments are present on the north and eastern slopes of the plateau. Riparian vegetation was measured at 52 level II surveys reaches in 1994 and 1995 and at 31 level III survey sites from 2004 to 2018. Active beaver colonies were noted at Fish Creek and Pine Creek in 1994 and 1995, respectively. Beaver activity was not noted during the most recent level III surveys. This unit contains several springs and numerous groundwater-fed wetlands, including many likely fens.

Dominance Groups

Within the 50-year floodplain, 24 percent of VCMQ-mapped vegetation is dominated by upland shrubs, 22 percent by herbaceous plants, 18 percent by upland woodland species, 16 percent by conifers, and 16 percent by woody riparian species (fig. G.5). Level II and level III surveys indicated that community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, low willows, tall deciduous trees, and tall willows (table G.5). Score: 1

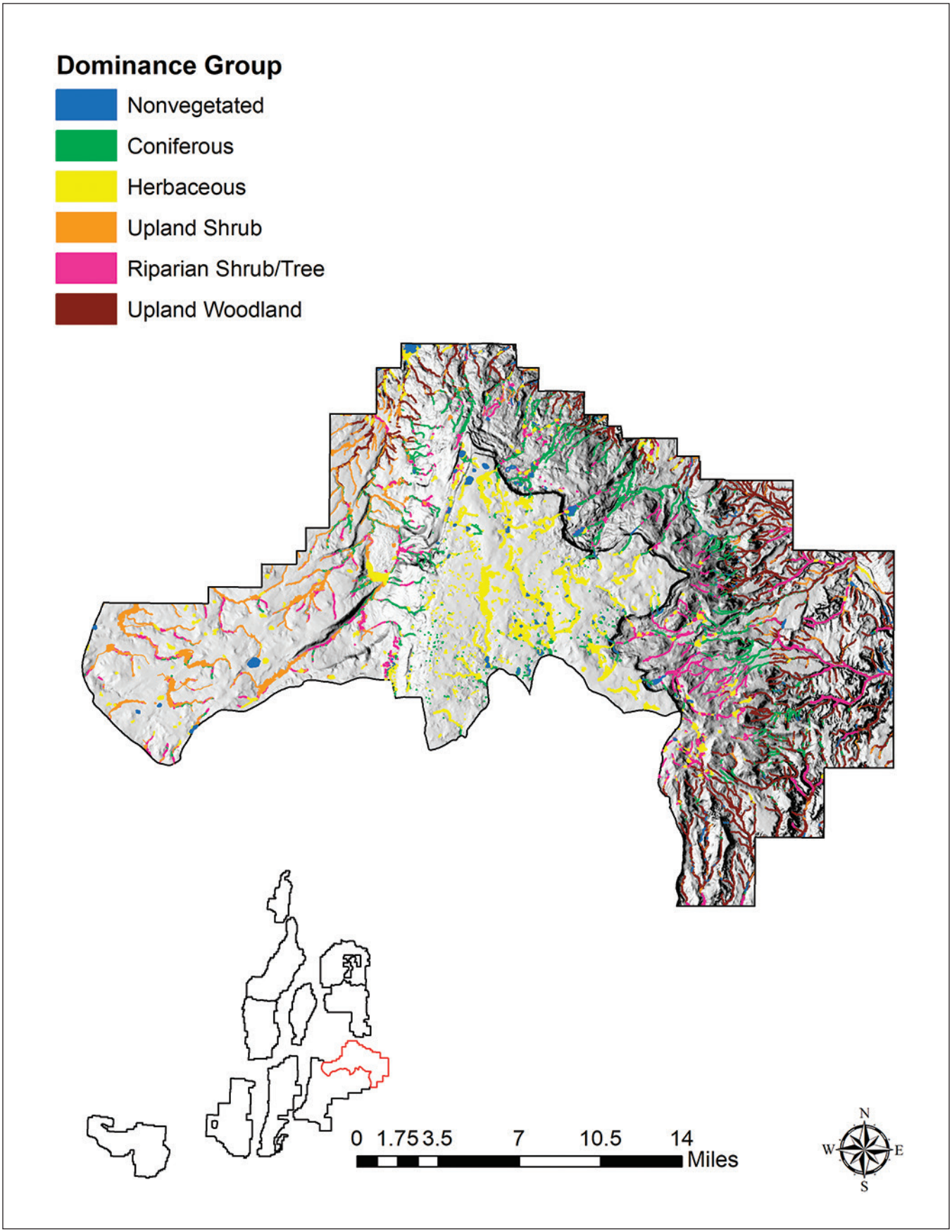


Figure G.5—Riparian dominance groups in the Boulder Mountain geographic unit.

Table G.5—Vegetation communities within the riparian dominance groups observed during level II and level III measurements in the Boulder Mountain geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Aconitum columbianum*
	Conifer/*Actaea rubra*
	Conifer/*Cornus sericea*
	Conifer/*Equisetum arvense*
	Conifer/Mesic Forb
	Conifer/*Poa pratensis*
	Misc. Conifer
Tall deciduous tree	*Populus angustifolia*/ *Betula occidentalis*
	Populus tremuloides/ *Betula occidentalis*
	Populus tremuloides/Poa pratensis
	Populus tremuloides/Salix spp.
	Populus tremuloides/Tall Shrub
Low deciduous tree	*Betula occidentalis/Cornus sericea*
	Betula occidentalis/ *Equisetum arvense*
	Betula occidentalis/Mesic Forb
	Betula occidentalis/Mesic Graminoid
	Betula occidentalis/Rosa woodsii
Tall willow	Misc. Willow/Mesic Graminoid
	Salix bebbiana/Mesic Graminoid
	Salix boothii/Carex nebrascensis
	Salix boothii/Mesic Graminoid
	Salix boothii/Poa pratensis
	Salix exigua/Barren
	Salix exigua/Mesic Graminoid
	Salix exigua/Rosa woodsii
Low willow	*Salix planifolia/Carex aquatilis*
Herbaceous	*Carex* spp.
	Carex aquatilis
	Carex nebrascensis
	Carex utriculata
	Juncus arcticus
	Misc. Graminoid
	Poa pratensis
	Scirpus americanus

Vegetation Ratings

During level II surveys, 60 percent of sites were rated as late seral or PNC, the greatest percentage of any unit. During the most recent level III measurements, 74 percent of sites were in desired condition, a relatively high percentage. Score: 1

Conversion

According to R-CAT results, vegetation along most (56 percent) perennial stream miles has not departed from the expected composition and structure. Score: 1

Stressors

Density of diversions is moderate, at 0.003 per acre. Floodplain road density is among the lowest of any unit, at 0.004 miles per acre. Wildfire hazard potential is high or very high within 14.1 percent of the 50-year floodplain, the lowest of any unit. Between 1984 and 2014, 0.4 percent of 50-year floodplain area was affected by moderate to high severity wildfire, a relatively low percentage. Noted stressors included ATVs and other recreation, timber harvest, livestock grazing, beaver removal, dams, and diversions. Fire suppression has led to conifer encroachment onto wet meadows (Hall 1971). Several of the community types observed (Conifer/*Poa pratensis*, *Populus tremuloides*/*Poa pratensis*, *Betula occidentalis*/*Rosa*

woodsii, *Salix boothii*/*Carex nebrascensis*, *Salix boothii*/*Poa pratensis*, *Salix exigua*/*Rosa woodsii*, *Carex nebrascensis*, *Juncus arcticus*, *Poa pratensis*) are indicative of heavy livestock use (Hansen et al. 1995). Score: 0

Improvement

There are multiple stressors affecting riparian ecosystems in this geographic unit. Among level III sites that have been remeasured two sites of 20 sites remeasured declined from desired conditions. Overall, there is little evidence for improvement in conditions brought upon by stressors. Score: 0

The composition and structure score is 3, indicating that the Boulder Mountain geographic unit is **moderately altered** from the NRV.

Canyon Mountains

Settings

An estimated 90 percent of perennial stream reaches are confined. In this arid range, perennial stream segments are limited to the western slope. Riparian vegetation was measured at 21 level II survey reaches in the Oak Creek Watershed in 2004. There were no signs of beaver activity noted during these surveys. This unit contains several springs, but groundwater-fed wetlands are few and relatively small. Extensive carbonate bedrock creates potential for karst development on the eastern and western slopes.

Dominance Groups

Within the 50-year floodplain, 50 percent of VCMQ-mapped vegetation is dominated by herbaceous plants, 38 percent by upland woodland species, 10 percent by upland shrubs, only 2 percent by woody riparian species, and less than 1 percent by conifers (fig. G.6). Conifer-, Tall deciduous tree-, and graminoid-dominated community types were observed at level II sites (table G.6). Score: 0

Vegetation Ratings

In the one watershed measured for level II surveys, 95 percent of reaches had a stable or upward forage trend, the highest percentage of any unit. Score: 1

Conversion

According to R-CAT results, vegetation along most (96 percent) perennial stream miles has departed from the expected composition and structure. Conifer encroachment, upland encroachment, and development are the most frequent causes of conversion. Score: 0

Stressors

Density of diversions is moderate, at 0.002 per acre. Floodplain road density is relatively high, at 0.006 miles per acre. Wildfire hazard potential is high or very high within 84.8 percent of the 50-year floodplain, a greater percentage than other geographic units. Between 1984 and 2014, 31.8 percent of the 50-year floodplain area was affected by moderate to high severity wildfire, a much greater percentage than at other units. During recent visits, it was noted that riparian vegetation along Oak Creek had been sprayed with herbicide to enhance water conveyance (Swensen and Kelly 2016). Despite fencing, livestock have access to the perennial portions of the creek. Current

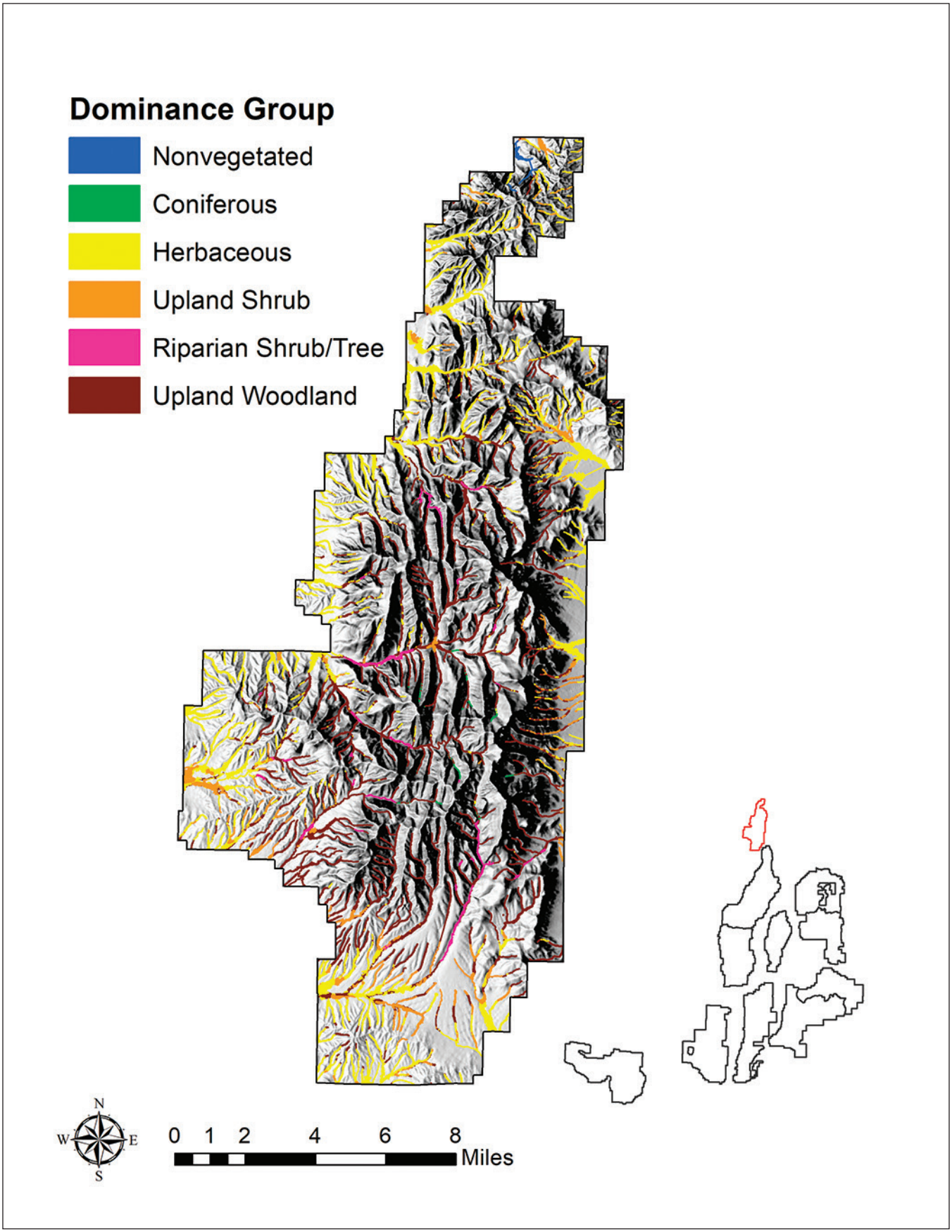


Figure G.6—Riparian dominance groups in the Canyon Mountains geographic unit.

Table G.6—Vegetation communities within the riparian dominance groups observed during level II measurements in the Canyon Mountains geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Deschampsia cespitosa*
	Conifer/*Equisetum arvense*
	Misc. Conifer
Tall deciduous tree	Misc. Tall Deciduous Tree
	Populus angustifolia/Cornus sericea
	Populus angustifolia/Poa pratensis
Herbaceous	*Deschampsia cespitosa*
	Mesic Graminoid

conditions are also affected by the Clay Springs wildfire, which burned 70 percent of the Canyon Mountains unit in 2012. Noted stressors were road crossings, culverts, beaver removal, and legacy of past overgrazing. The observed *Populus angustifolia*/*Poa pratensis* community type is indicative of heavy livestock use (Hansen et al. 1995). Score: 0

Improvement

There are numerous stressors affecting riparian ecosystems in this geographic unit. Based on recent site visits, condition of riparian vegetation appears to have declined since level II data were collected. Score: 0

The composition and structure score is 1, indicating that the Canyon Mountains geographic unit is **outside** of the NRV.

Fishlake–Thousand Lake

Settings

In this unit, most perennial stream segments are associated with the Fremont River and U M Creek watersheds near the Fishlake–Hightop Plateau. An estimated 80 percent of perennial stream reaches in the unit are confined. Riparian vegetation was measured at 194 level II surveys reaches. Reaches were measured in the Fishlake–Hightop area in 2002 and 2004; and along Sand Creek near the Thousand Lake Plateau in 2006. Riparian vegetation was also measured at 26 level III survey sites from 2007 to 2017. Active beaver dams were reported in level II surveys of the U M Creek watershed, Lake Creek, Sevenmile Creek, and Tasha Creek. Level III surveys reported beaver activity at Tasha Creek in 2017. This unit contains numerous springs and extensive groundwater-fed wetlands, including several likely fens.

Dominance Groups

Within the 50-year floodplain, 33 percent of VCMQ-mapped vegetation is dominated by upland shrubs, 21 percent by upland woodland species, 18 percent by woody riparian species, 13 percent by herbaceous plants, and 5 percent by conifers (fig. G.7). At level II reaches and level III sites, community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, low willows, nonwillow shrubs, tall deciduous trees, and tall willows (table G.7). Score: 1

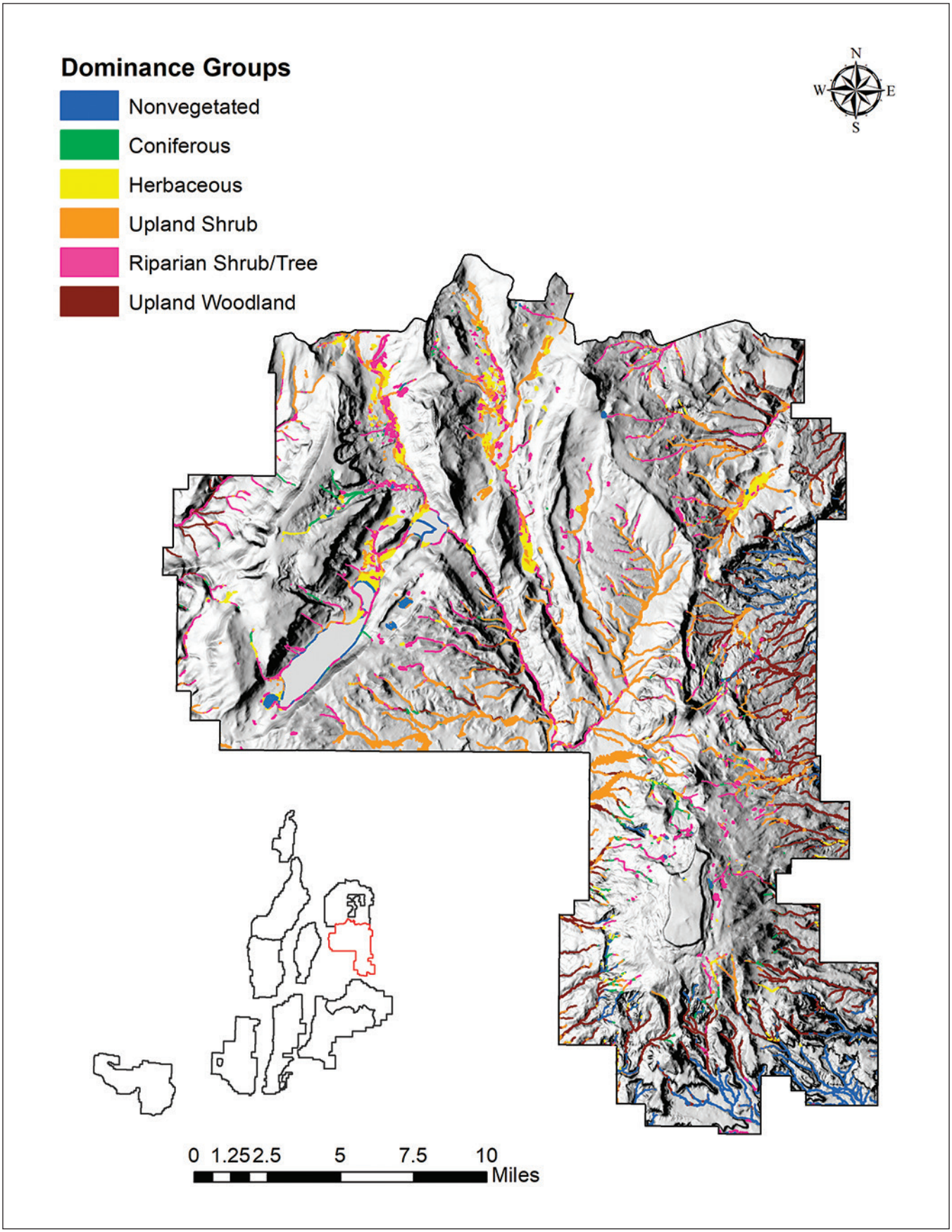


Figure G.7—Riparian dominance groups in the Fishlake–Thousand Lake geographic unit.

Table G.7—Vegetation communities within the riparian dominance groups observed during level II and level III measurements in the Fishlake–Thousand Lake geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Aconitum columbianum*
	Conifer/*Calamagrostis canadensis*
	Conifer/*Deschampsia cespitosa*
	Conifer/*Equisetum arvense*
	Conifer/Mesic Forb
	Conifer/*Poa pratensis*
	Conifer/*Trifolium* spp.
	Misc. Conifer
Tall deciduous tree	*Populus angustifolia/ Betula occidentalis*
	Populus angustifolia/ Mesic Graminoid
Low deciduous tree	*Alnus incana*
	Alnus incana/Cornus sericea
	Alnus incana/Equisetum arvense
	*Alnus incana/*Mesic Forb
	*Alnus incana/*Mesic Graminoid
	Betula occidentalis/Cornus sericea
	Misc. Tall Deciduous Tree
Tall willow	*Salix boothii/*Mesic Forb
	*Salix boothii/*Mesic Graminoid
	*Salix exigua/*Barren
	*Salix exigua /*Mesic Graminoid
	Salix geyeriana/Carex utriculata
	*Salix geyeriana/*Mesic Graminoid
	*Salix geyeriana/*Mesic Forb
	Salix lutea-Salix exigua/ Mesic Graminoid
Low willow	*Salix planifolia/Carex aquatilis*
	Salix planifolia/ Deschampsia cespitosa
Nonwillow shrub	*Dasiphora fruticosa/Poa pratensis*
Herbaceous	*Carex aquatilis*
	Carex nebrascensis
	Carex utriculata
	Deschampsia cespitosa
	Juncus arcticus
	Mesic Graminoid
	Misc. Herbaceous
	Poa pratensis

Vegetation Ratings

During level II surveys, forage trend was stable or up at 54 percent of reaches, the lowest percentage of any unit. During the most recent level III surveys, 73 percent of sites were in desired condition, a relatively high percentage. Score: 1

Conversion

According to R-CAT results, vegetation along most (54 percent) perennial stream miles has departed from the expected composition and structure. Conifer encroachment and upland encroachment are the most frequent causes of conversion. Score: 0.

Stressors

Density of diversions is moderate, at 0.005 per acre. Floodplain road density is relatively low, at 0.004 miles per acre. Wildfire hazard potential is high or very high within 20 percent of the 50-year floodplain, a relatively low percentage. Between 1984 and 2014, 0.2 percent of 50-year floodplain area was affected by moderate to high severity wildfire, among the lowest percentages of any unit. Noted stressors include livestock impacts, which were especially significant along U M Creek. Additional stressors were roads, highways, road crossings, ATVs, and other forms of recreation. Invasive

plant species in the Fremont River watershed included *Cirsium vulgare* and *Cirsium arvense*. Numerous invasive plants were noted along Sand Creek, including *Bromus tectorum*, *Elaeagnus angustifolia*, *Salsola* spp., and *Tamarix ramosissima*. Several of the community types observed (Conifer/*Poa pratensis*, *Dasiphora fruticosa*/*Poa pratensis*, *Carex nebrascensis*, *Juncus arcticus*, *Poa pratensis*) are indicative of heavy livestock use (Hansen et al. 1995). Score: 0

Improvement

A revisit of U M Creek in 2009 showed that conditions had improved since 2002 as a result of grazing exclosures installed in 2003. In the time between surveys, late seral sedges and grasses reestablished on streambanks, narrowing the channel, shading the stream, and forming undercut banks. Increases in beaver activity lowered the erosive power of the stream and exclusion of ATVs aided the recovery of wet meadows (Shell Valley Consulting 2009). Among level III sites that have been remeasured, 2 of 17 sites remeasured improved to meet desired conditions. Conditions at two sites declined from desired. Though methodologies differed, Level II and level III surveys indicated that conditions improved between measurements. Much of the documented damage in the U M Creek watershed appears capable of repair. Score: 1

The composition and structure score is 3, indicating that the Fishlake–Thousand Lake geographic unit is **moderately altered** from the NRV.

Monroe Mountain

Settings

Perennial stream segments are present on the western and eastern slopes of this unit. An estimated 96 percent of perennial stream reaches are confined. Riparian vegetation was measured at 188 level II survey reaches in 2004 and 2006. Active beaver dams were observed on Manning Creek on the western slope in 2004 and at six streams on the eastern slope in 2006. This unit contains numerous springs and groundwater-fed wetlands, including several likely fens.

Dominance Groups

Within the 50-year floodplain, 39 percent of VCMQ-mapped vegetation is dominated by woody riparian species, 23 percent by upland shrubs, 22 percent by upland woodland species, 6 percent by conifers, and 5 percent by herbaceous plants (fig. G.8). At level II survey reaches, community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, nonwillow shrubs, tall deciduous trees, and tall willows (table G.8). Score: 1

Vegetation Ratings

During level II surveys, forage trend was stable or up at 85 percent of reaches, a relatively high percentage. Score: 1

Conversion

According to R-CAT results, vegetation along most (60 percent) perennial stream miles has departed from the expected composition and structure. Conifer encroachment is the most frequent cause of conversion. Score: 0

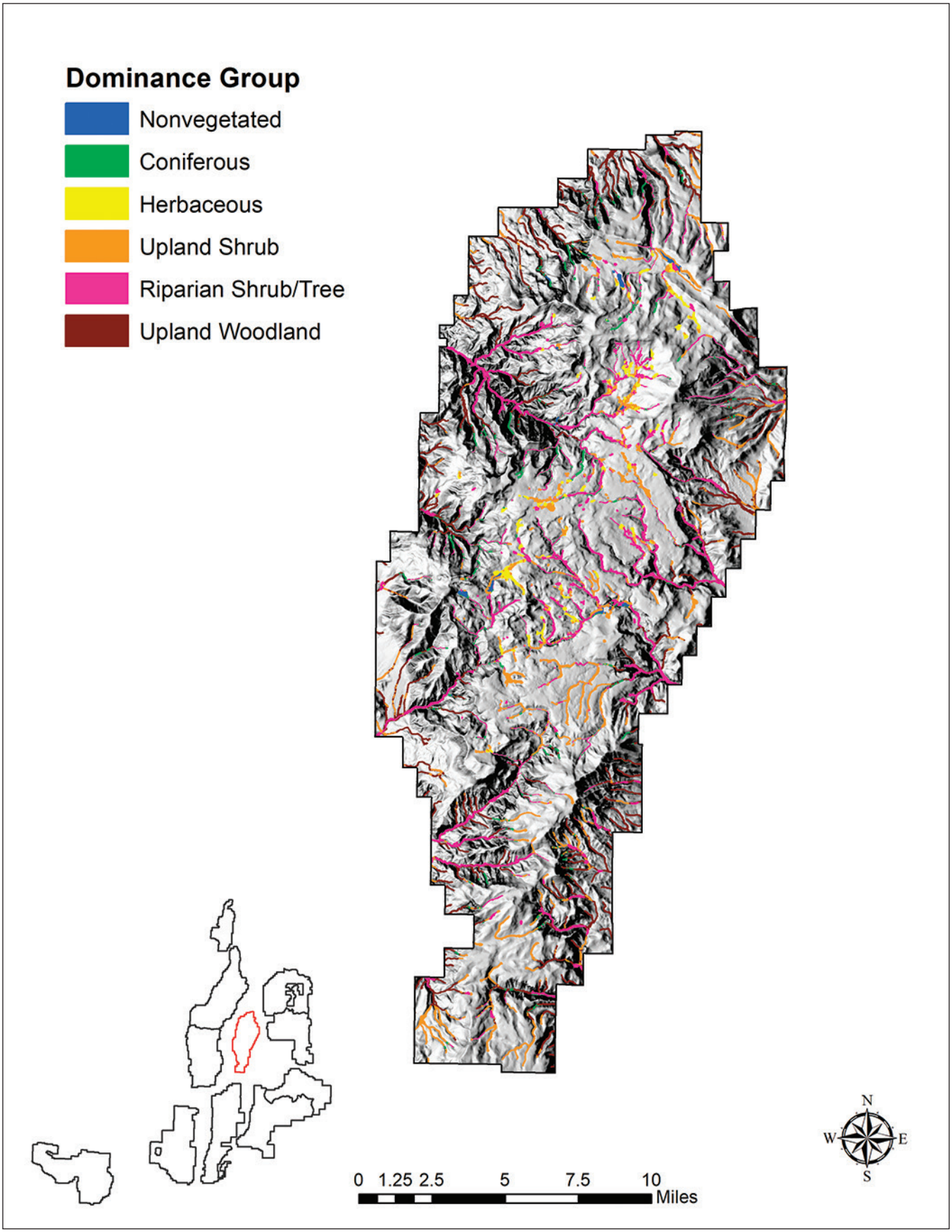


Figure G.8—Riparian dominance groups in the Monroe Mountain geographic unit.

Table G.8—Vegetation communities within the riparian dominance groups observed during level II measurements in the Monroe Mountain geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Actaea rubra*
	Conifer/*Deschampsia cespitosa*
	Conifer/*Equisetum arvense*
	Conifer/Mesic Forb
	Conifer/Mesic Graminoid
	Misc. Conifer
Tall deciduous tree	Misc. Tall Deciduous Tree
	Populus angustifolia/ Betula occidentalis
	Populus angustifolia/Cornus sericea
	Populus angustifolia/Mesic Forb
	Populus angustifolia/Poa pratensis
	Populus tremuloides/Poa pratensis
Low deciduous tree	*Betula occidentalis/Cornus sericea*
	Betula occidentalis/Mesic Forb
	Betula occidentalis/Poa pratensis
Tall willow	*Misc. Willow*
	Salix boothii / Carex aquatilis
	Salix boothii/Equisetum arvense
	Salix boothii/Mesic Forb
	Salix boothii/Mesic Graminoid
	Salix exigua/Mesic Graminoid
	Salix geyeriana/Carex aquatilis
	Salix geyeriana/Carex microptera
	Salix geyeriana/Equisetum arvense
	Salix geyeriana/Mesic Forb
	Salix geyeriana /Mesic Graminoid
Nonwillow shrub	*Artemisia cana/Poa pratensis*
	Cornus sericea
Herbaceous	*Carex aquatilis*
	Carex microptera
	Carex nebrascensis
	Deschampsia cespitosa
	Equisetum arvense
	Mesic Forb
	Mesic Graminoid

Stressors

Density of diversions is moderate, at 0.004 per acres. Floodplain road density is moderate, at 0.005 miles per acre. Wildfire hazard potential is high or very high within 40.7 percent of the 50-year floodplain, a moderate percentage. Between 1984 and 2014, 0.3 percent of the 50-year floodplain area was affected by moderate to high severity wildfire, a relatively low percentage. Noted stressors included livestock grazing, invasive plants, ATVs and other recreation impacts, roads, road crossings, several reservoirs, irrigation diversions, and wildfire. Invasive plant species include *Cirsium vulgare*, *Cirsium arvense*, *Centaurea* spp., and *Bromus tectorum*. Several of the community types observed (*Populus angustifolia*/*Poa pratensis*, *Populus tremuloides*/*Poa pratensis*, *Betula occidentalis*/*Poa pratensis*, *Artemisia cana*/*Poa pratensis*, *Carex nebrascensis*) are indicative of heavy livestock use (Hansen et al. 1995). Score: 0

Improvement

There are numerous stressors affecting riparian ecosystems in this geographic unit. There is no evidence of improvement in conditions brought upon by these stressors. Score: 0

The composition and structure score is 2, indicating that the Monroe Mountains geographic unit is **moderately altered** from the NRV.

Pavant Range

Settings

An estimated 96 percent of perennial stream reaches are confined. The eastern slope of the range has a high density of incised channels, but most of the perennial stream segments are on the western slope and southern end of the unit. Riparian vegetation was measured at 332 level II survey reaches from 2002 to 2006. Active beaver dams were reported at only one level II survey reach, on the North Fork of Chalk Creek. This unit contains numerous springs and some groundwater-fed wetlands, including several likely fens. Extensive carbonate bedrock creates potential for karst development on the western slope.

Dominance Groups

Within the 50-year floodplain, 54 percent of VCMQ-mapped vegetation is dominated by upland woodland species, 20 percent by upland shrubs, 14 percent by woody riparian species, 8 percent by conifers, and 4 percent by herbaceous plants (fig. G.9). At level II reaches, community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, nonwillow shrubs, tall deciduous trees, and tall willows (table G.9). Score: 1

Vegetation Ratings

During level II surveys, forage trend was stable or up at 81 percent of reaches, a moderate percentage. Score: 1

Conversion

According to R-CAT results, vegetation along most (61 percent) perennial stream miles has departed from the expected composition and structure. Conifer encroachment and upland encroachment are the most frequent causes of conversion. Score: 0

Stressors

Density of diversions is 0.001, among the lowest of the geographic units. Floodplain road density is moderate, at 0.005 miles per acre. Wildfire hazard potential is high or very high within 77.3 percent of the 50-year floodplain, a relatively high percentage. Between 1984 and 2014, 3.8 percent of 50-year floodplain area was affected by moderate to high severity wildfire, a moderate percentage. Noted stressors were roads, highways, road crossings, livestock grazing, beaver removal, and ATVs. Invasive plant species included *Calysetgia* spp., *Cirsium vulgare*, *Arctium minus*, *Cirsium arvense*, *Hieracium cynoglossoides*, *Euphorbia esula*, *Centaurea* spp., *Tamarix ramosissima*, *Onopordum acanthium*, and *Linaria vulgaris*. Several of the community types observed (Conifer/*Poa pratensis*, *Populus angustifolia*/*Poa pratensis*, *Populus angustifolia*/*Rosa woodsia*, *Populus tremuloides*/*Poa pratensis*, *Betula occidentalis*/*Poa pratensis*, *Salix boothii*/*Poa pratensis*, *Salix exigua*/*Juncus arcticus*, *Salix exigua*/*Poa pratensis*, *Carex nebrascensis*, *Juncus arcticus*, *Poa pratensis*) are indicative of heavy livestock use (Hansen et al. 1995). Score: 0

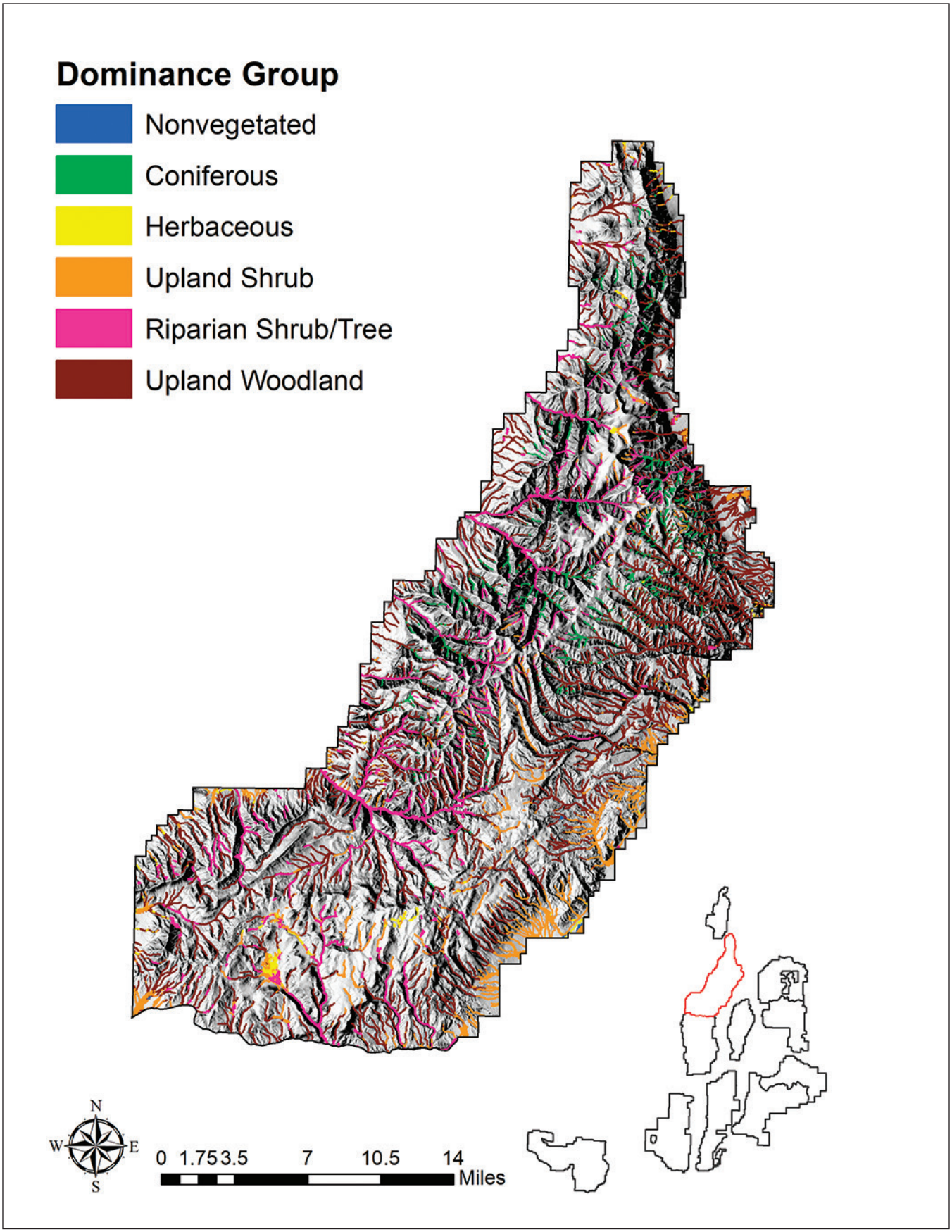


Figure G.9—Riparian dominance groups in the Pavant Range geographic unit.

Table G.9—Vegetation communities within the riparian dominance groups observed during level II measurements in the Pavant Range geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Aconitum columbianum*
	Conifer/*Actaea rubra*
	Conifer/*Cornus sericea*
	Conifer/*Deschampsia cespitosa*
	Conifer/*Elymus glaucus*
	Conifer/*Equisetum arvense*
	Conifer/Misc.Tall Deciduous Tree
	Conifer/*Poa pratensis*
	Misc. Conifer
Tall deciduous tree	*Acer negundo/Cornus sericea*
	Misc. Tall Deciduous Tree
	Populus angustifolia/ Acer grandidentatum
	Populus angustifolia/ Betula occidentalis
	Populus angustifolia/Cornus sericea
	Populus angustifolia/Poa pratensis
	Populus angustifolia/Rosa woodsii
	Populus angustifolia/Salix exigua
	Populus tremuloides/Poa pratensis
Low deciduous tree	*Betula occidentalis/Cornus sericea*
	*Betula occidentalis/*Mesic Forb
	Betula occidentalis/Poa pratensis
	Misc. Low Deciduous Tree
Tall willow	*Salix boothii/*Mesic Forb
	*Salix boothii/*Mesic Graminoid
	Salix boothii/Poa pratensis
	*Salix exigua/*Mesic Forb
	*Salix exigua/*Mesic Graminoid
	Salix exigua/Juncus arcticus
	Salix exigua/Poa pratensis
	*Salix geyeriana/*Mesic Forb
Nonwillow shrub	Xeric Shrub
Herbaceous	*Carex aquatilis*
	Carex nebrascensis
	Deschampsia cespitosa
	Juncus arcticus
	Misc. Herbaceous
	Mesic Graminoid
	Mesic Forb
	Poa pratensis

Improvement

There are numerous stressors affecting riparian ecosystems in this geographic unit. There is no evidence of improvement in conditions brought upon by these stressors. Score: 0

The composition and structure score is 2, indicating that the Pavant Range geographic unit is **moderately altered** from the NRV.

Tushar Mountains

Settings

This volcanic unit contains many perennial stream segments. Extensive stands of riparian vegetation are present in the Clear Creek watershed in the northern portion of the unit. An estimated 91 percent of reaches are confined. Riparian vegetation was measured at 694 level II survey reaches from 2002 to 2006 and at 10 level III survey sites in 2012 and 2017. Beaver were apparently absent from most streams visited for level II surveys in the Beaver River watershed. Briggs Creek, Indian Creek, North Fork North Creek, South Fork North Creek, and Three Creeks were the only streams in this watershed with active dams or beaver activity noted. In the Sevier

River Basin, Clear Creek, Line Canyon, Picnic Creek, and Shingle Creek had active dams or signs of recent activity. Beaver activity was not noted during the most recent level III surveys. This unit contains numerous springs and some groundwater-fed wetlands, including several likely fens.

Dominance Groups

Within the 50-year floodplain, 42 percent of VCMQ-mapped vegetation is dominated by upland woodland species, 22 percent by woody riparian species, 21 percent by conifers, 8 percent by upland shrubs, and 3 percent by herbaceous plants (fig. G.10). Level II and level III surveys indicated that community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, low willows, nonwillow shrubs, tall deciduous trees, and tall willows (table G.10). Score: 1

Vegetation Ratings

During level II surveys, forage trend was stable or up at 71 percent of reaches, a relatively low percentage. During the most recent level III measurements, 40 percent of sites were in desired condition, also a low percentage. Score: 0

Conversion

According to R-CAT results, vegetation along most (72 percent) perennial stream miles has departed from the expected composition and structure. Conifer encroachment and upland encroachment are the most frequent causes of conversion. Score: 0

Stressors

Density of diversions is 0.004, a moderate percentage. Floodplain road density is 0.007 miles per acre, among the highest of any unit. Wildfire hazard potential is high or very high within 52.2 percent of the 50-year floodplain, a relatively high percentage. Between 1984 and 2014, 5.1 percent of 50-year floodplain area was affected by moderate to high severity wildfire, also a relatively high percentage. Impacts from recreation (ATVs), beaver removal, and heavy grazing were noted along streams in the Beaver River watershed in 2002 and 2003. Roads, ATVs, and grazing effects were noted at eastern slope streams in 2004, 2005, and 2006. Grazing effects were not noted as frequently along eastern slope streams they were in the Beaver River watershed. Additional stressors included highways, drought, fire, dams, and diversions. Invasive species noted in the Beaver River watershed include *Cirsium vulgare* and *Cirsium arvense*. A greater number of invasive species were reported in the Clear Creek watershed, including *Tamarix ramosissima*, *Cirsium arvense*, *Onopordum acanthium*, *Cirsium vulgare*, *Euphorbia esula*, *Cynoglossum officinale*, *Bromus tectorum*, *Centaurea* spp., and *Arctium minus*. Several of the community types observed (Conifer/*Poa pratensis*, *Populus angustifolia*/*Poa pratensis*, *Populus angustifolia*/*Rosa woodsia*, *Populus tremuloides*/*Poa pratensis*, *Betula occidentalis*/*Poa pratensis*, *Salix boothii*/*Poa pratensis*, *Rosa woodsia*/*Poa pratensis*, *Agrostis stolonifera*, *Carex nebrascensis*, *Juncus arcticus*, *Poa pratensis*) are indicative of heavy livestock use (Hansen et al. 1995). Score: 0

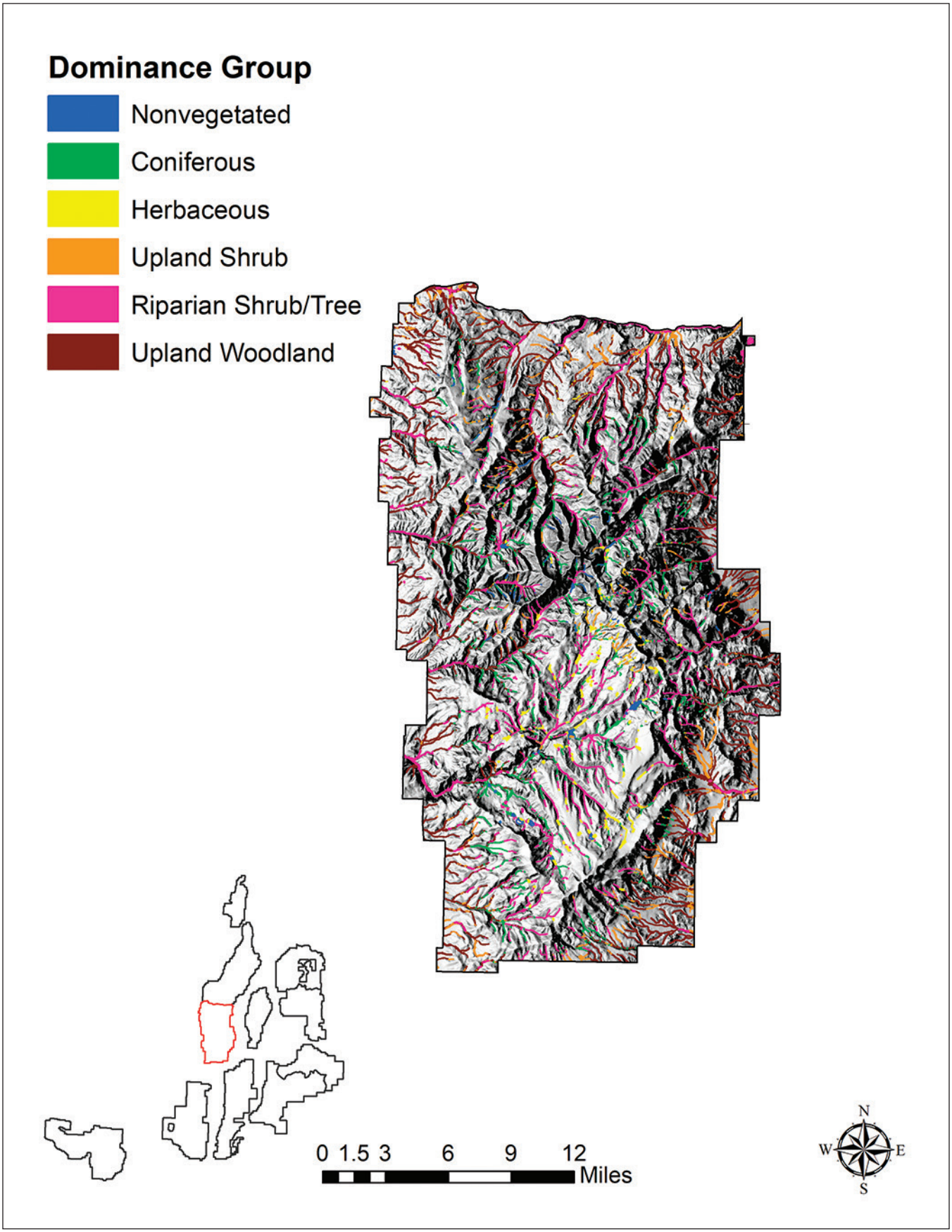


Figure G.10—Riparian dominance groups in the Tushar Mountains geographic unit.

Table G.10—Vegetation communities within the riparian dominance groups observed during level II and level III measurements in the Tushar Mountains geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Actaea rubra*
	Conifer/*Aconitum columbianum*
	Conifer/Barren
	Conifer/*Betula occidentalis*
	Conifer/*Calamagrostis canadensis*
	Conifer/*Cornus sericea*
	Conifer/*Equisetum arvense*
	Conifer/Mesic Forb
	Conifer/Mesic Graminoid
	Conifer/*Poa pratensis*
	Conifer/*Deschampsia cespitosa*
	Conifer/*Elymus glaucus*
	Misc. Conifer
Tall deciduous tree	Misc. Tall Deciduous Tree
	Populus angustifolia/ Acer grandidentatum
	*Populus angustifolia/*Barren
	*Populus angustifolia/*Bar
	Populus angustifolia/ Betula occidentalis
	Populus angustifolia/Cornus sericea
	Populus angustifolia/ Equisetum arvense
	*Populus angustifolia/*Mesic Forb
	Populus angustifolia/ Mesic Graminoid
	Populus angustifolia/Poa pratensis
	Populus angustifolia/Rosa woodsii
	Populus angustifolia/Salix lucida
	Populus angustifolia/Rhus trilobata
	Populus tremuloides
	Populus tremuloides/ Betula occidentalis
	*Populus tremuloides/*Mesic Forb
	Populus tremuloides/ Mesic Graminoid
	Populus tremuloides/Poa pratensis
Low deciduous tree	*Betula occidentalis/*Mesic Forb
	*Betula occidentalis/*Mesic Graminoid
	Betula occidentalis/Poa pratensis
	Misc. Low Deciduous Tree
Tall willow	Misc. Willow
	Salix boothii/Poa pratensis
	*Salix exigua/*Mesic Forb
	*Salix exigua/*Mesic Graminoid
	Salix geyeriana/Carex aquatilis
	*Salix geyeriana/*Mesic Graminoid
	*Salix lasiandra/*Mesic Forb
Low willow	*Salix planifolia/ Deschampsia cespitosa*
Nonwillow shrub	*Rosa woodsia/Poa pratensis*
Herbaceous	*Agrostis stolonifera*
	Carex aquatilis
	Carex microptera
	Carex nebrascensis
	Carex utriculata
	Deschampsia cespitosa
	Eleocharis palustris
	Juncus arcticus
	Mesic Forb
	Mesic Graminoid
	Misc. Herbaceous
	Poa pratensis

Improvement

There are numerous stressors affecting riparian ecosystems in this geographic unit. Among level III sites that have been remeasured two of 17 sites remeasured improved to meet desired conditions, but conditions at two sites declined from desired. There is little evidence of improvement in conditions brought upon by these stressors. Score: 0

The composition and structure score is 1, indicating that the Tushar Mountains geographic unit is **outside** of the NRV.

White Mountain

Settings

Perennial stream segments are distributed throughout the unit. An estimated 84 percent of reaches are confined. Riparian vegetation was measured at 309 level II survey reaches from 2003 to 2006. Salina Creek and Niotche Creek were the only streams with active beaver dams during level II surveys, though several reaches had signs of recent activity. This unit contains numerous springs and groundwater-fed wetlands, including several likely fens.

Dominance Groups

Within the 50-year floodplain, 44 percent of VCMQ-mapped vegetation is dominated by upland woodland species, 21 percent by woody riparian species, 19 percent by upland shrubs, 10 percent by herbaceous plants, and 3 percent by conifers (fig. G.11). At level II reaches, community types were dominated by coniferous trees, herbaceous plants, low deciduous trees, low willows, tall deciduous trees, and tall willows (table G.11). Score: 1

Vegetation Ratings

During level II surveys, forage trend was stable or up at 87 percent of reaches, a relatively high percentage. Score: 1

Conversion

According to R-CAT results, vegetation along most (61 percent) perennial stream miles has departed from the expected composition and structure. Conifer encroachment and development (mostly highways) are the most frequent causes of conversion. Score: 0

Stressors

Density of diversions is moderate, at 0.005 per acre. Floodplain road density is relatively high, at 0.006 miles per acre. Wildfire hazard potential is high or very high within 47 percent of the 50-year floodplain, a moderate percentage. Between 1984 and 2014, 0.2 percent of the 50-year floodplain area was affected by moderate to high severity wildfire, among the lowest percentages of any unit. Noted stressors included livestock grazing, elk herbivory, roads, crossings, stream confinement for highway construction, reservoirs, dams, ATVs, and campsites. Invasive plants had high density and richness in areas such as Salina Creek and Pickle Keg Creek. Invasive species include *Cirsium vulgare*, *Cirsium arvense*, *Carduus nutans*, *Bromus tectorum*, *Hieracium cynoglossoides*, *Elaeagnus angustifolia*, and *Tamarix ramosissima*. Several of the community types observed (Conifer/

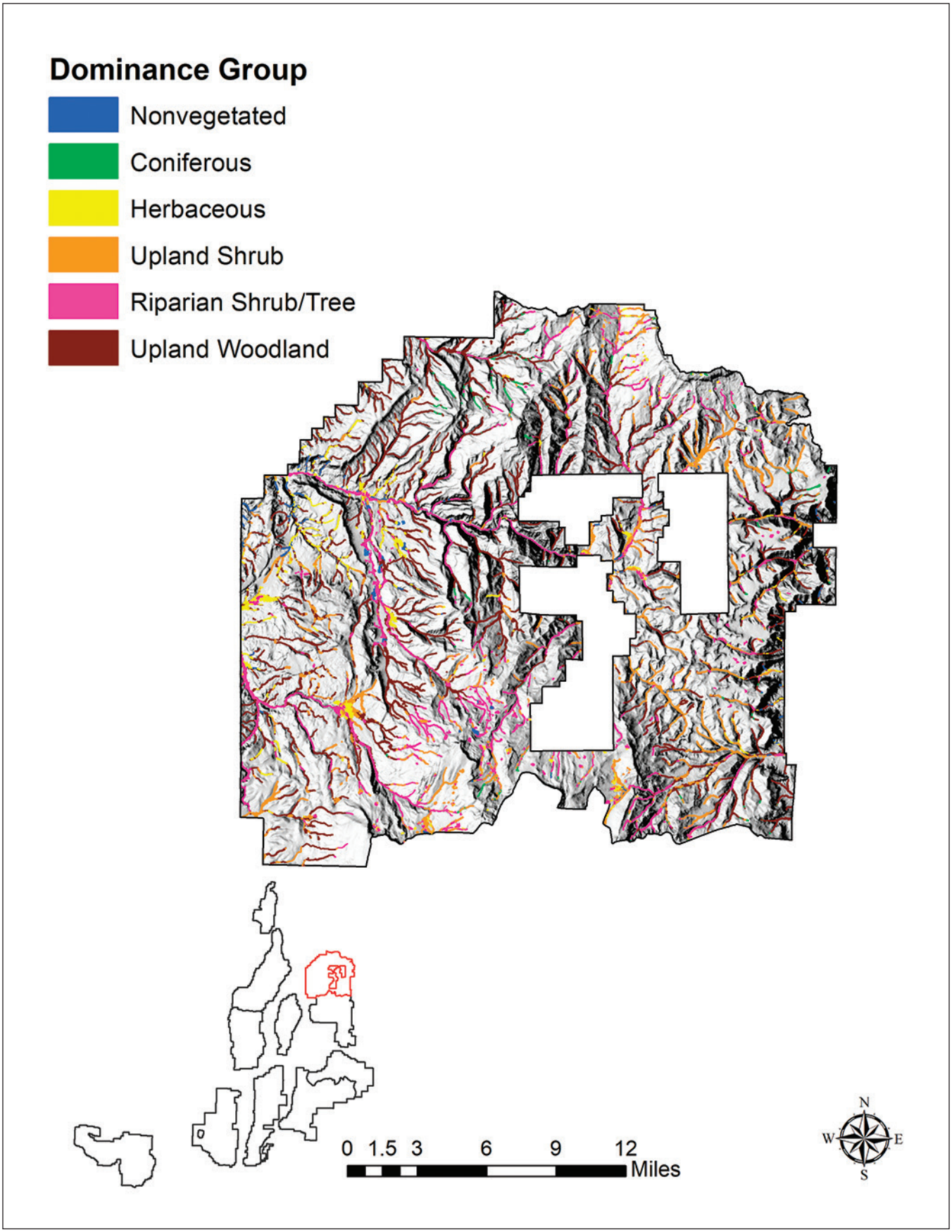


Figure G.11—Riparian dominance groups in the Escalante geographic unit.

Table G.11—Vegetation communities within the riparian dominance groups observed during level II measurements in the White Mountain geographic unit.

Dominance group	Communities
Coniferous tree	Conifer/*Equisetum arvense*
	Conifer/*Elymus glaucus*
	Conifer/*Aconitum columbianum*
	Conifer/*Cornus sericea*
	Conifer/Mesic Graminoid
	Conifer/*Poa pratensis*
Tall deciduous tree	*Acer negundo/Cornus sericea*
	Misc. Tall Deciduous Tree
	Populus angustifolia/ Acer grandidentatum
	Populus angustifolia/Alnus incana
	Populus angustifolia/ Betula occidentalis
	Populus angustifolia/Cornus sericea
	Populus angustifolia/Poa pratensis
	Populus angustifolia/Rhus trilobata
	Populus angustifolia/Rosa woodsii
Low deciduous tree	*Alnus incana/Equisetum arvense*
	Alnus incana/Mesic Forb
	Alnus incana/Mesic Graminoid
	Alnus incana/Poa pratensis
	Betula occidentalis/Mesic Forb
	Betula occidentalis/Mesic Graminoid
	Betula occidentalis/Poa pratensis
	Betula occidentalis/Rosa woodsii
	Betula occidentalis/Salix exigua
	Elaeagnus angustifolia
Tall willow	Misc. Willow
	Salix boothii/Carex aquatilis
	Salix boothii/Equisetum arvense
	Salix boothii/Mesic Forb
	Salix boothii/Mesic Graminoid
	Salix boothii/Poa pratensis
	Salix exigua/Barren
	Salix exigua/Mesic Graminoid
	Salix exigua/Poa pratensis
	Salix geyeriana/Carex nebrascensis
	Salix geyeriana/Mesic Forb
Low willow	*Salix planifolia/Carex microptera*
	Salix planifolia/ Deschampsia cespitosa
Herbaceous	*Carex aquatilis*
	Carex microptera
	Deschampsia cespitosa
	Equisetum arvense
	Juncus arcticus
	Mesic Graminoid
	Misc. Graminoid
	Misc. Herbaceous
	Poa pratensis

Poa pratensis, *Populus angustifolia*/*Poa pratensis*, *Populus angustifolia*/*Rosa woodsia*, *Betula occidentalis*/*Poa pratensis*, *Betula occidentalis*/*Rosa woodsia*, *Salix boothii*/*Poa pratensis*, *Salix exigua*/*Poa pratensis*, *Salix geyeriana*/*Carex nebrascensis*, *Juncus arcticus*, *Poa pratensis*) are indicative of heavy livestock use (Hansen et al. 1995). Score: 0

Improvement

There are numerous stressors affecting riparian ecosystems in this geographic unit. There is no evidence of improvement in conditions brought upon by these stressors. Score: 0

The composition and structure score is 2, indicating that the White Mountain geographic unit is **moderately altered** from the NRV.

Appendix H. Watershed Maps

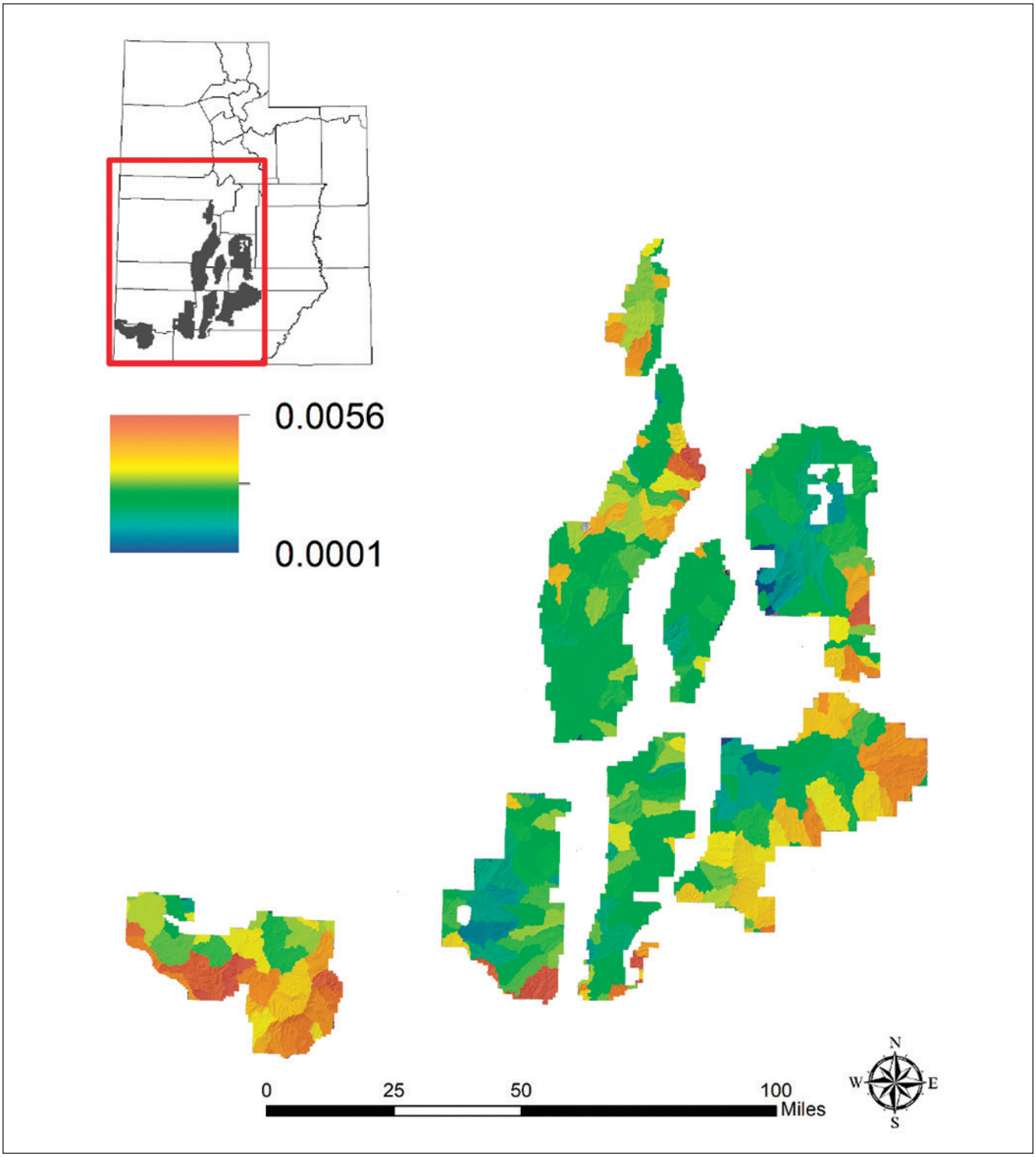


Figure H.1—Stream density in miles per acre by watershed.

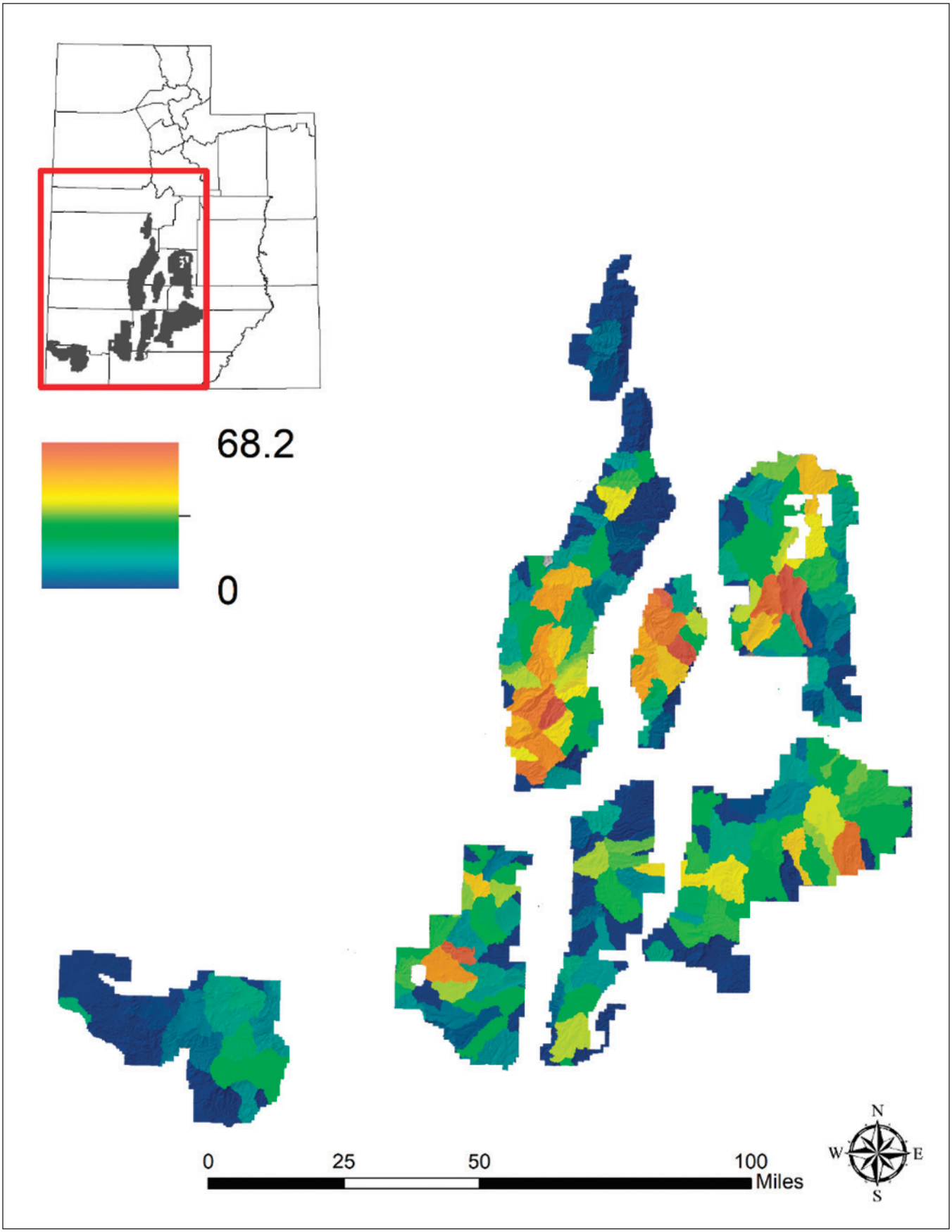


Figure H.2—Percent of streams within a watershed classified by NHD as perennial.

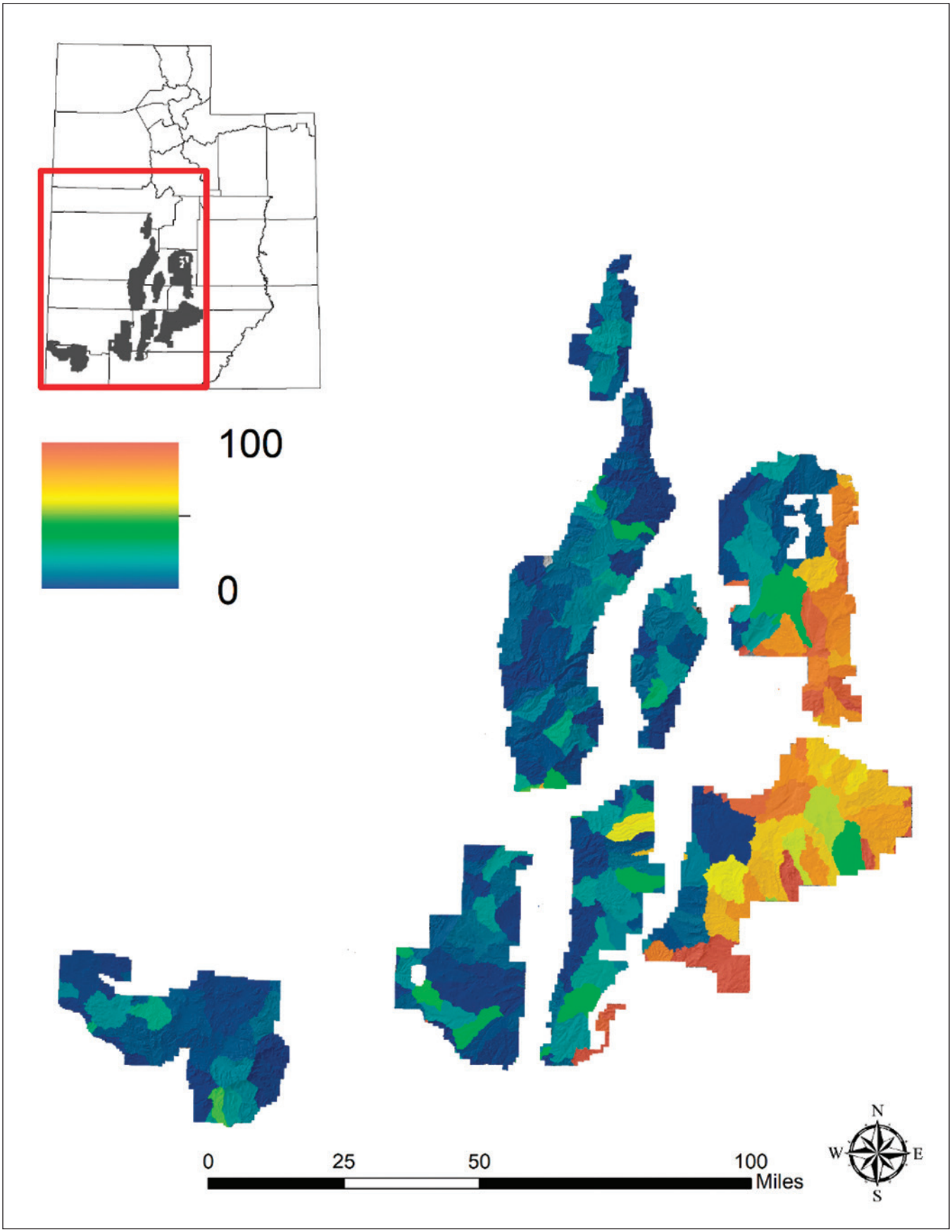


Figure H.3—Percent of streams within a watershed classified by NHD as intermittent.

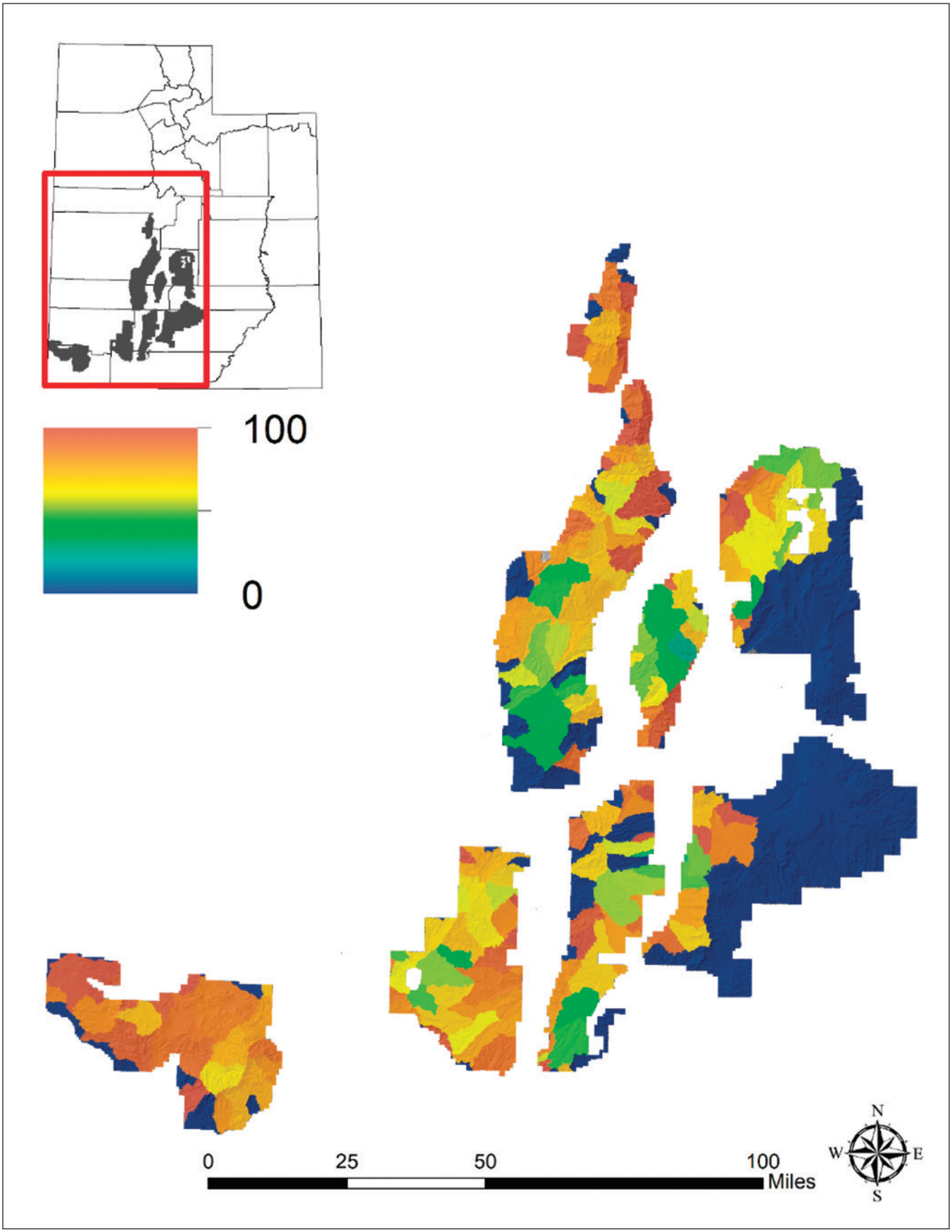


Figure H.4—Percent of streams within a watershed classified by NHD as ephemeral.

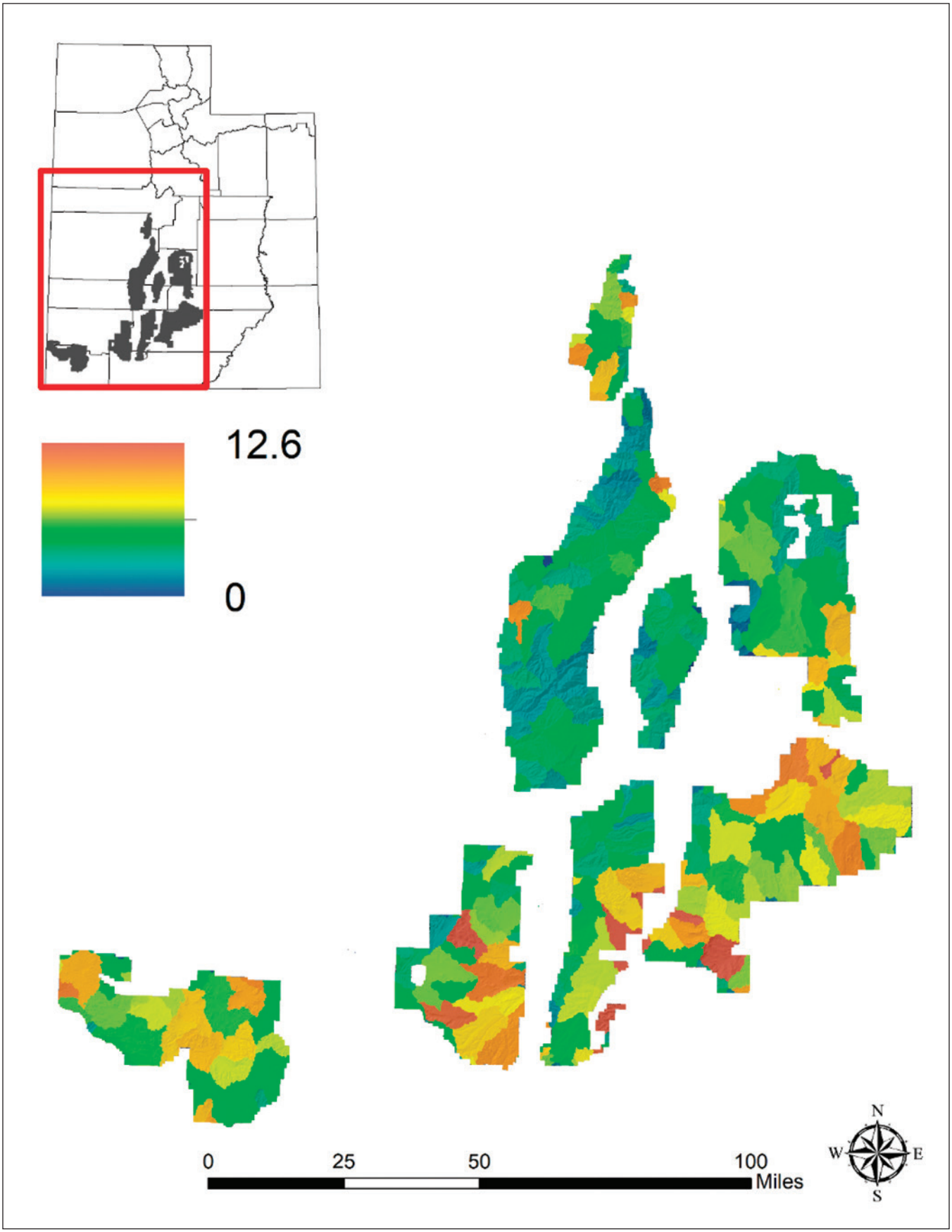


Figure H.5—Percent of watershed located within the 50-year floodplain.

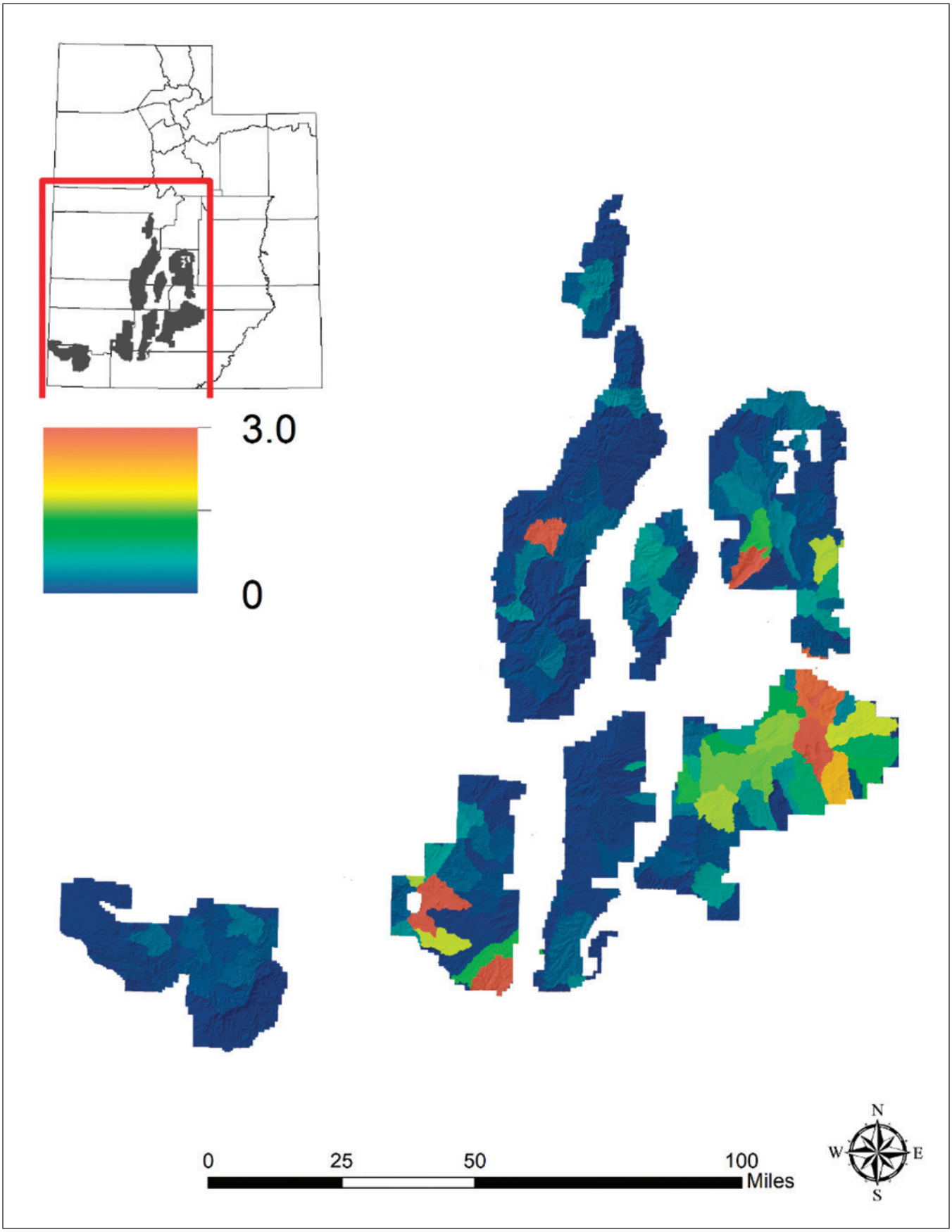


Figure H.6—Percent of watershed classified as wetland by NWI.

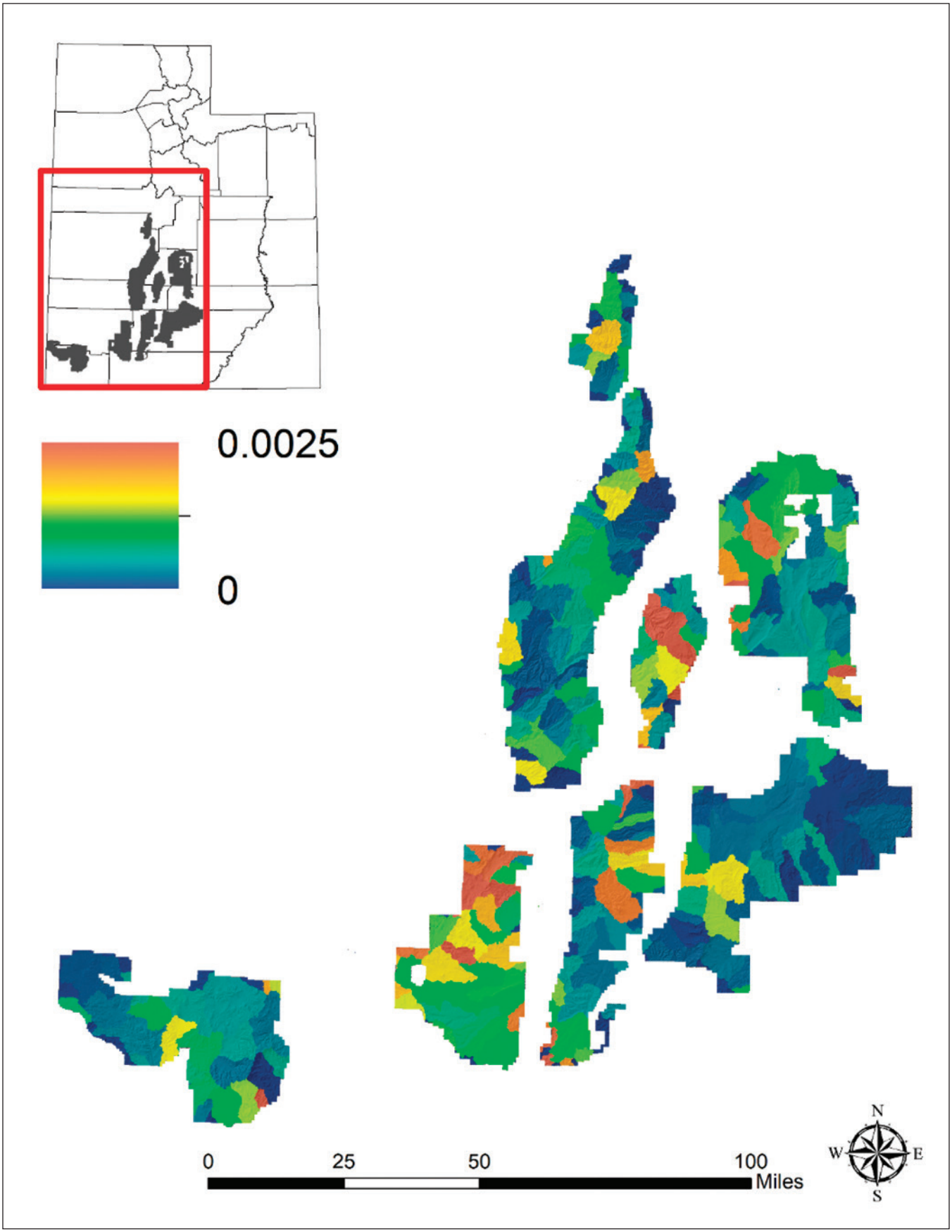


Figure H.7—Spring density (number of springs per acre) within each watershed based on NHD data.



Figure H.8—Riparian areas associated with perennial streams that have not converted to alterative cover types. Results are based on R-CAT output.

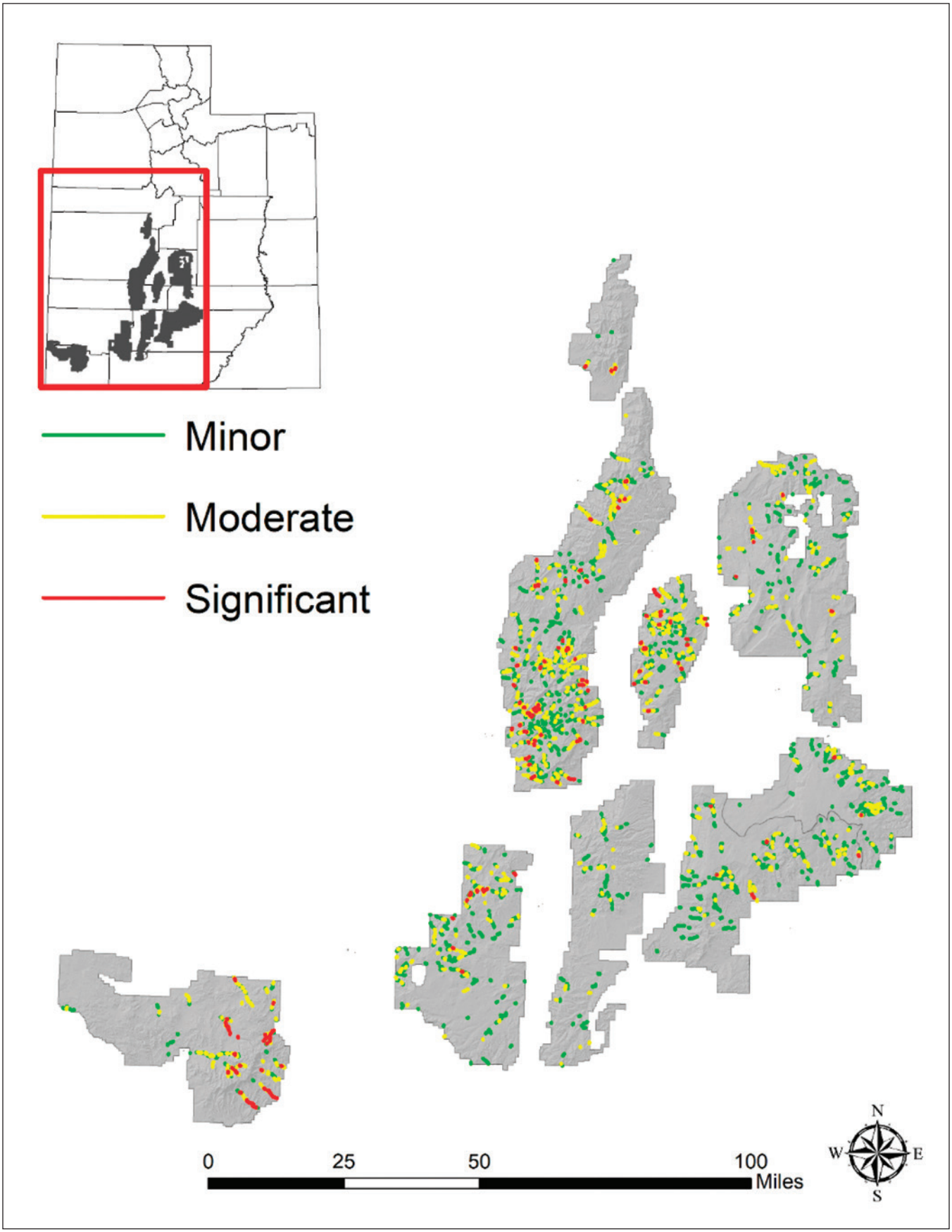


Figure H.9—Conifer encroachment into riparian areas associated with perennial streams. Results are based on R-CAT output.

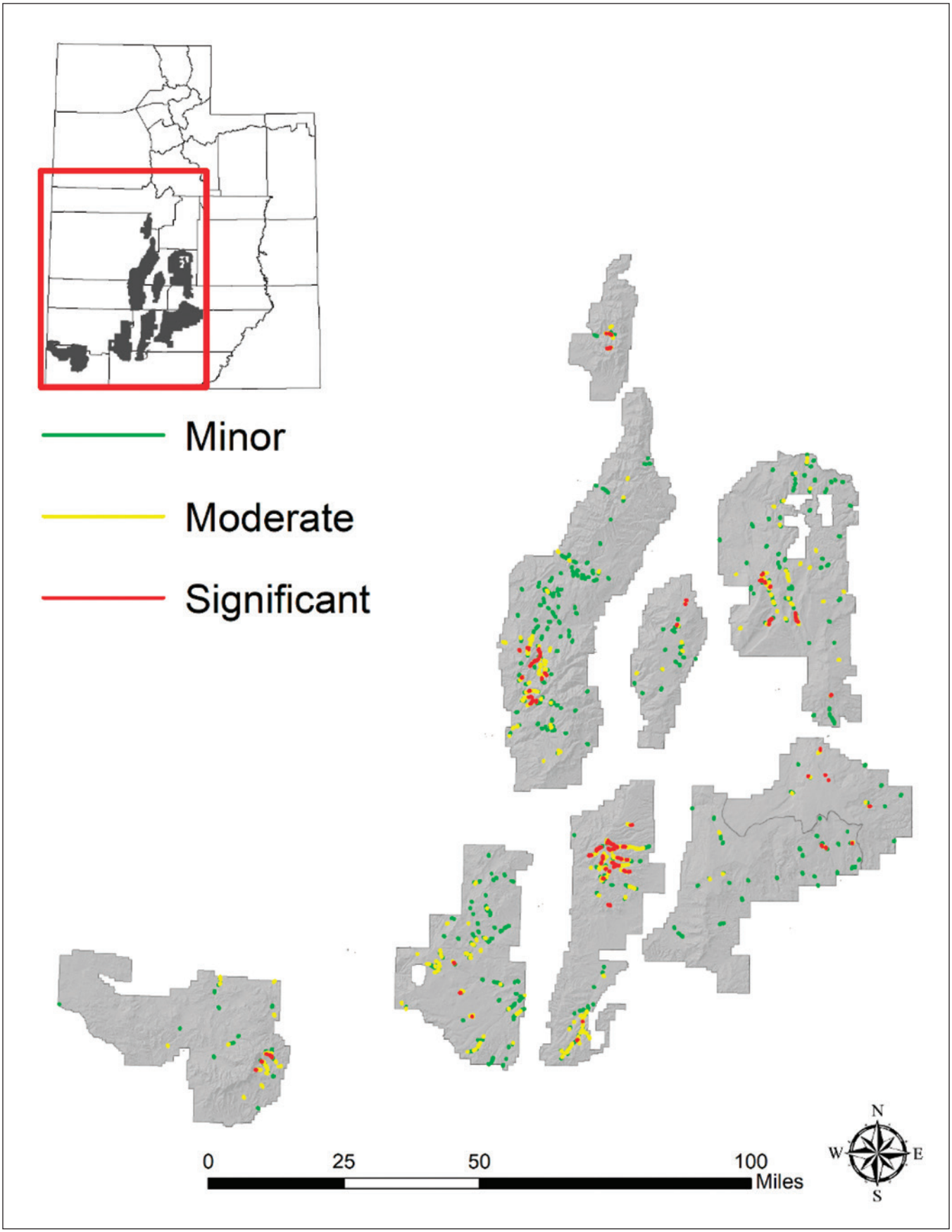


Figure H.10—Conversion of riparian areas associated with perennial streams to upland grass and shrub species. Results are based on R-CAT output.

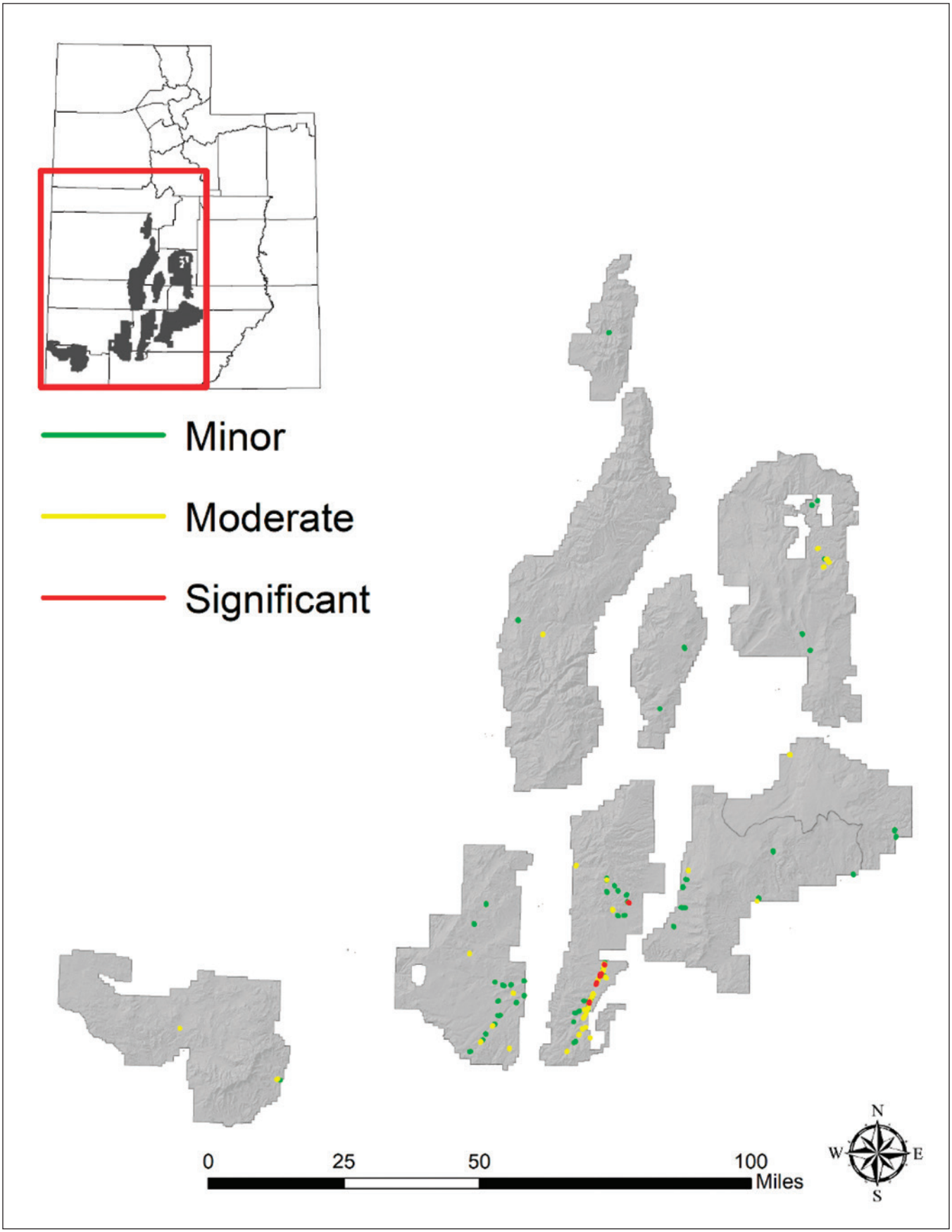


Figure H.11—Conversion of riparian area associated with perennial streams to invasive species. Results are based on R-CAT output.

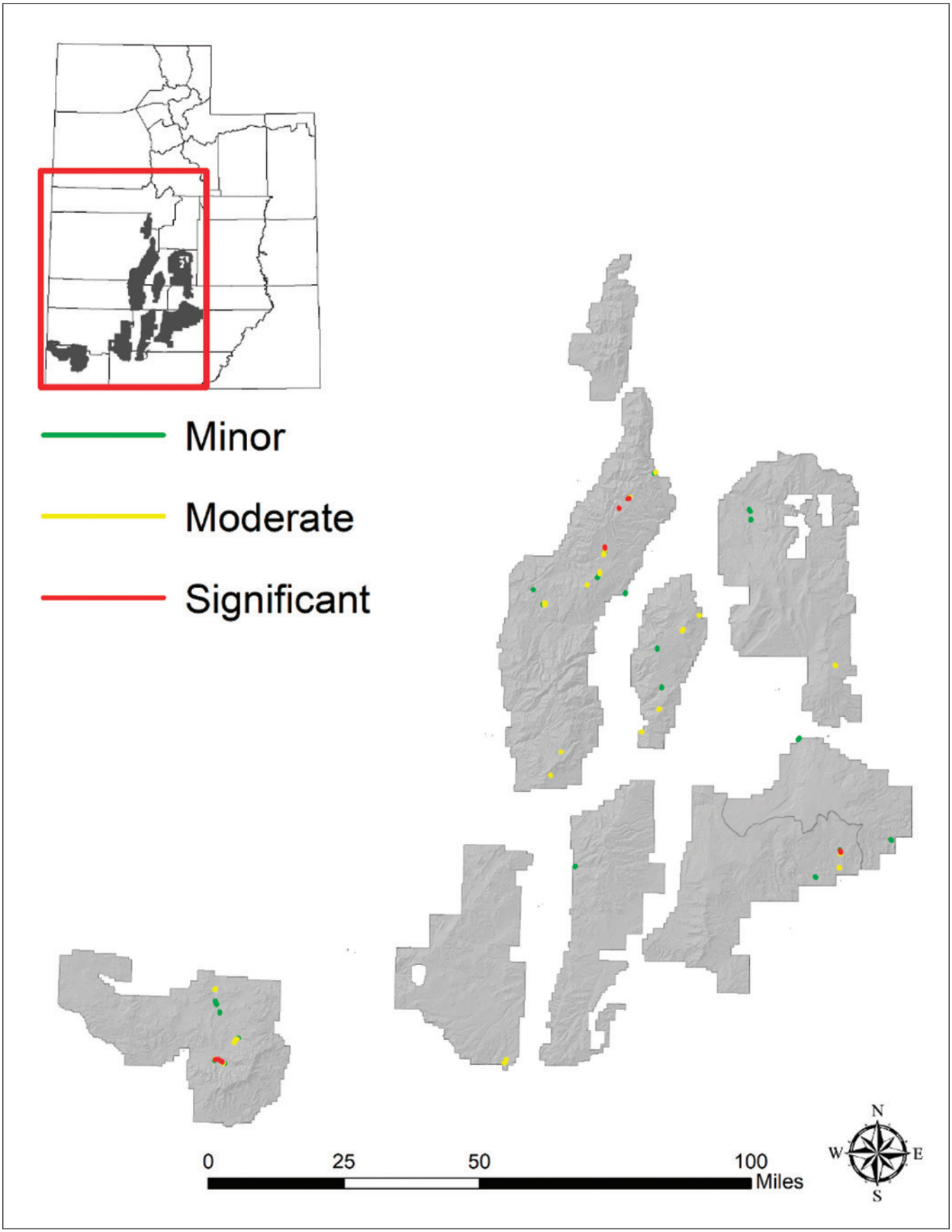


Figure H.12—Conversion of riparian area associated with perennial streams to agricultural cover. Results are based on R-CAT output.

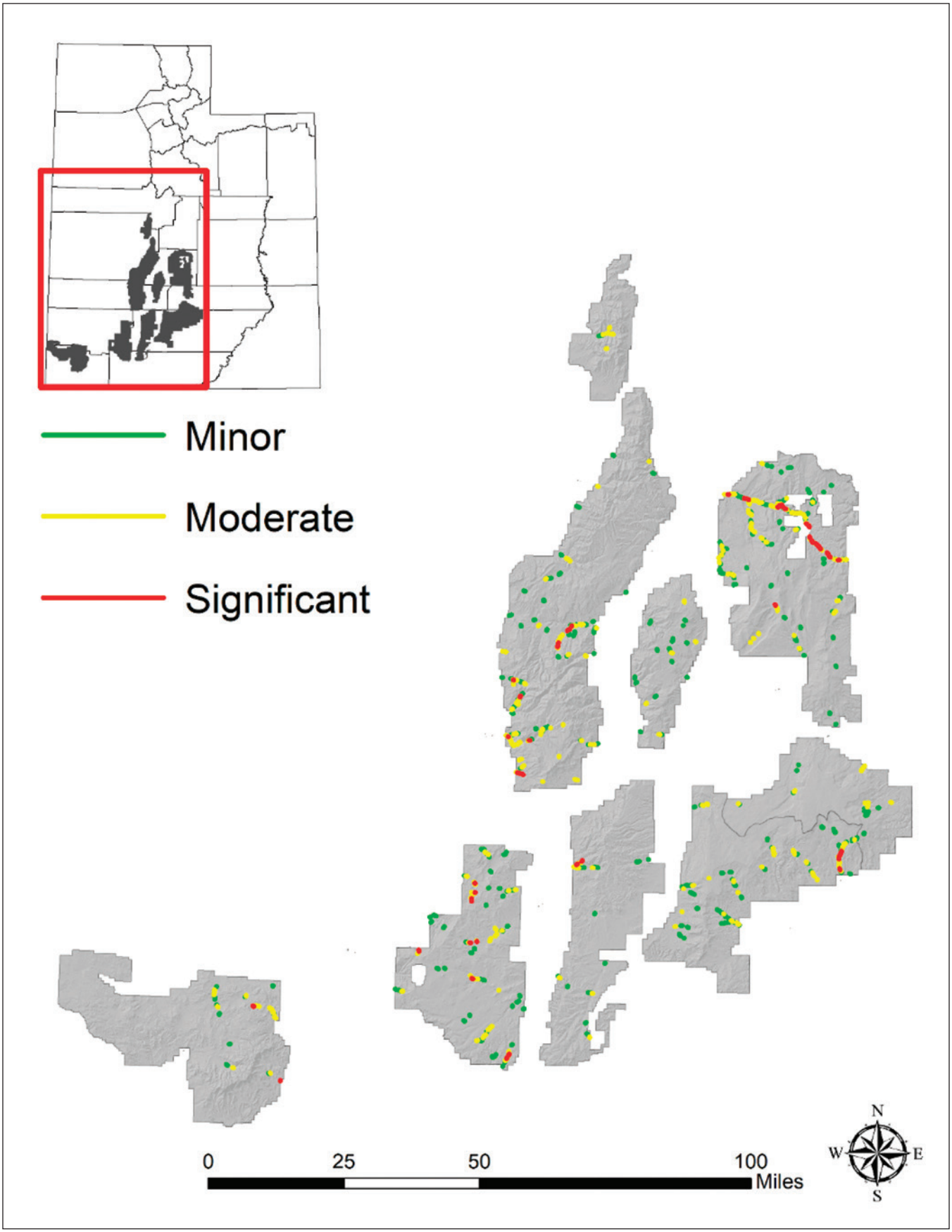


Figure H.13—Conversion of riparian area associated with perennial streams to development. Results are based on R-CAT output.

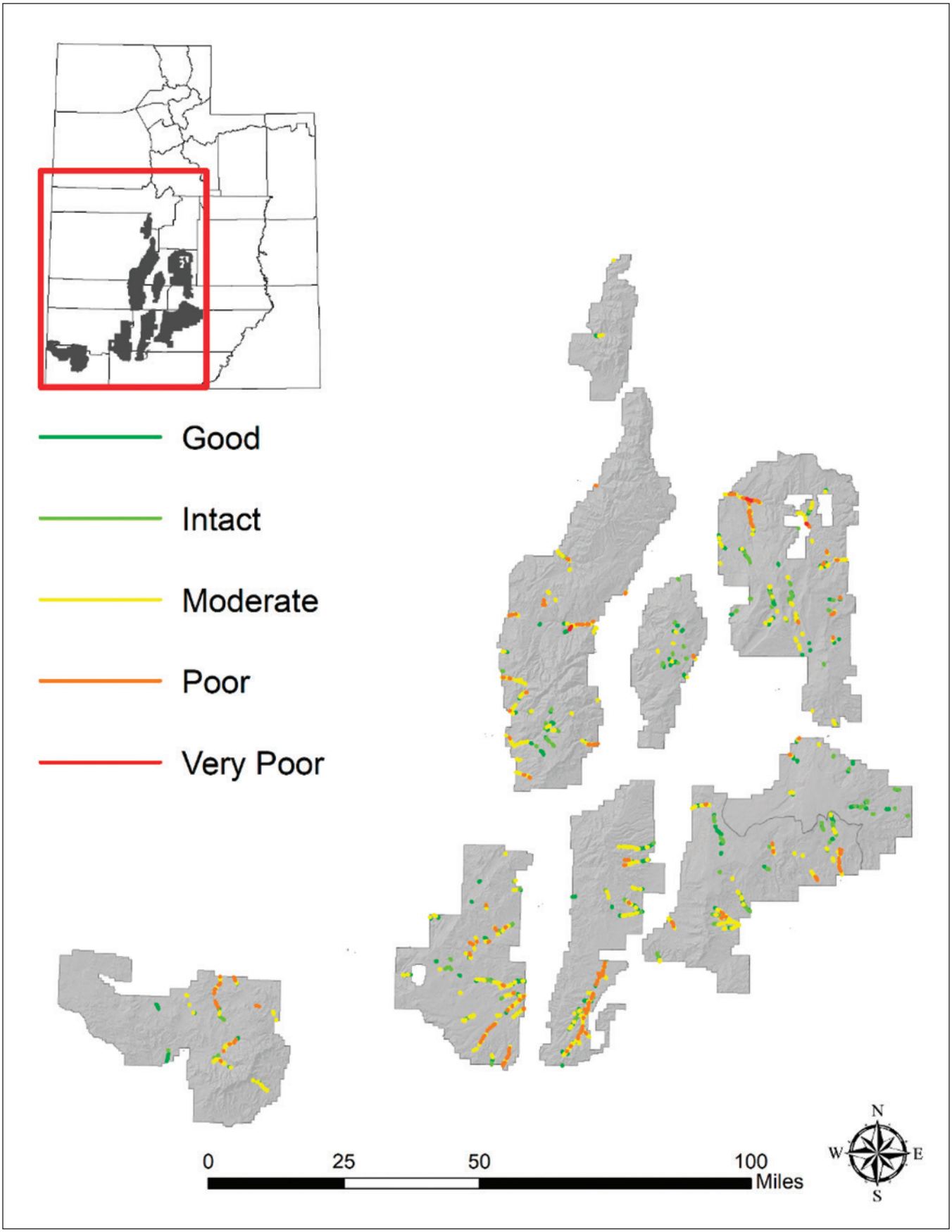


Figure H.14—Condition of unconfined reaches associated with perennial streams. Results are based on R-CAT output.

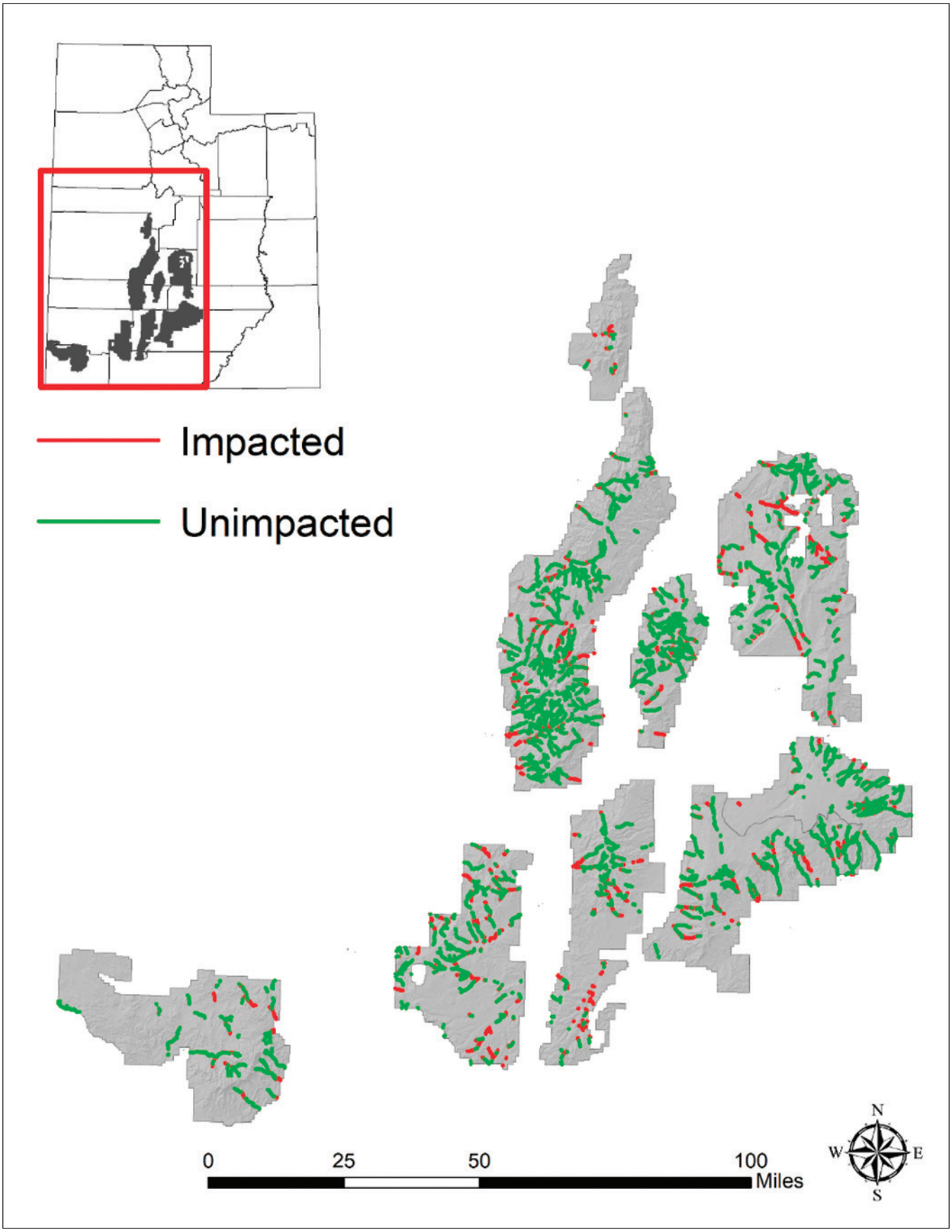


Figure H.15—Condition of confined reaches associated with perennial streams. Results are based on R-CAT output.

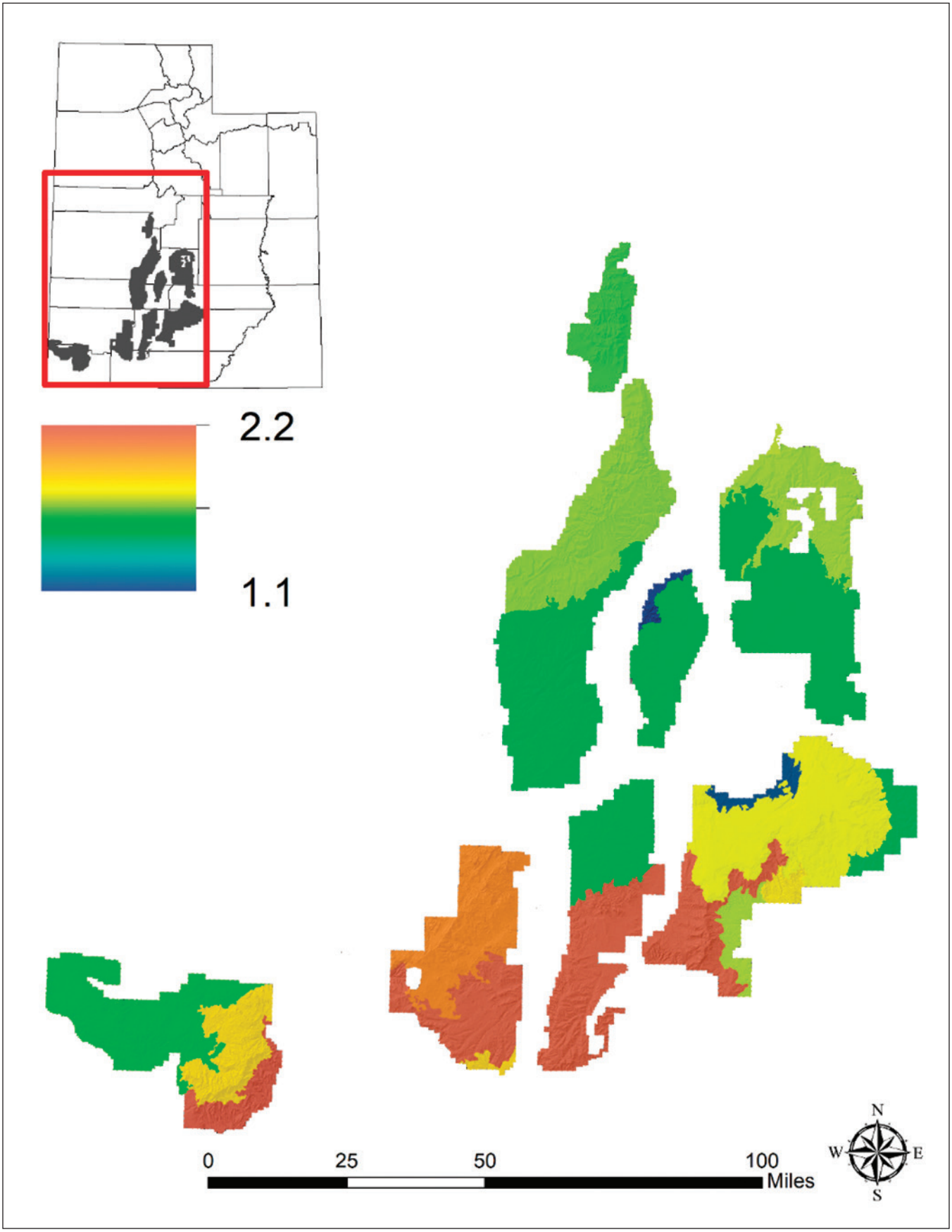


Figure H.16—Deviation in autumn temperature (°F) from 2010 to 2014 compared to the previous century. Based on TCA data.

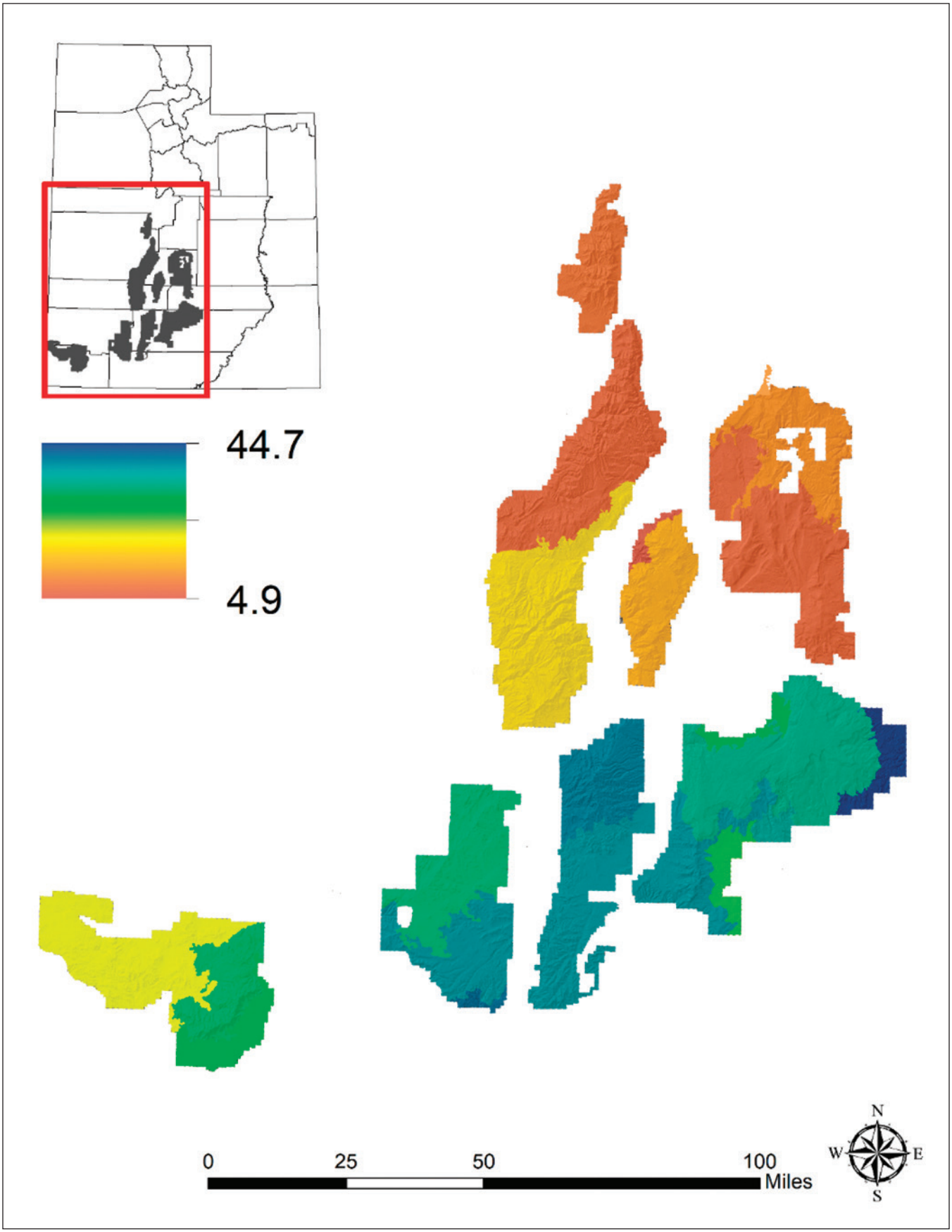


Figure H.17—Percent deviation in autumn precipitation from 2010 to 2014 compared to the previous century. Based on TCA data.

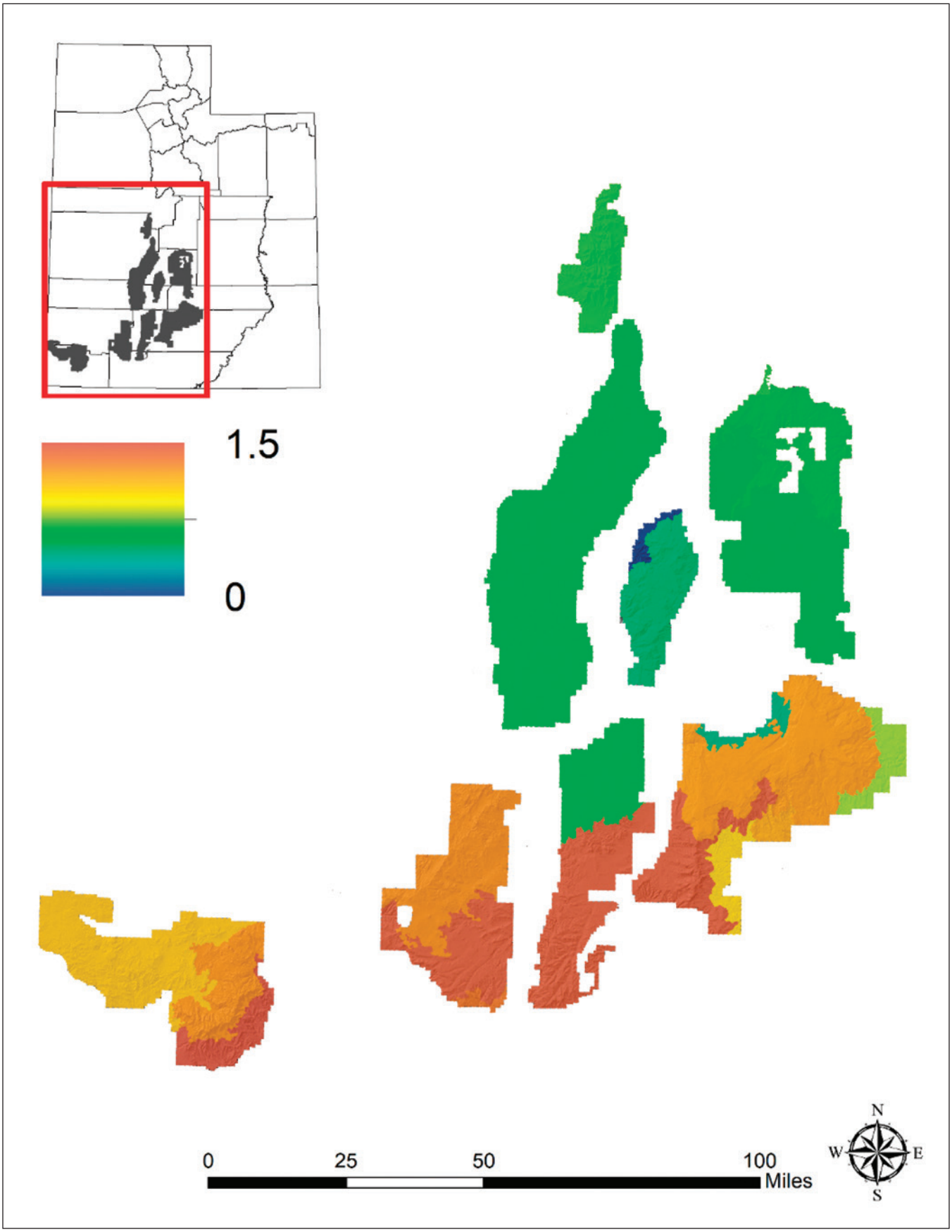


Figure H.18—Deviation in spring temperature (°F) based on TCA data from 2010 to 2014 compared to the previous century.

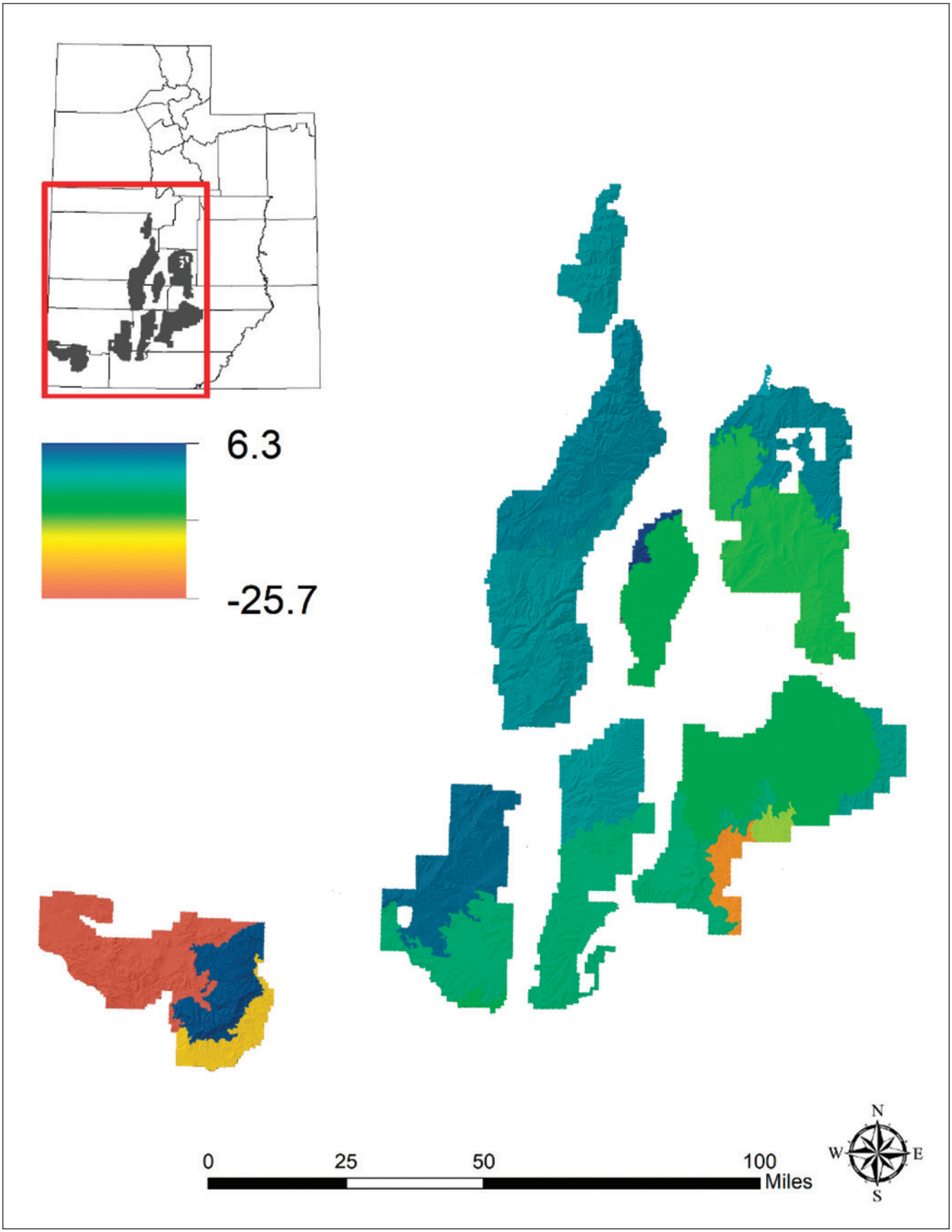


Figure H.19—Percent deviation in spring precipitation from 2010 to 2014 compared to the previous century. Based on TCA data.

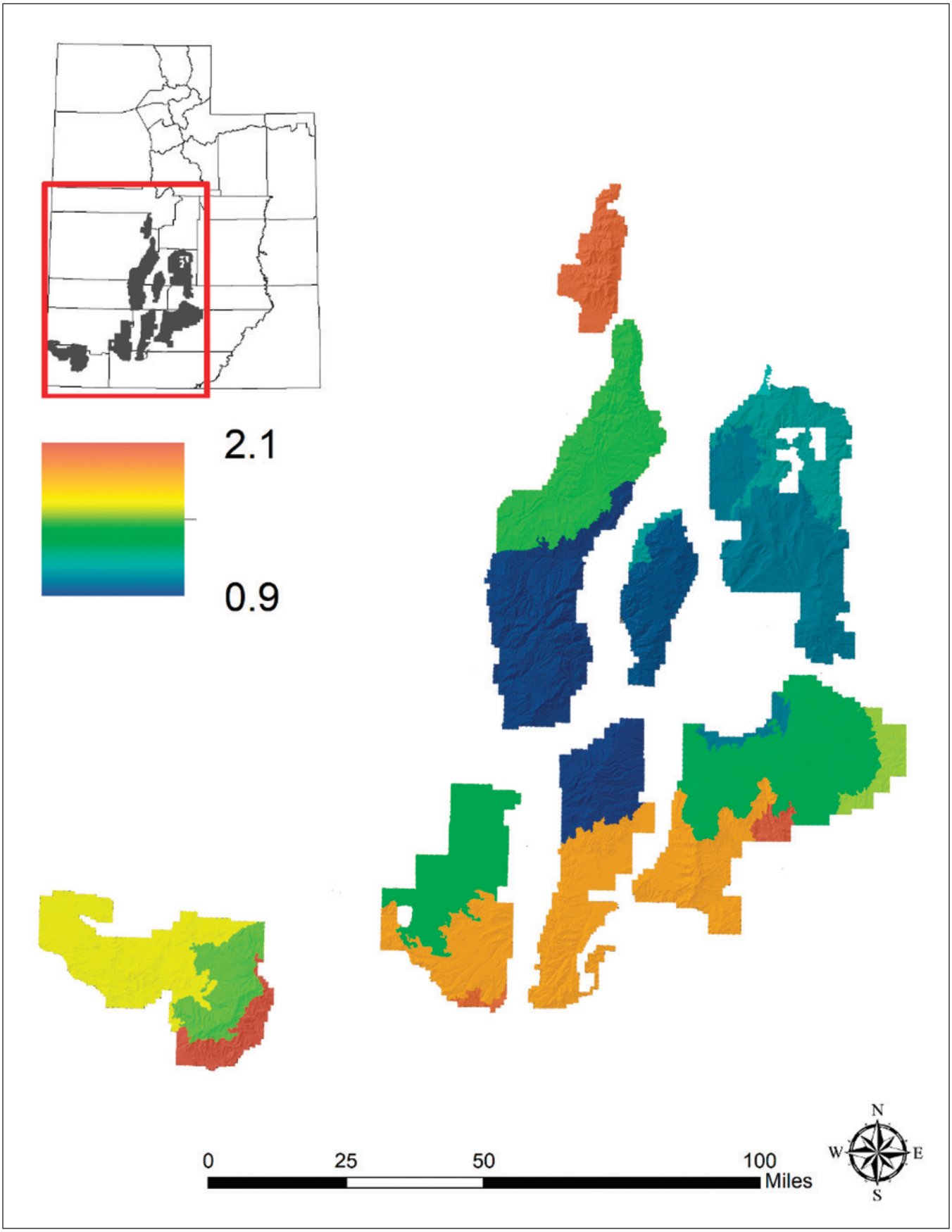


Figure H.20—Deviation in summer temperature (°F) from 2010 to 2014 compared to the previous century. Based on TCA data.

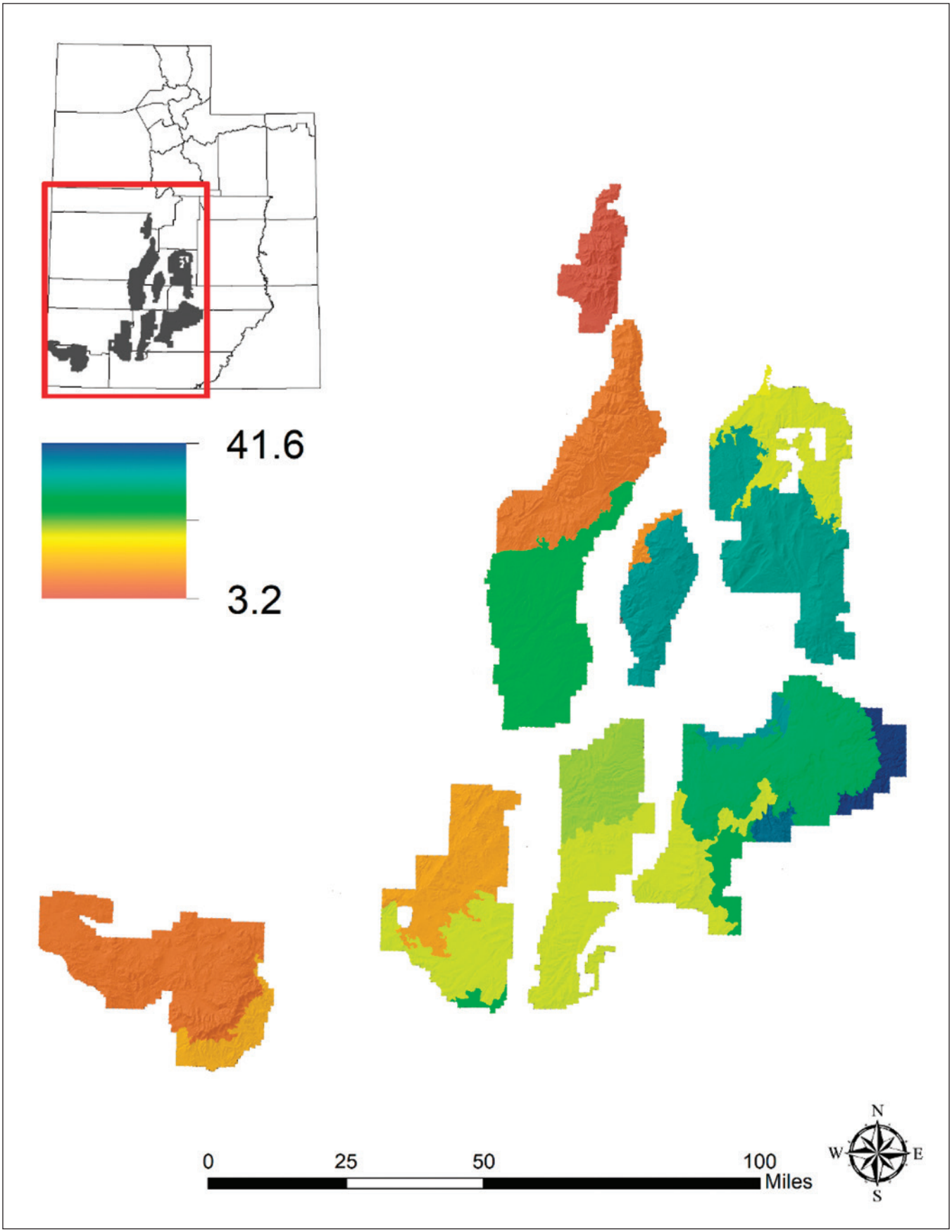


Figure H.21—Percent deviation in summer precipitation from 2010 to 2014 compared to the previous century. Based on TCA data.

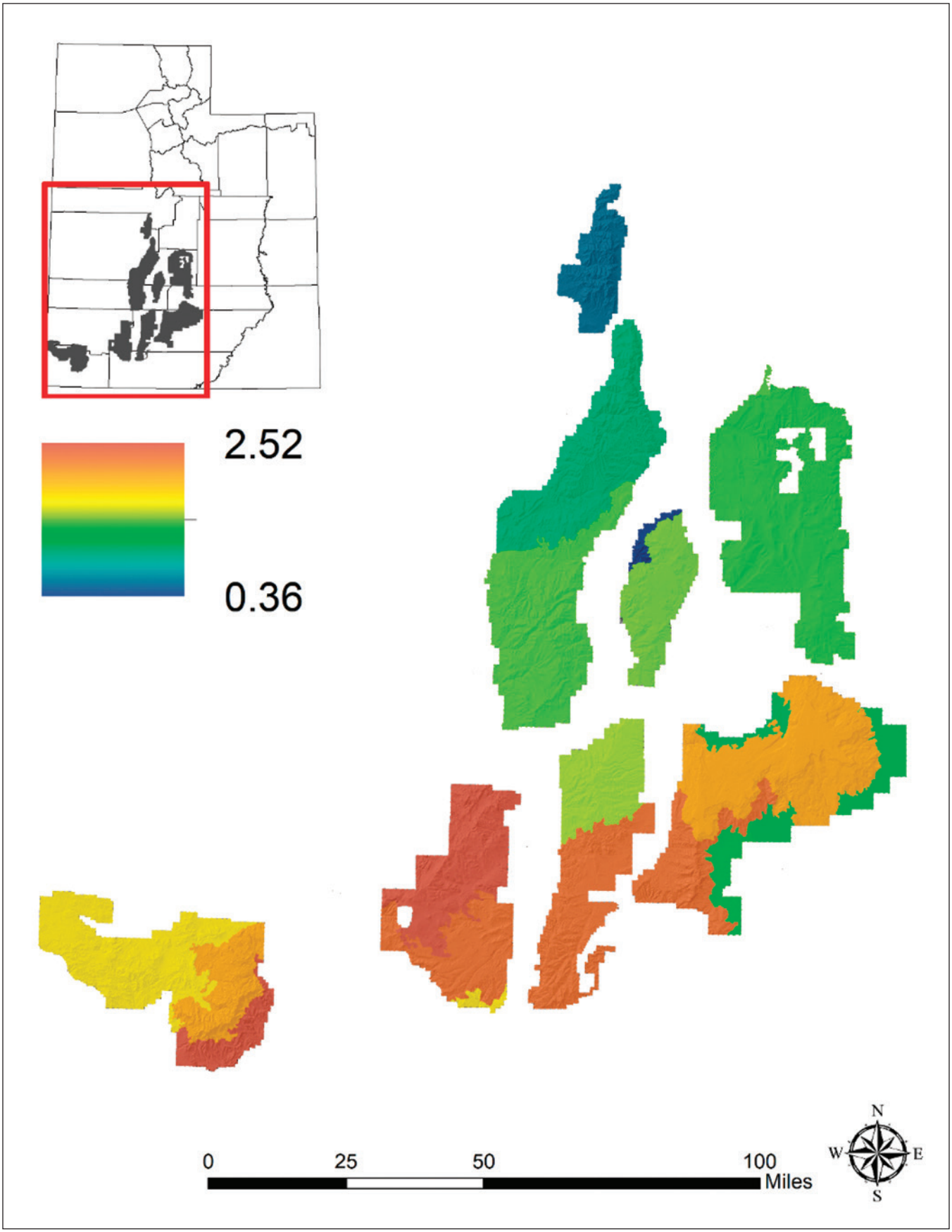


Figure H.22—Deviation in winter temperature (°F) from 2010 to 2014 compared to the previous century. Based on TCA data.

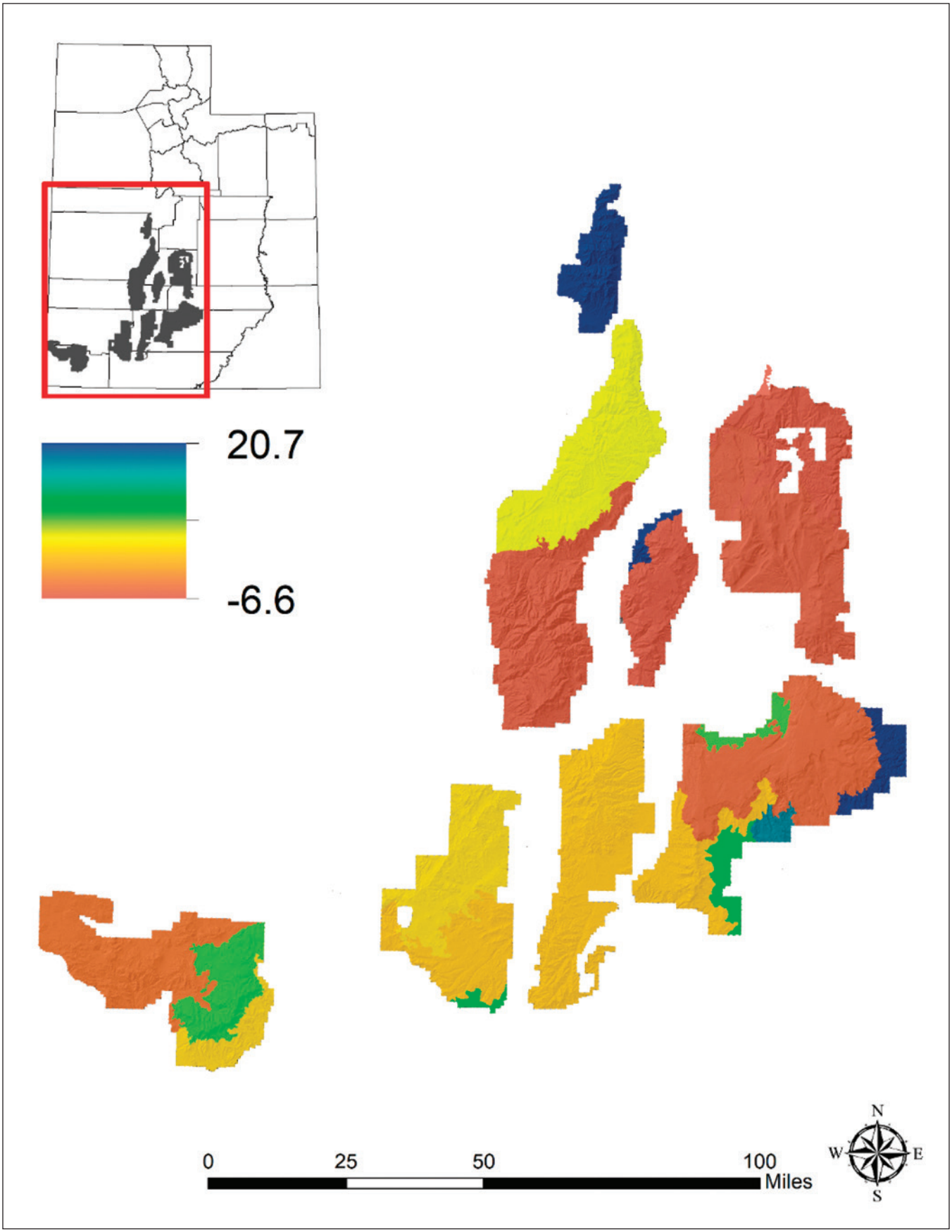


Figure H.23—Percent deviation in winter precipitation from 2010 to 2014 compared to the previous century. Based on TCA data.

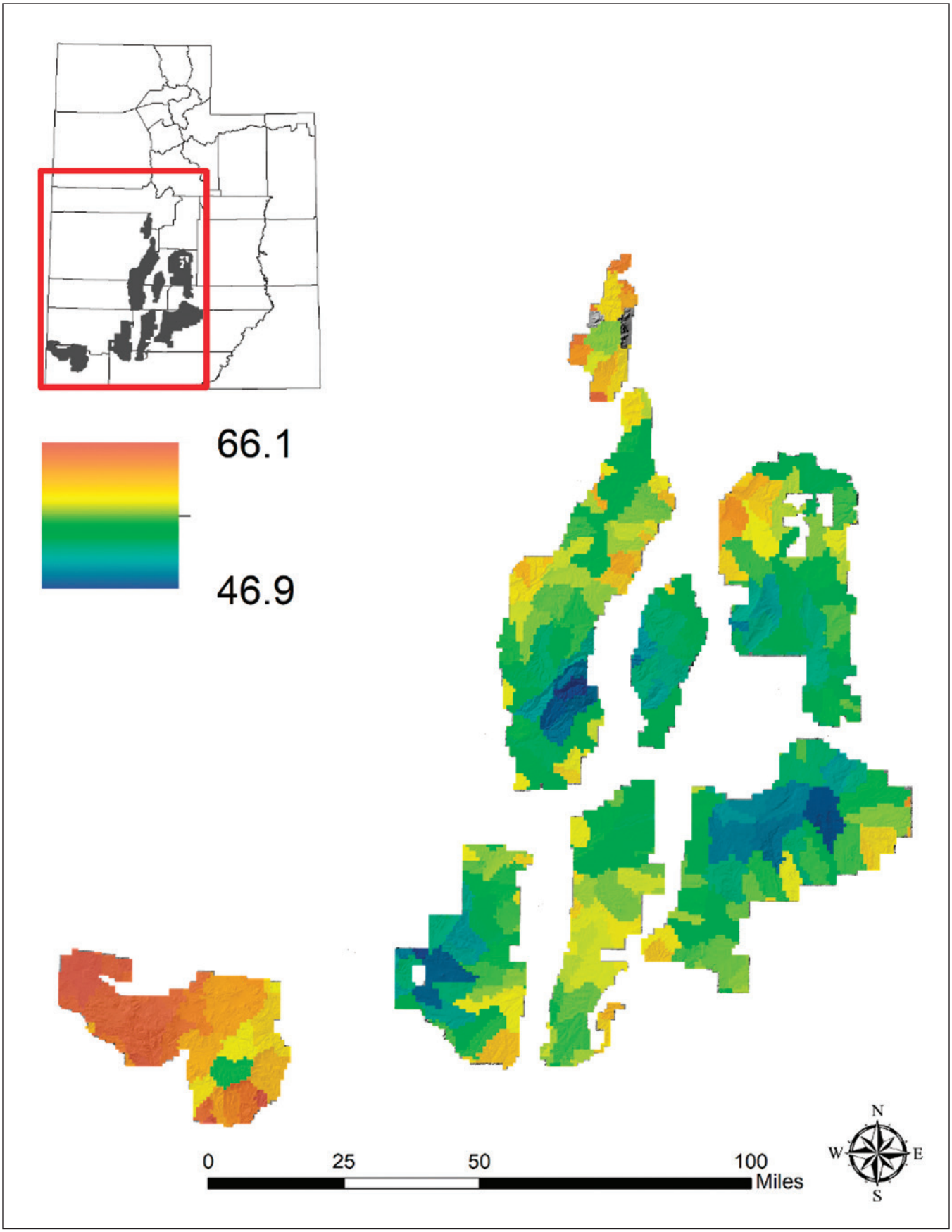


Figure H.24—Mean August stream temperature (1993–2011) within each watershed. Based on the NorWest Stream Temperature Model.

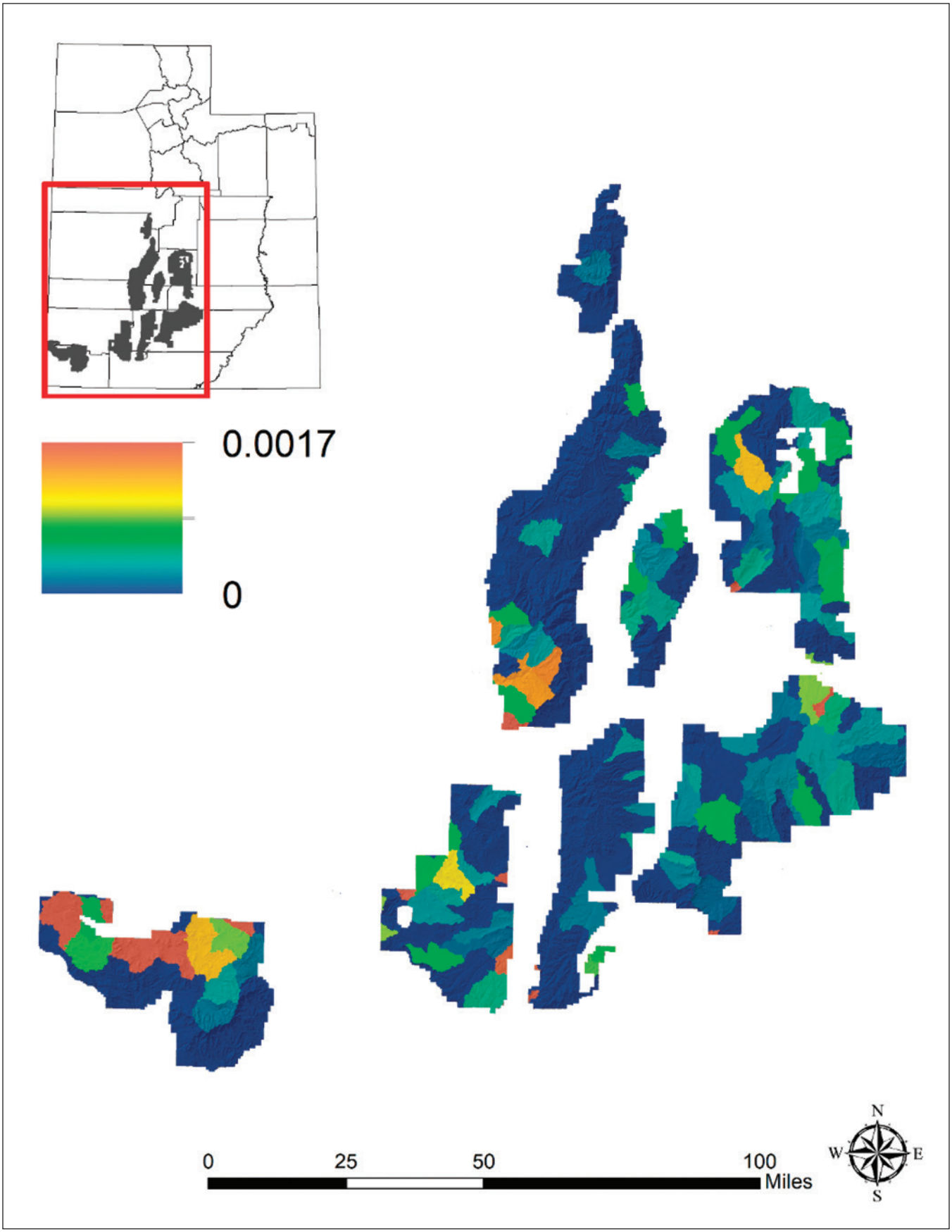


Figure H.25—Dam density (dams per stream mile) within each watershed.

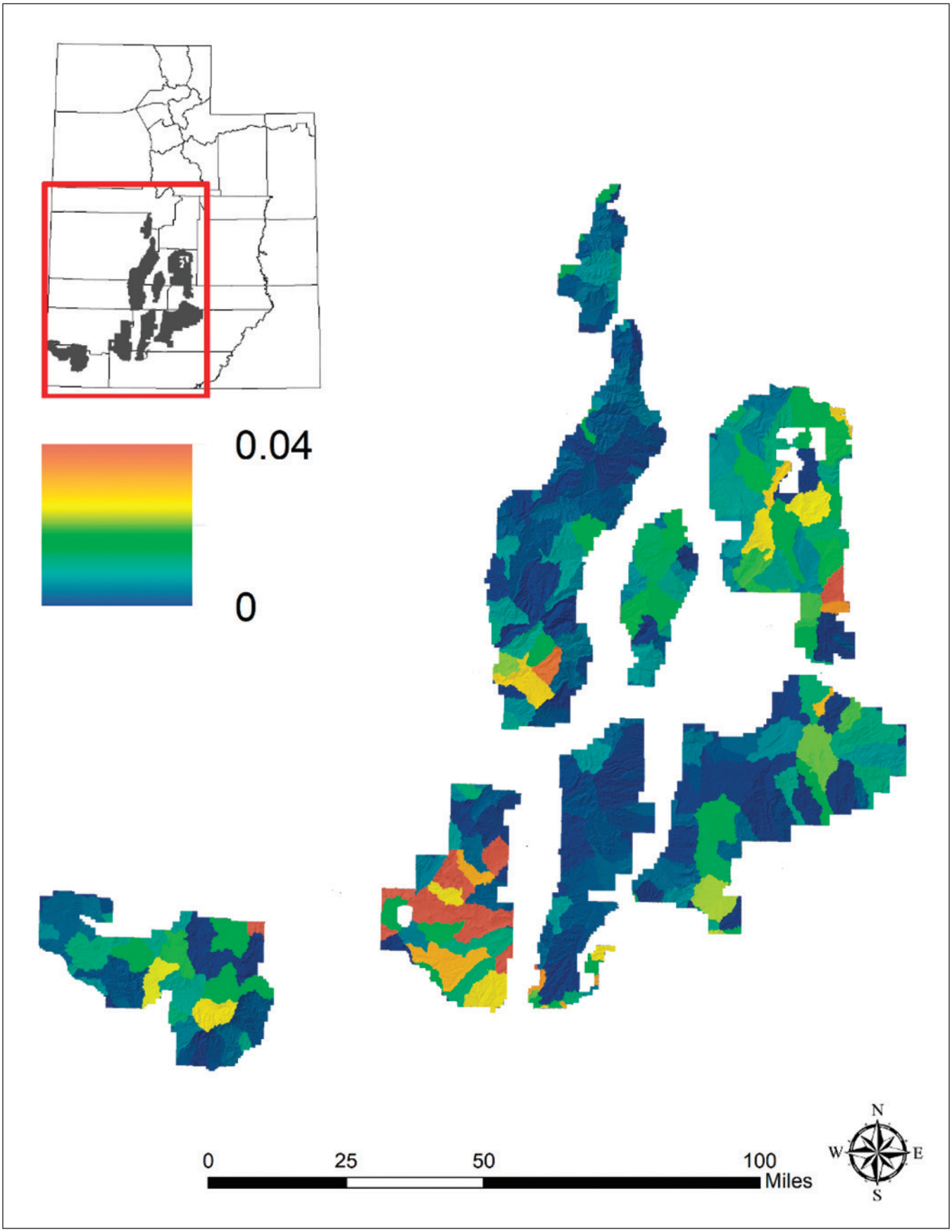


Figure H.26—Diversion density (diversions per stream mile) within each watershed. Based on Utah POD data.

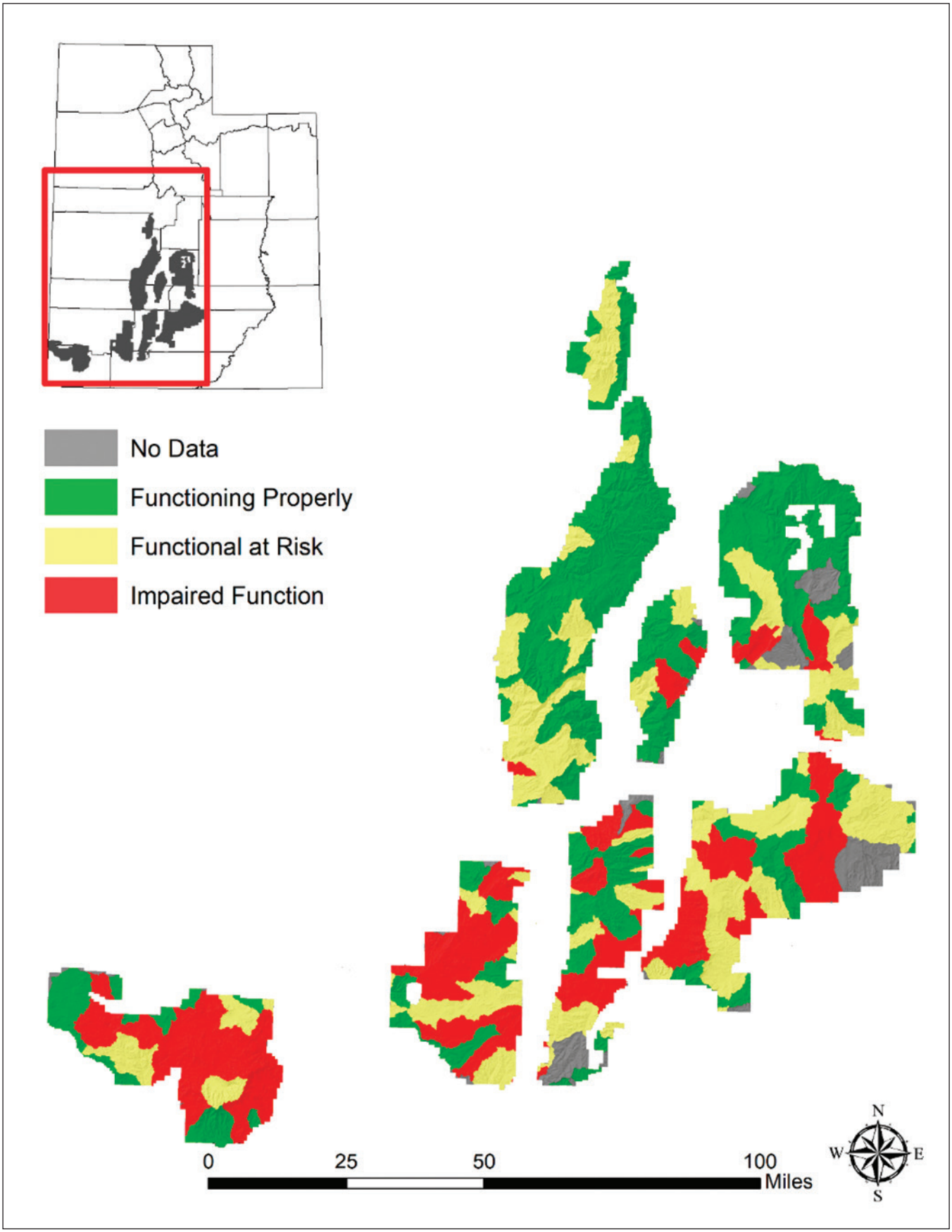


Figure H.27—Condition of natural flow regimes based on the WCF flow characteristics data.

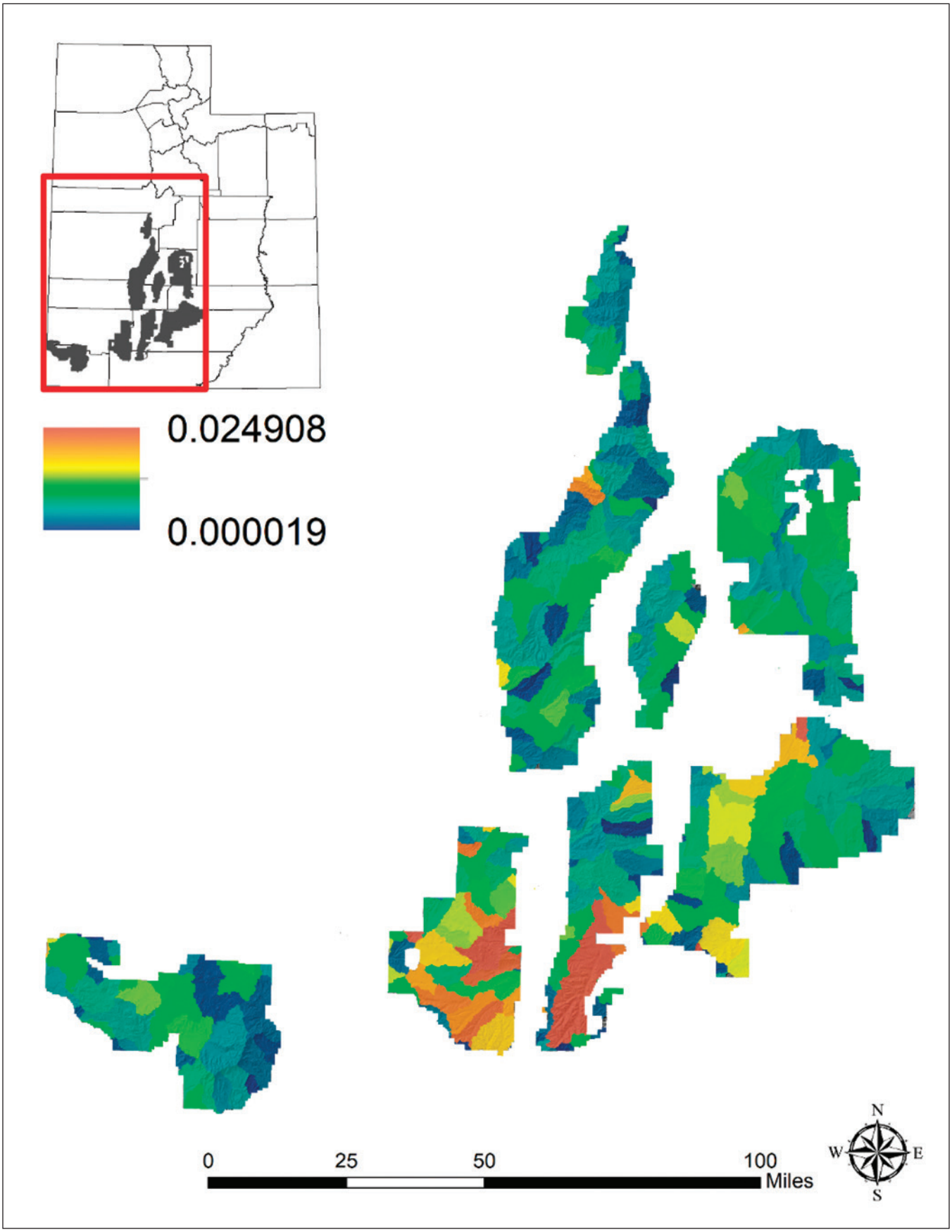


Figure H.28--Road density (miles per acre) within each watershed.

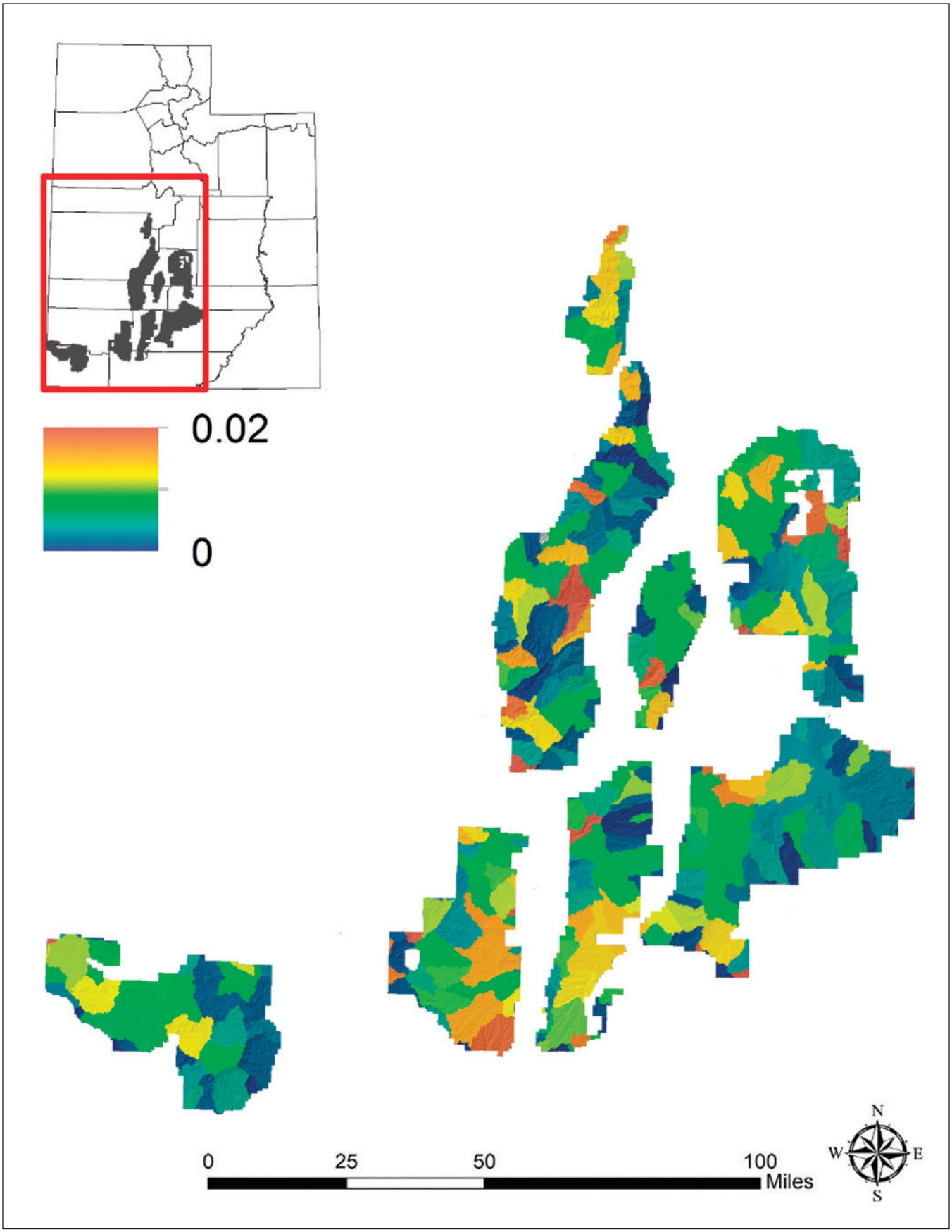


Figure H.29—Density of roads within the 50-year floodplain (miles per acre) within each watershed.

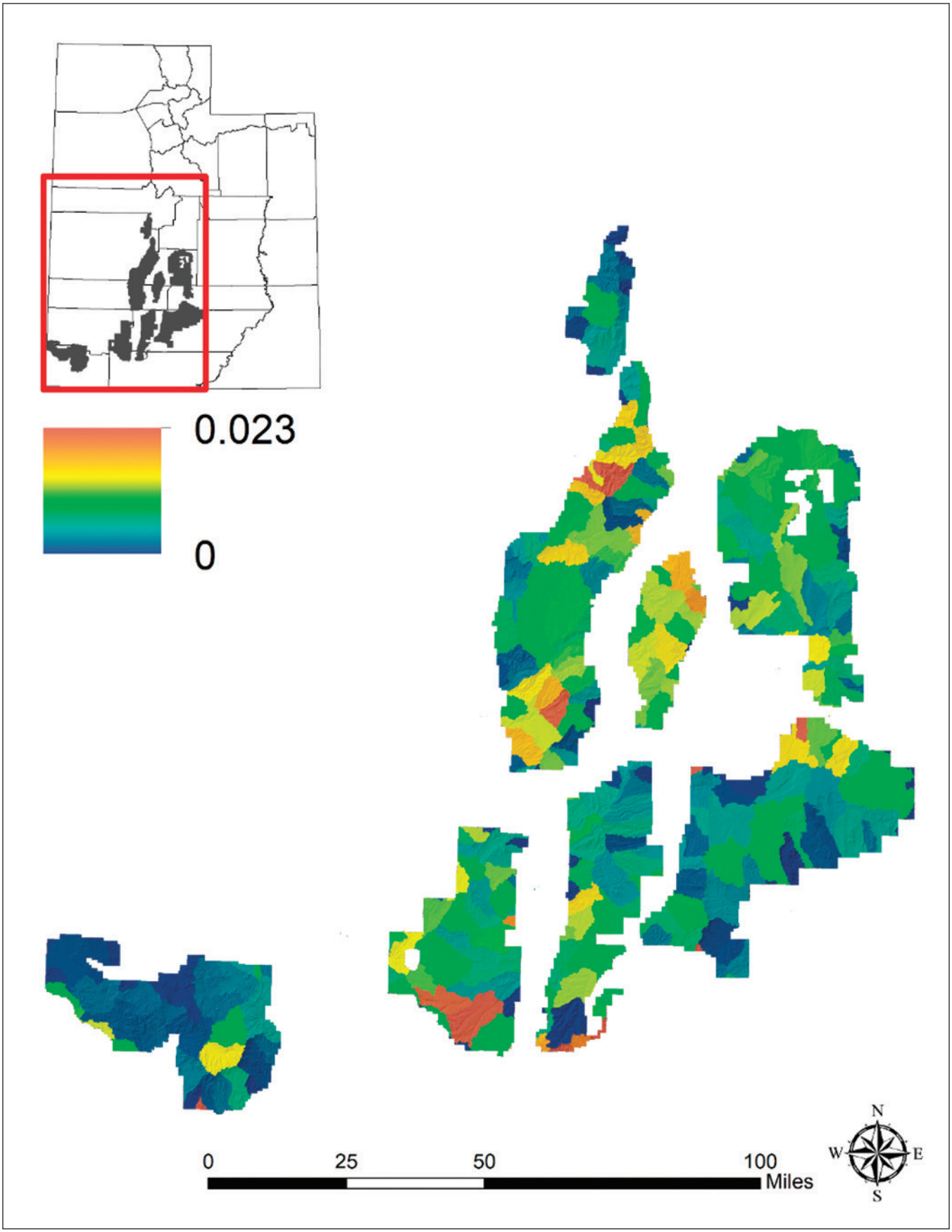


Figure H.30—Trail density (miles per acre) within each watershed.

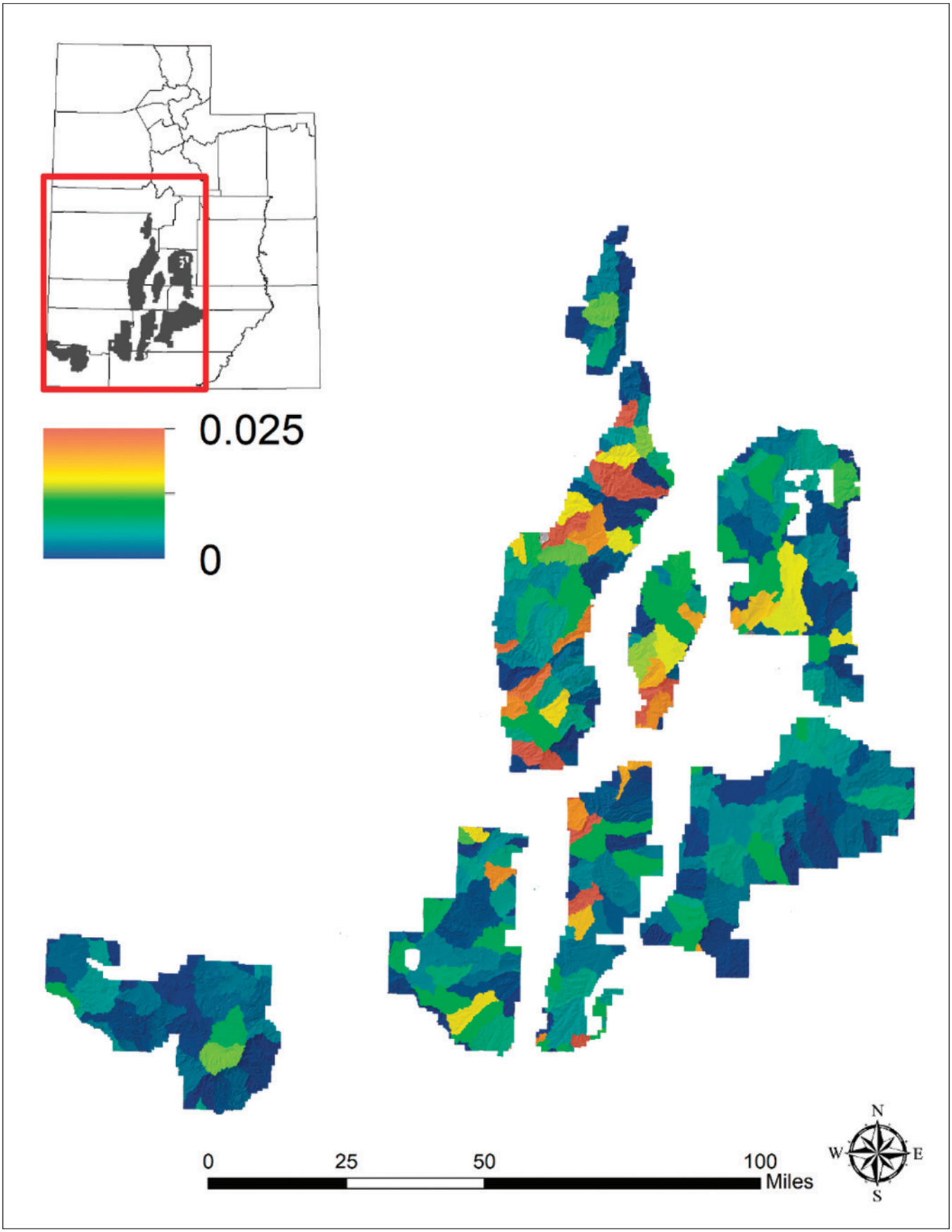


Figure H.31—Density of trails within the 50-year floodplain (miles per acre) within each watershed.

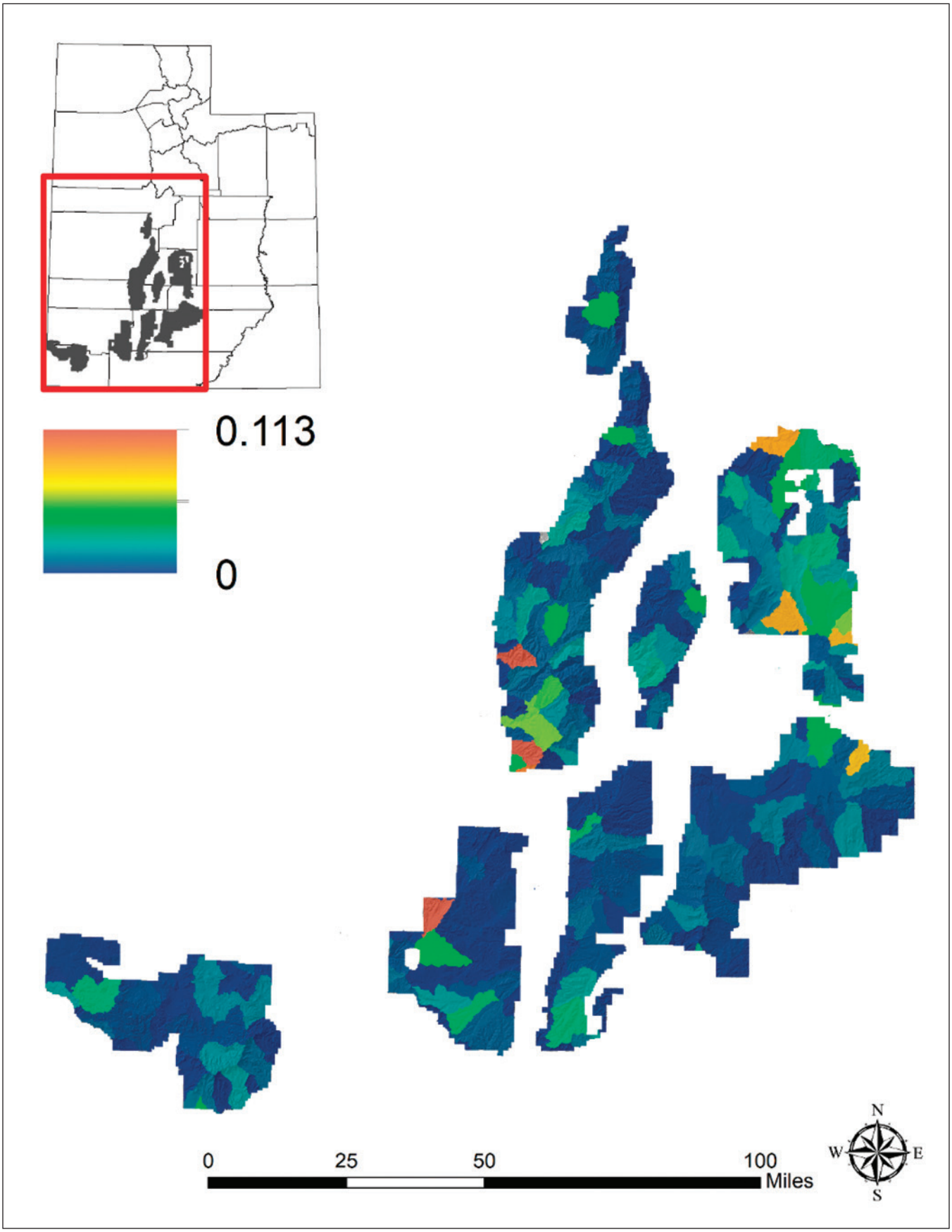


Figure H.32—Density of recreation sites within the 50-year floodplain (sites per acre) in each watershed.

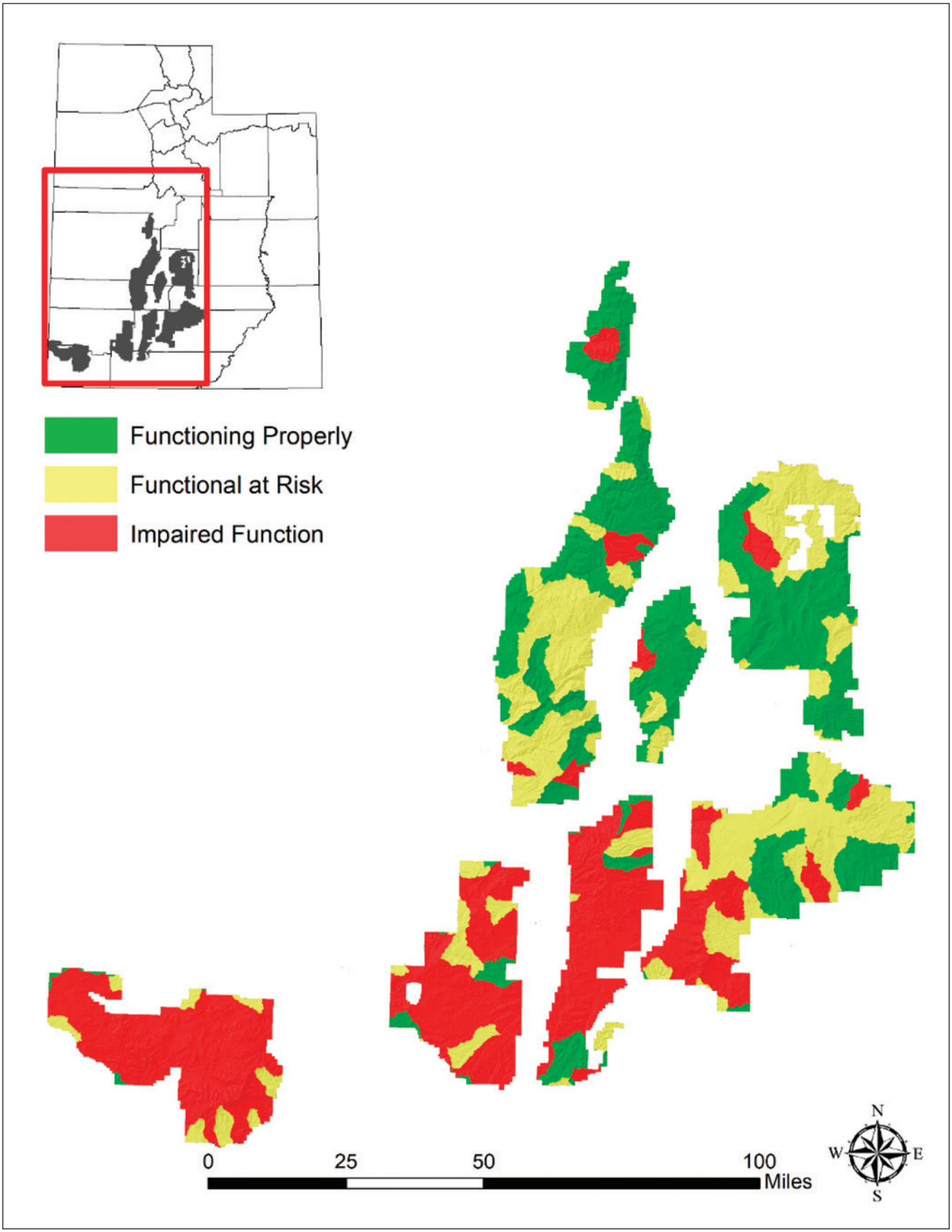


Figure H.33—The level of change to hydrologic and sediment regimes due to the density, location, distribution, and maintenance of the road and trail network. Based on WCF data.

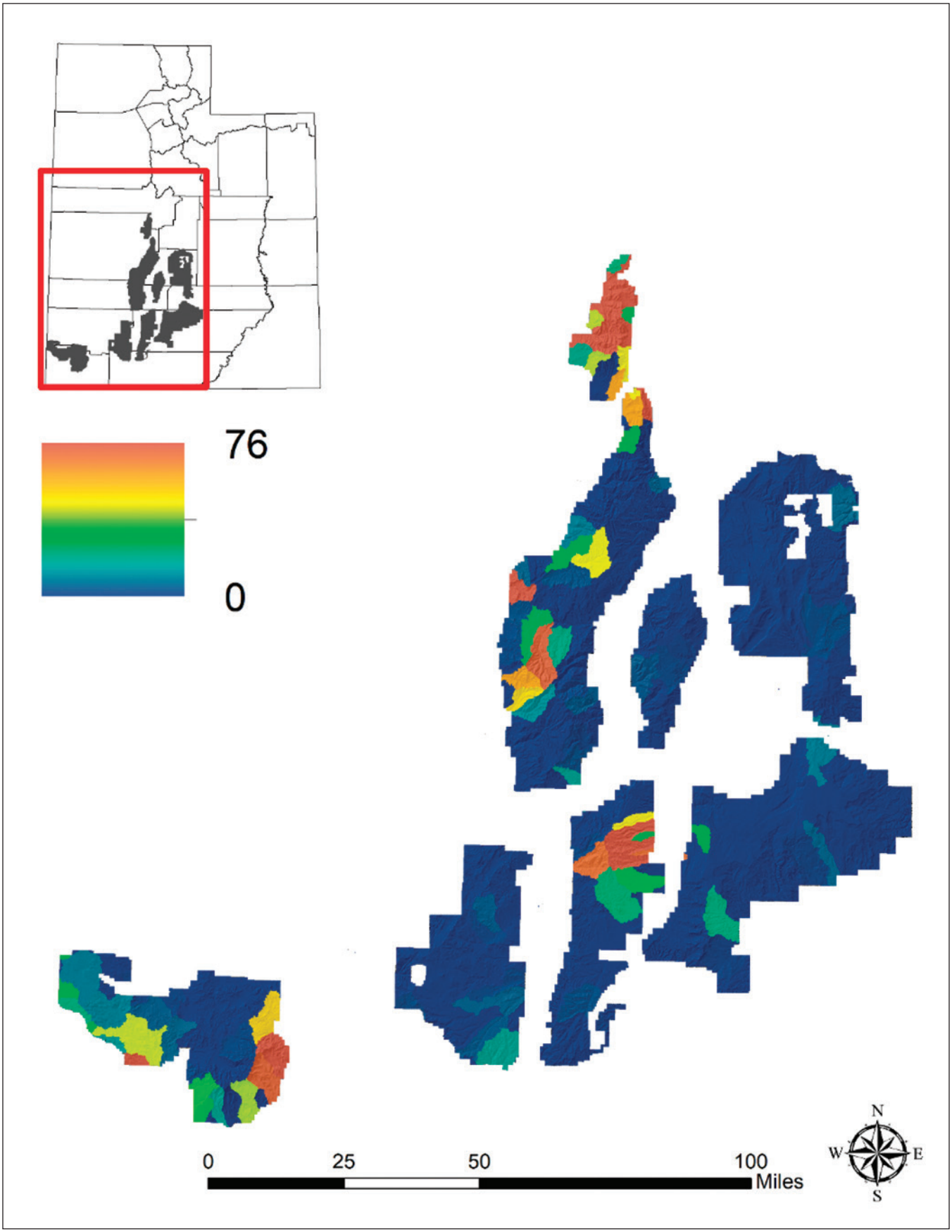


Figure H.34—Percentage of floodplain burned by moderate to high severity fire between 1984 and 2014, based on TCA data.

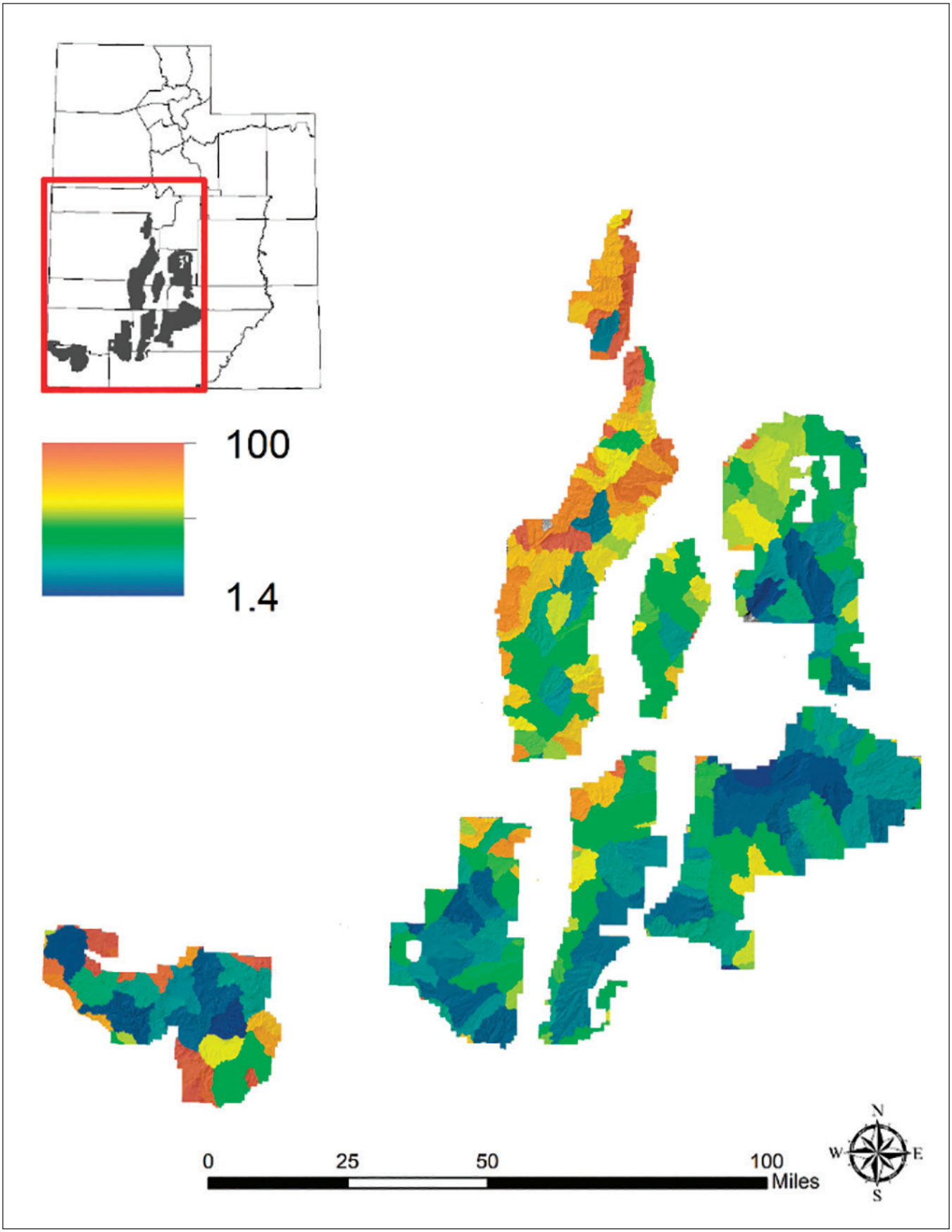


Figure H.35—Percentage of floodplain with high or very high wildfire potential, based on TCA data.

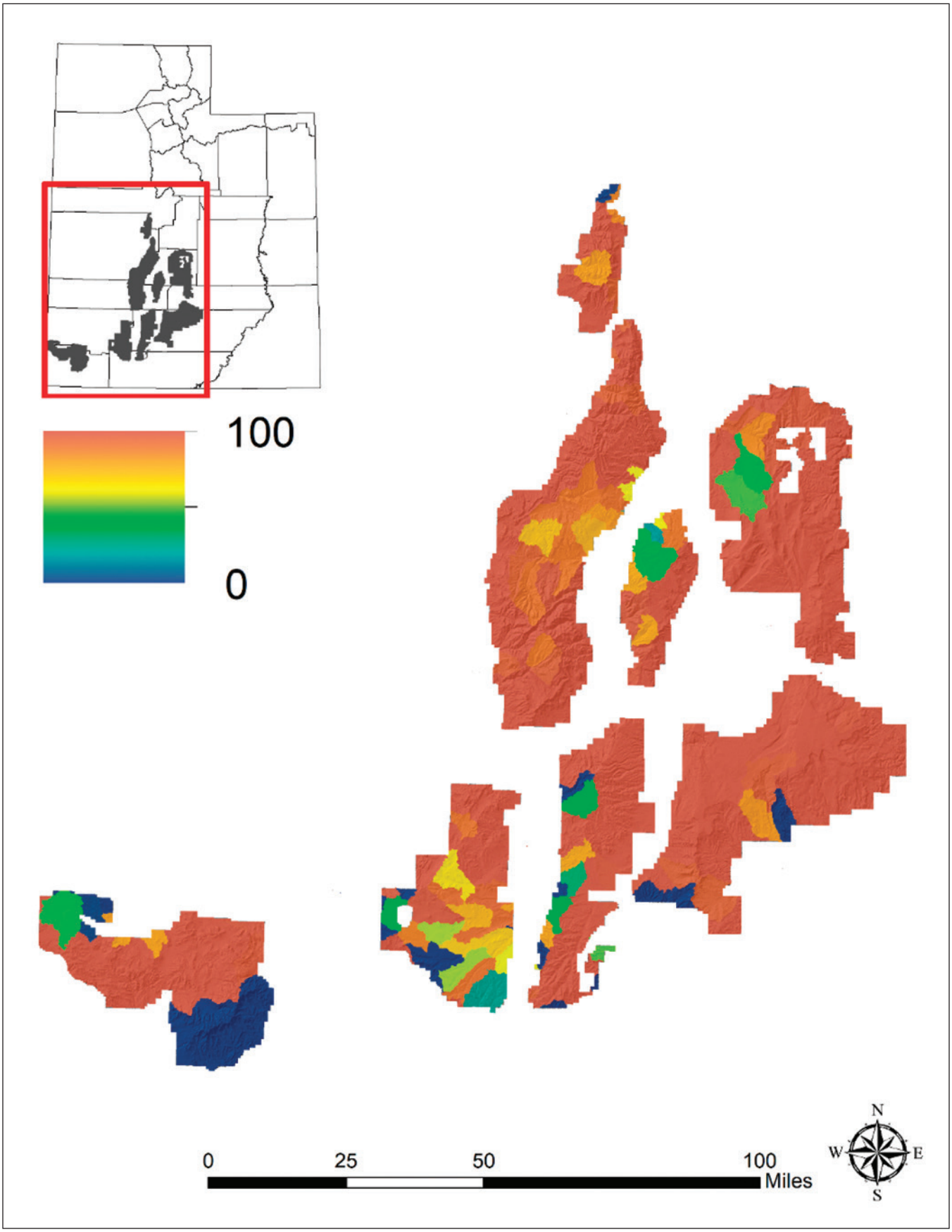


Figure H.36—Percent of watershed located within a range management unit.

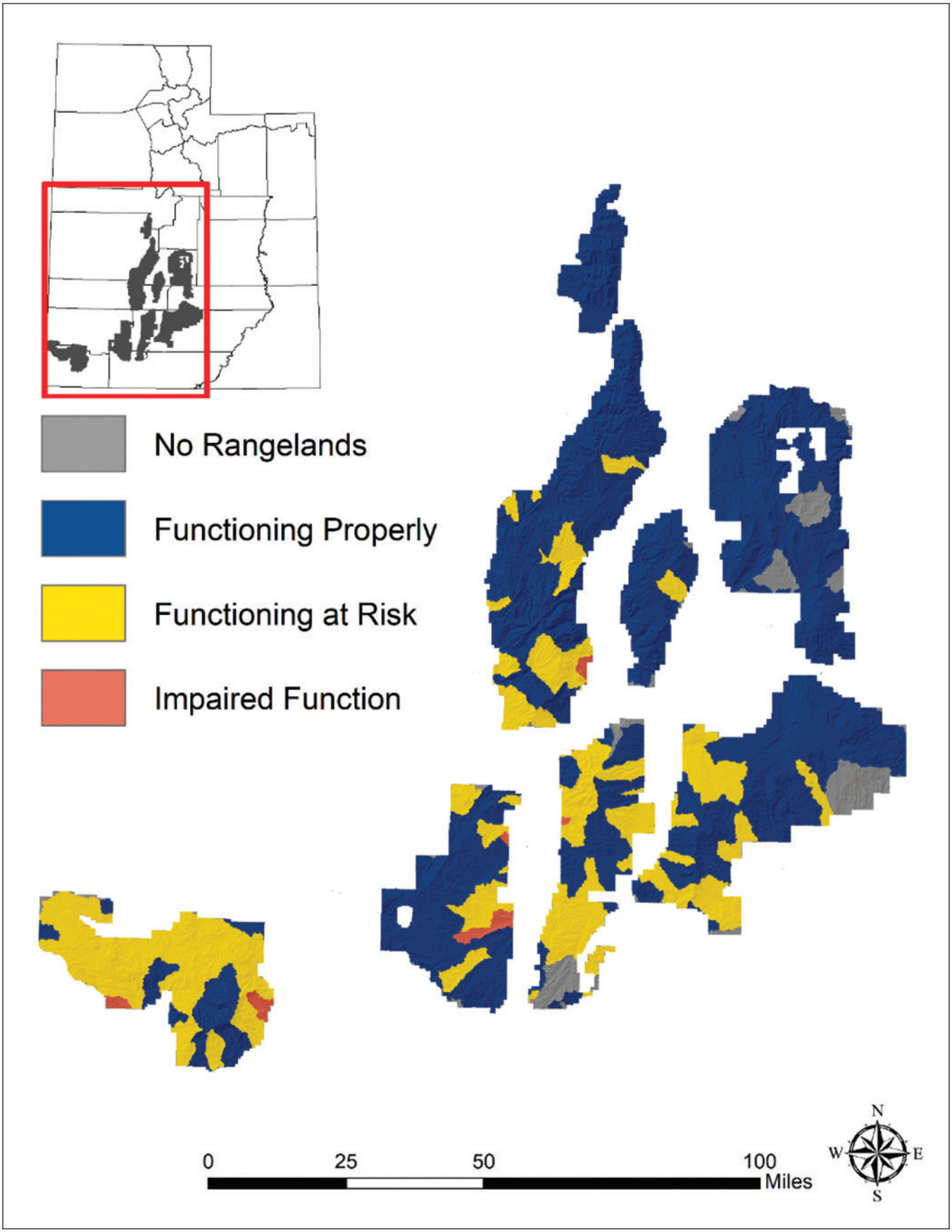


Figure H.37—Condition of rangelands within each watershed unit based on WCF data.

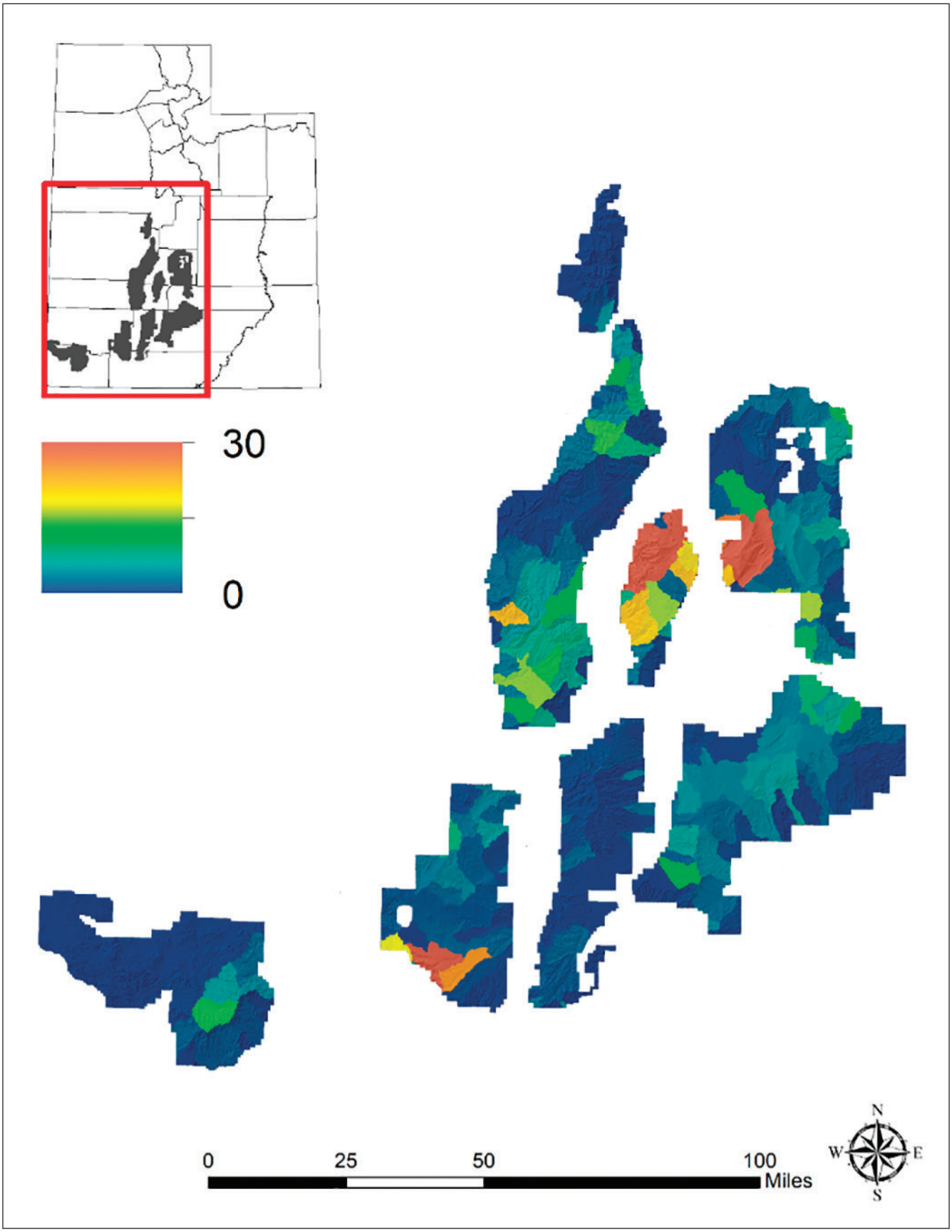


Figure H.38—Percent of unit impacted by tree mortality and defoliation. Based on TCA data.

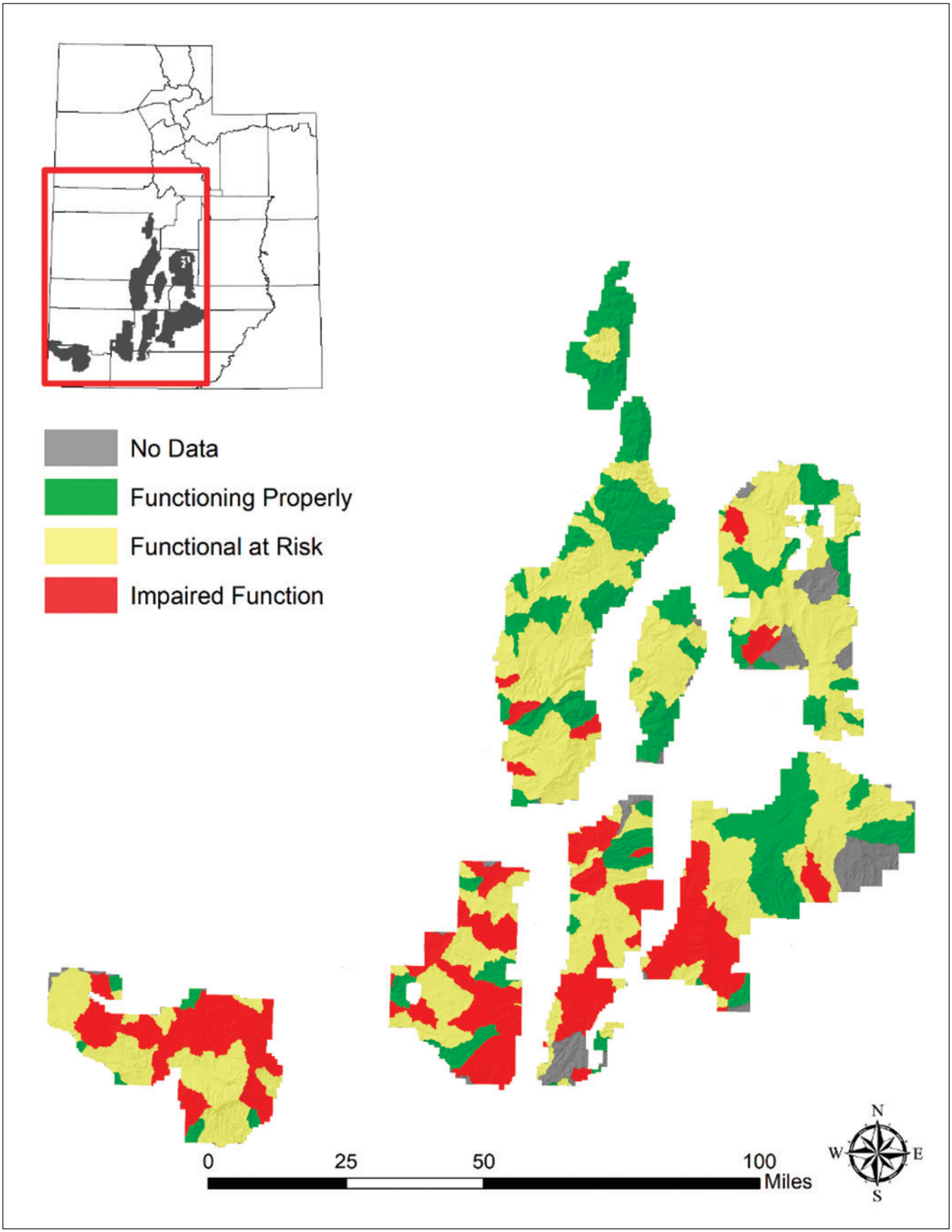


Figure H.39—The condition of channel shape and function based on WCF data.

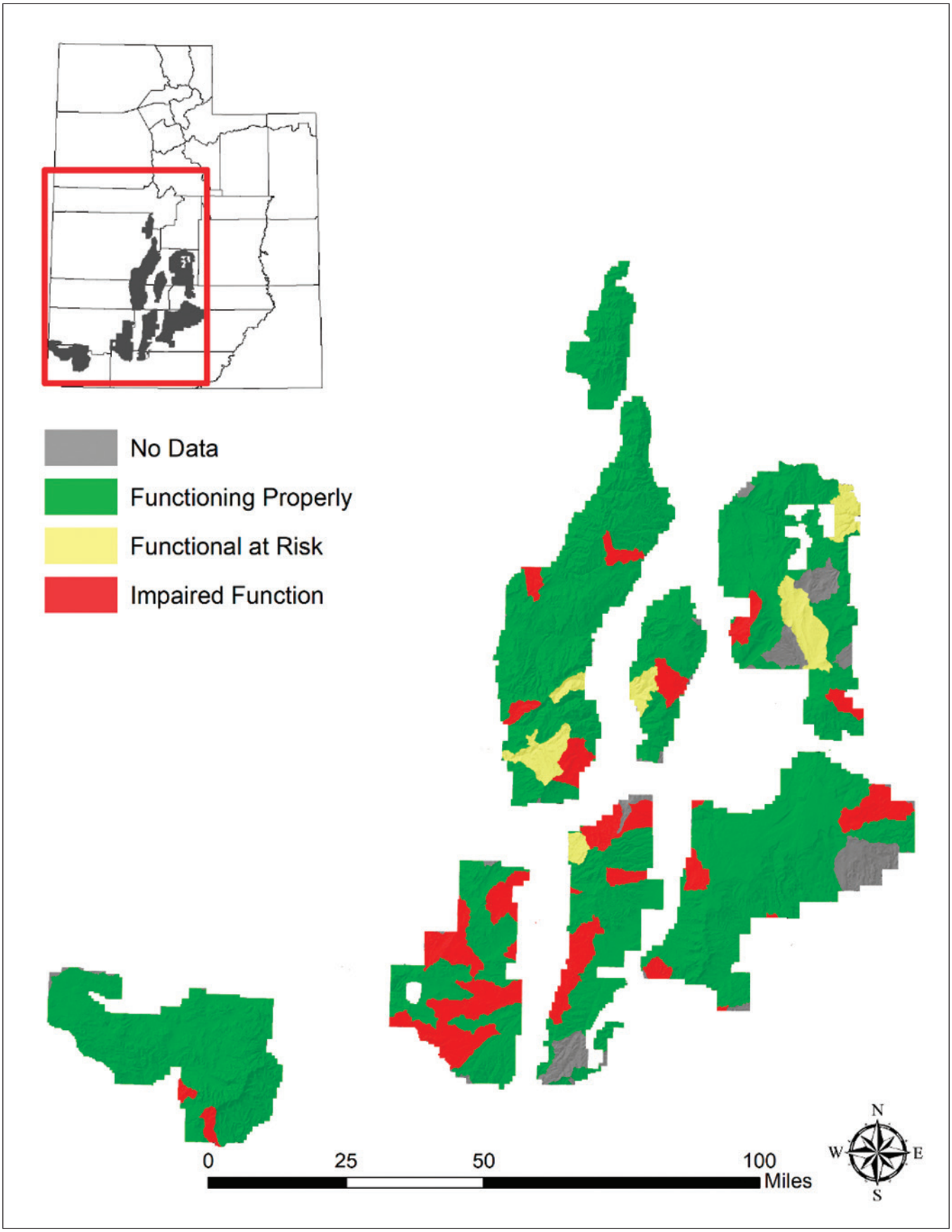


Figure H.40—The condition of classified impaired waters based on WCF data.

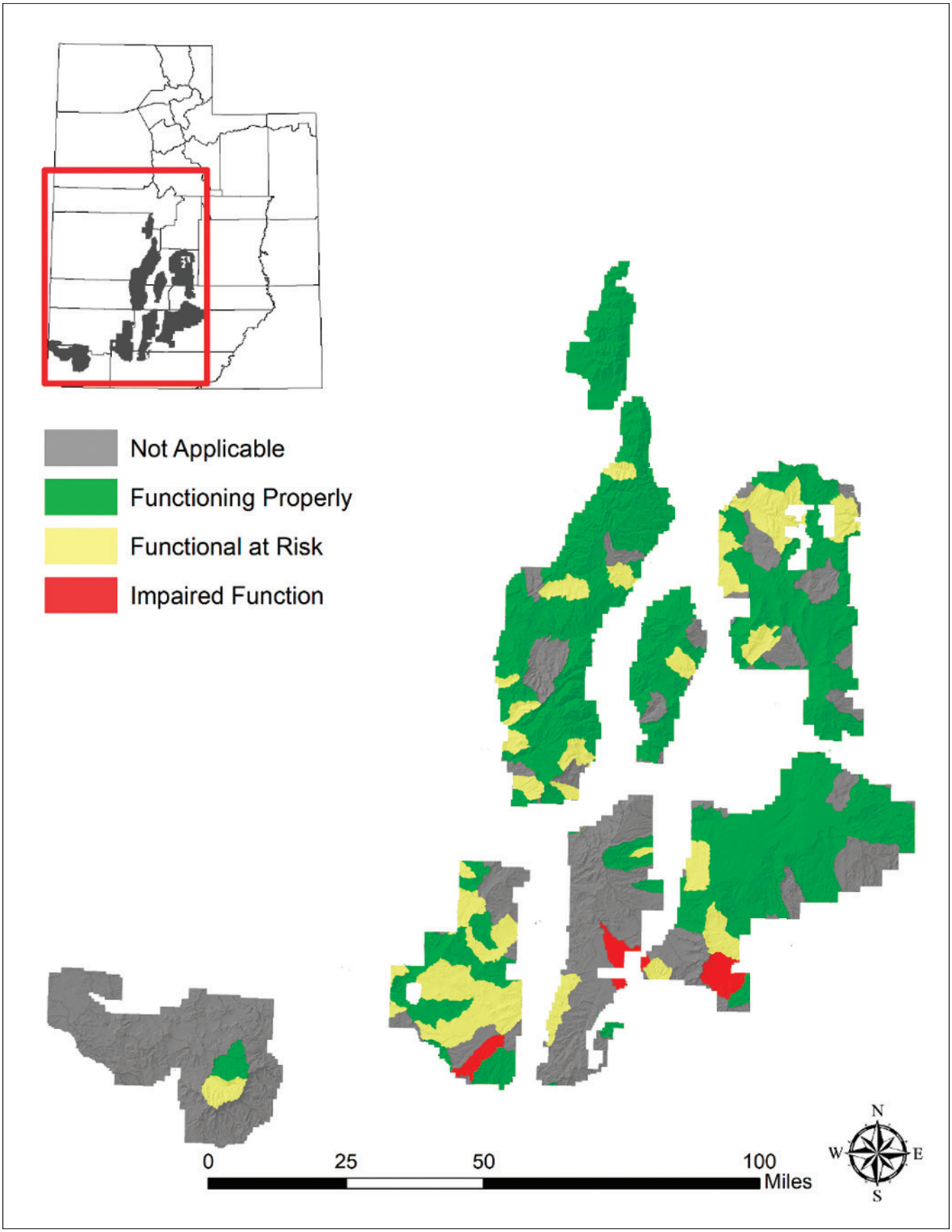


Figure H.41—Whether large woody debris is present and continues to be recruited at appropriate rates to systems that evolved with wood near the stream. Based on WCF data.

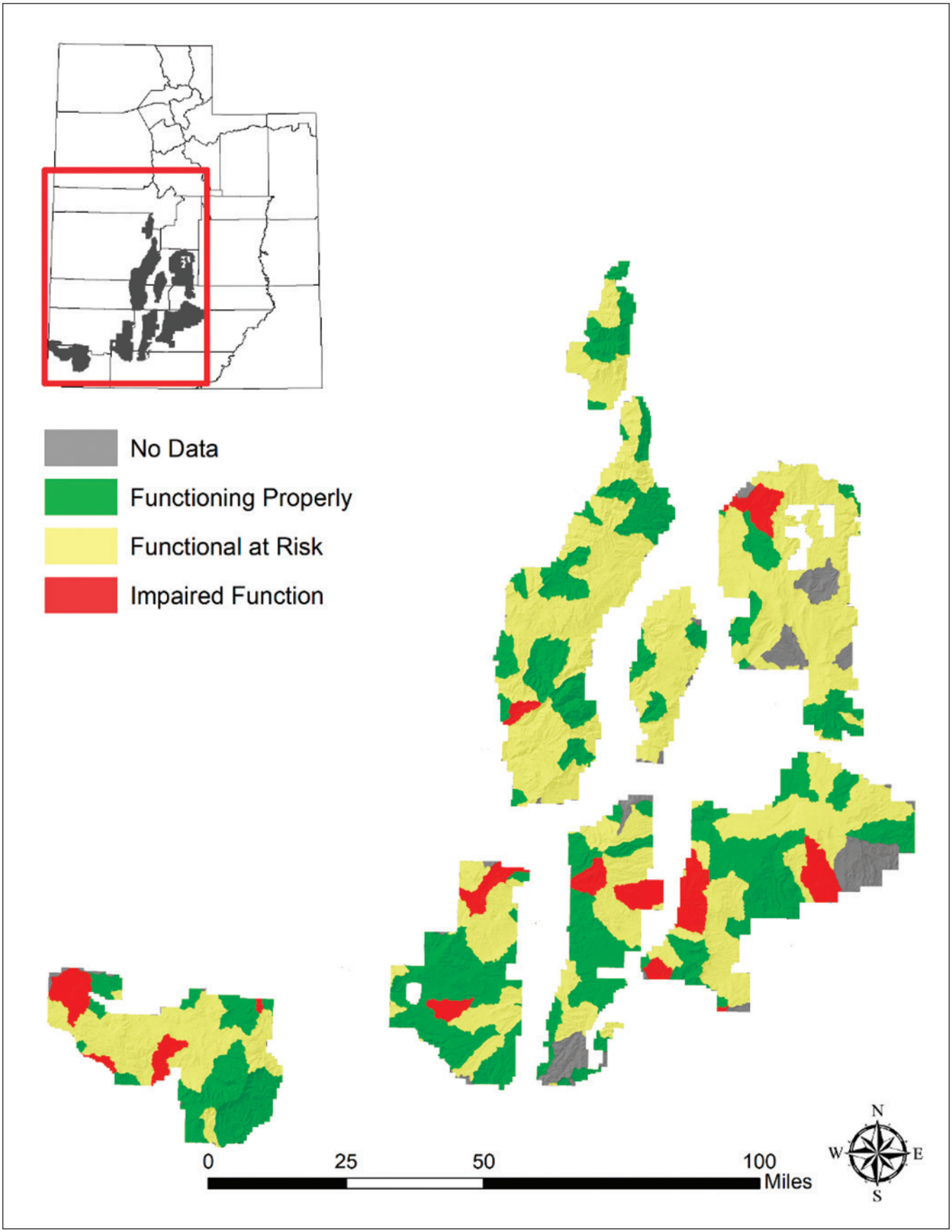


Figure H.42—The condition of native riparian vegetation along streams, water bodies, and wetlands based on WCF data.

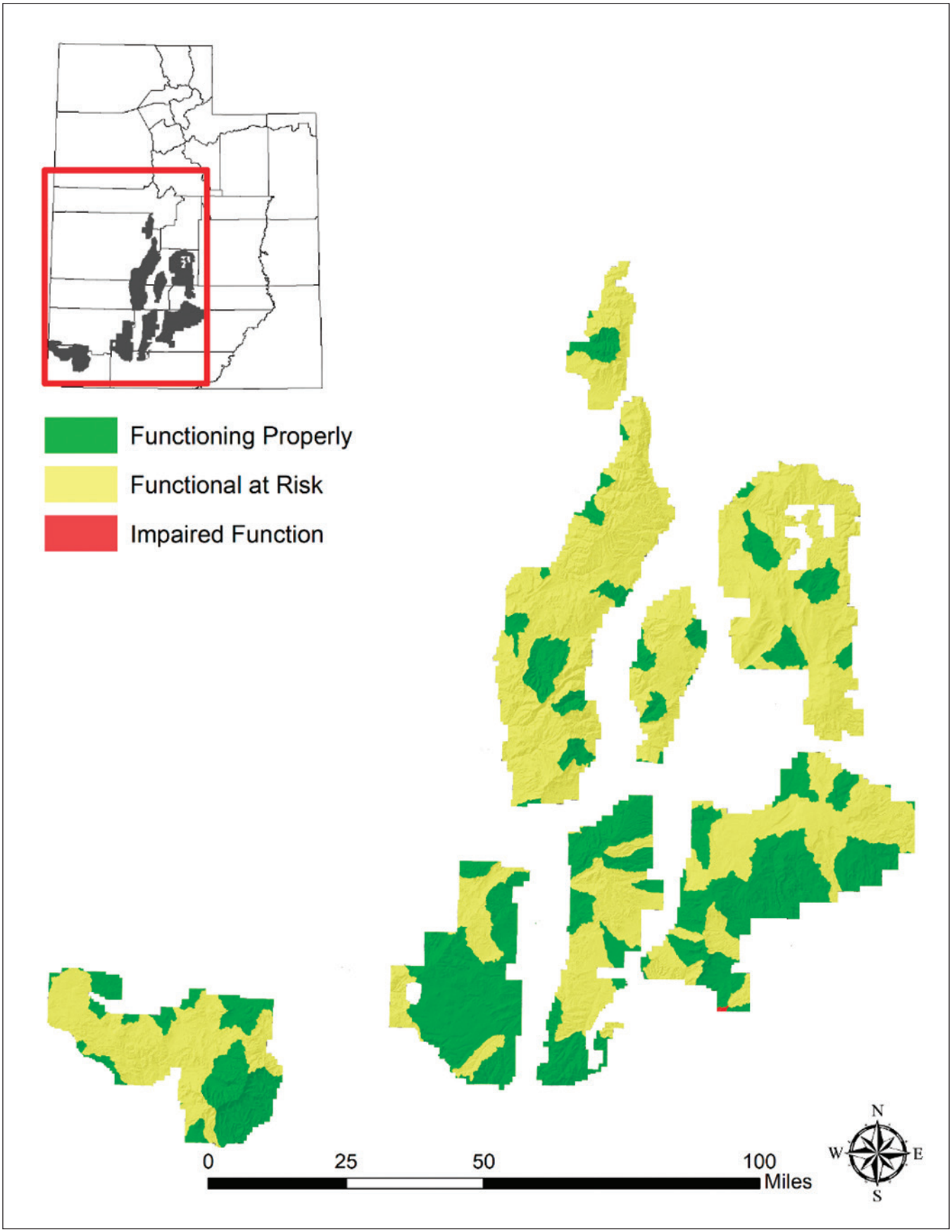


Figure H.43—Alterations to natural soil condition, including productivity, erosion, and chemical contamination based on WCF data.

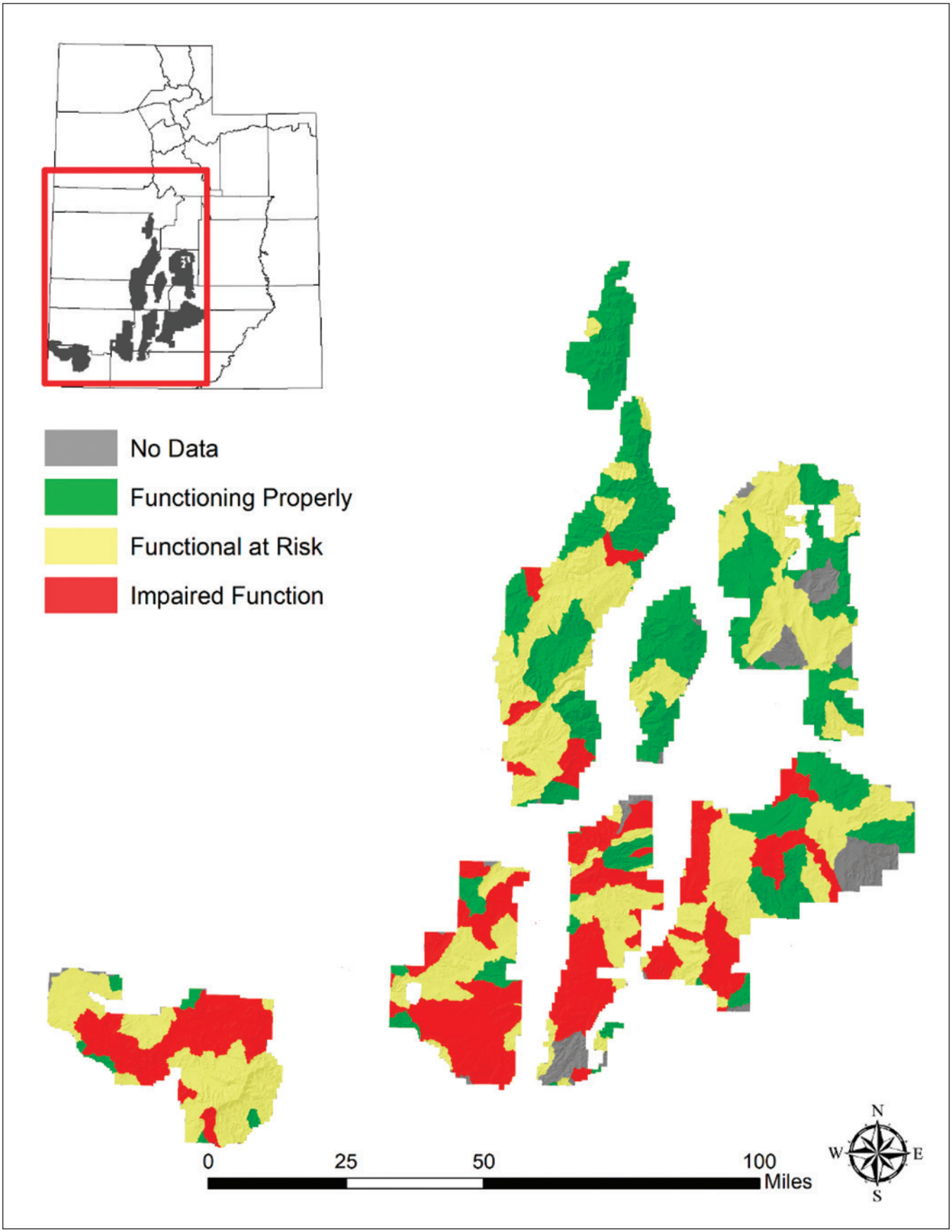


Figure H.44—Level of water quality problems including excessive sediment, nutrients, or chemical pollution based on WCF data.

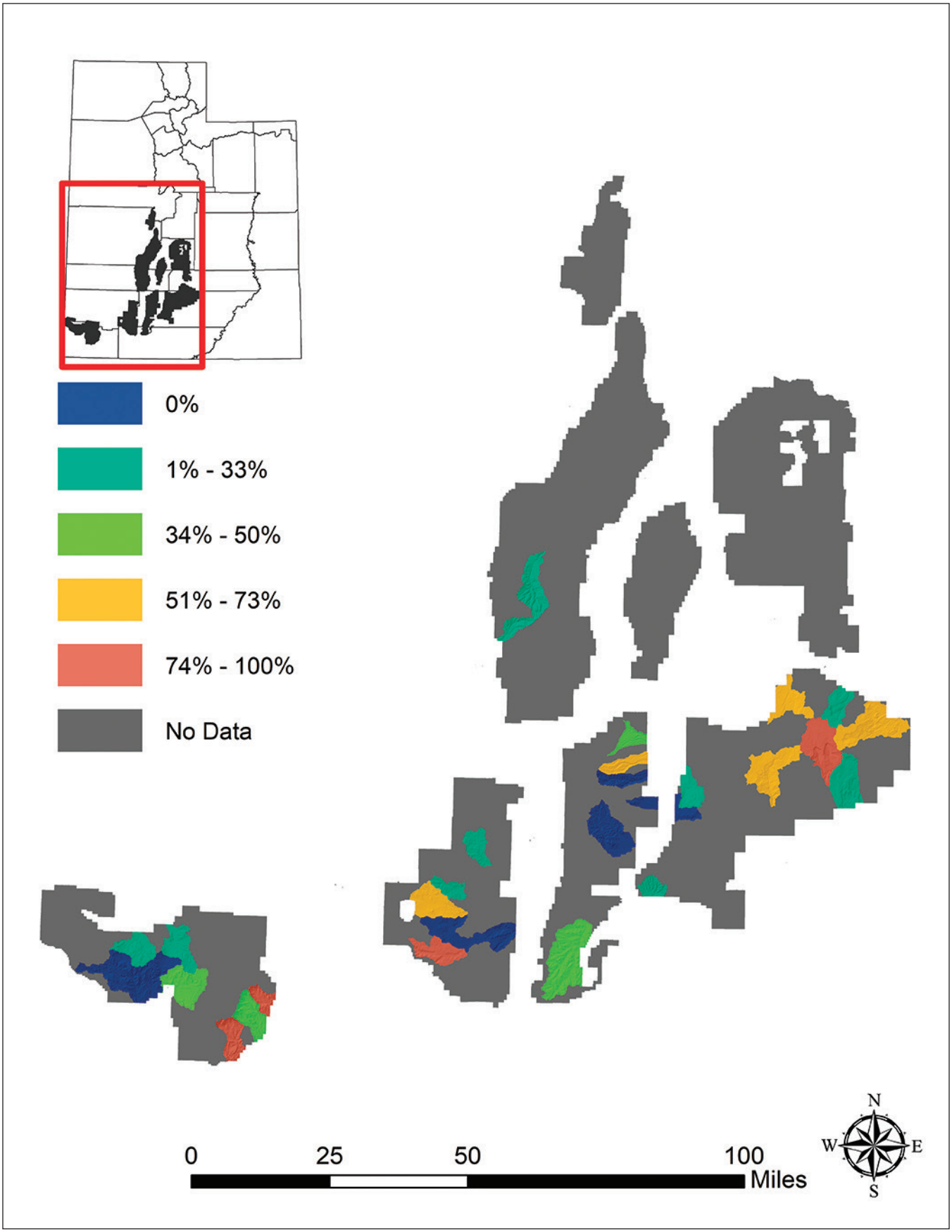


Figure H.45—Percentage of level II riparian survey reaches in HUC 12 watersheds classified as late seral or PNC in the DNF and Boulder Mountain unit of the FNF.

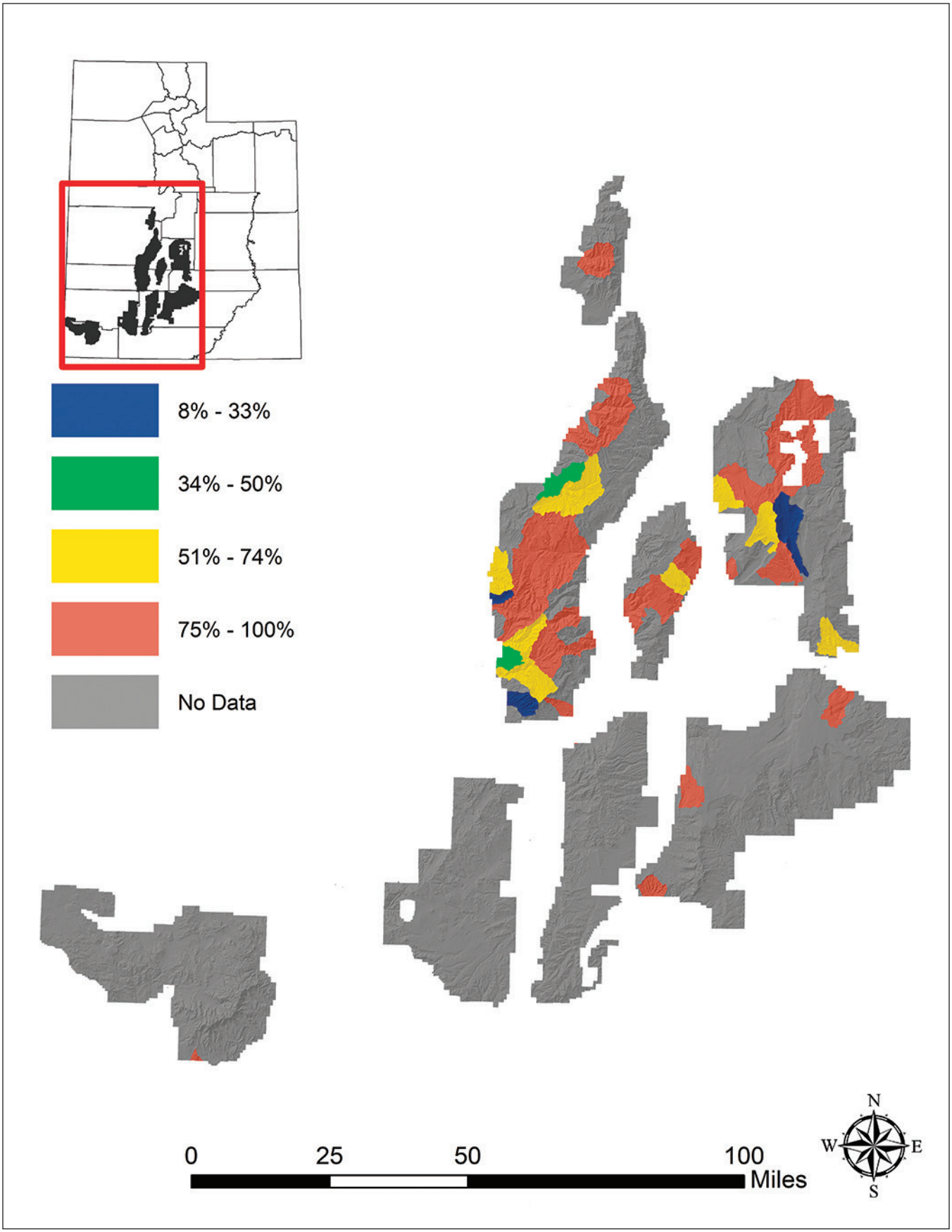


Figure H.46—Percentage of level II riparian survey reaches in HUC 12 watersheds classified as stable or upward forage trend in the FNF.

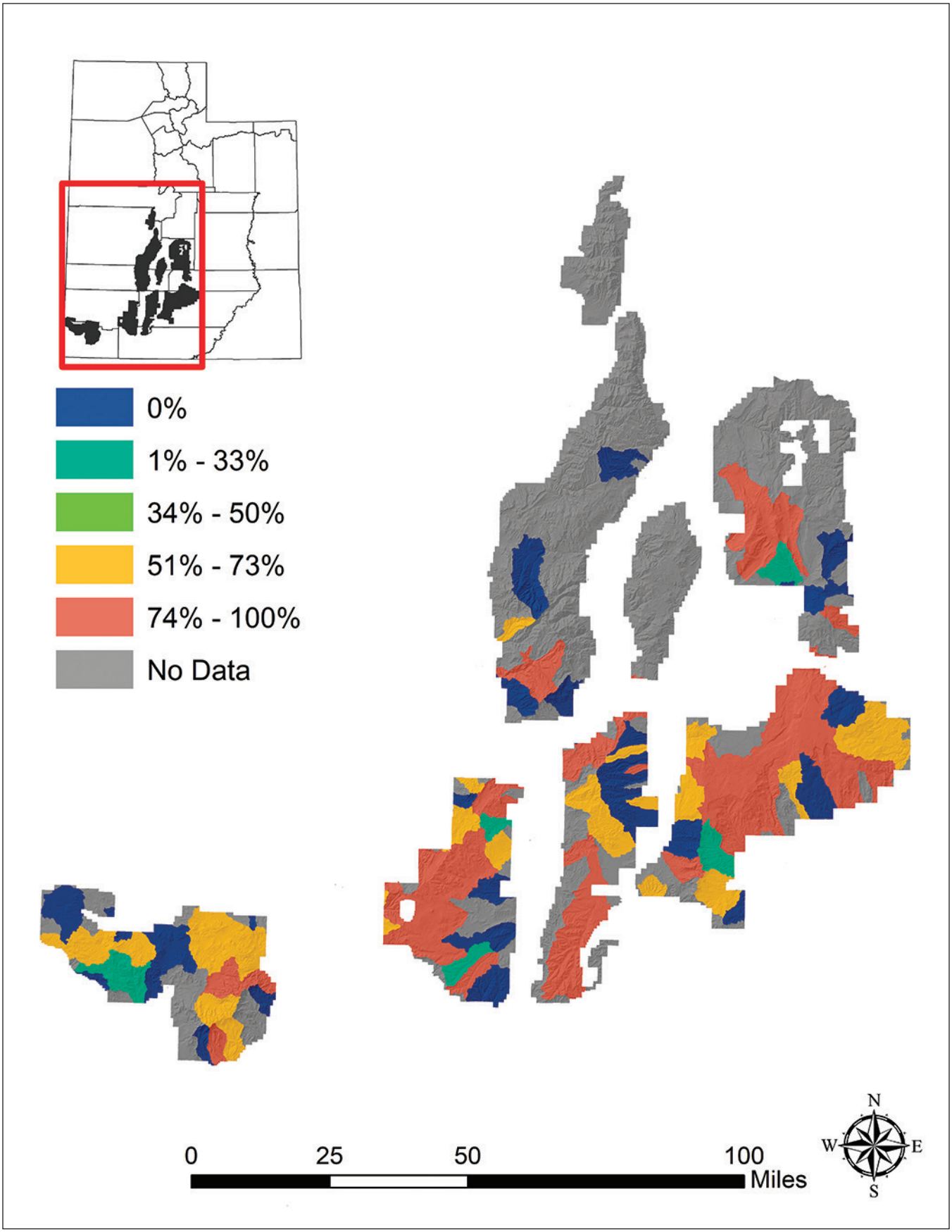


Figure H.47—Percentage of level III riparian survey sites in HUC 12 watersheds determined to be in desired condition in the DNF and FNF.

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