OPTIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

The SLV is a relatively arid environment and the distribution of vegetation communities historically present at Monte Vista NWR was influenced greatly by the timing and availability of surface water. Annual surface water inputs to the Monte Vista region were highly pulsed and dynamic in spring and early summer, depending on annual snowmelt and runoff from the San Juan Mountains. Summer rains allowed native plants to germinate, flower, and grow. Most wetlands probably dried by fall in most years, although deeper wetland depressions may have had semi-permanent water regimes during wet years. Consequently, annual variation in creek flows and summer rains likely caused significant annual variation in the amount and distribution of flooded wetland area and corresponding wetland vegetation communities. Salt desert shrub and meadow grassland communities were supported by sparse annual precipitation and irregular disturbance from fire and herbivory. The historical creek, wetland, meadow, and shrub/grassland habitats provided resources to help support populations of many animal species associated within the Rocky Mountain ecoregion (USFWS 2010).

The primary change to the ecosystem structure, function, and processes at Monte Vista NWR since the late-1800s has been the extensive alterations of SLV-wide and refuge site-specific distribution, chronology, and abundance of surface and groundwater. The history of water diversion, use, and management throughout the SLV, and specifically on Monte Vista NWR, both prior to and after refuge establishment is complex and reflect attempts by man, common throughout the arid western U.S., to obtain water for agricultural and community uses where surface water is limited. At Monte Vista NWR, the many issues that have affected water diversion, surface water flow into and across the refuge, extraction and use of groundwater, and management of available water, including the development of extensive artificial infrastructure, has created the highly modified landscape now present. The many modifications to the refuge and surrounding area have resulted in many ecological consequences; most of which have been detrimental to the long-term sustainability of native communities and resources. For example, attempts to increase irrigation/water diversion capabilities to extensive areas on the refuge to increase wetland habitats has: 1) destroyed and degraded the once extensive and predominant salt desert shrub community (including resources used by species dependent on this habitat) on the refuge; 2) modified and/or eliminated natural surface water flow pathways and patterns across the refuge (and further downstream off refuge lands); 3) facilitated invasion and expansion of invasive plant species, especially tall whitetop; and 4) altered basic soil chemistry and topography attributes of the system. Most of the system modifications on Monte Vista NWR after it was established were motivated by desires to increase annually consistent dabbling duck production regardless of the refuges position in the landscape in relation to waterfowl population life cycle events. This objective was met through alteration of existing shrubland habitat to seasonal and semipermanent wetland habitats through extensive compartmentalization of the refuge into over 80 wetland sub-units that are separated by various roads, dikes, ditches and drains, and water-control structures along with over 100 small ring-dikes around artesian well sites.

While past planning efforts for Monte Vista NWR were largely based on the desire to continue previous water management among the extensively developed wetland sub-units for breeding ducks (see refuge annual narratives and discussion in USFWS 2003), current refuge planning is considering a more system-based and holistic approach for future management strategies and desired states for the refuge. Considerations for a more "system-based" management approach requires that managers address basic questions about how to, and if they can realistically, restore more natural and sustainable communities and resources on Monte Vista NWR. This HGM report provides an evaluation of existing hydrogeomorphic information to help understand potential general options for restoration efforts and certain management actions that will be needed to sustain and support restorations. This information is useful only if the refuge seeks to achieve at least some restoration of native ecosystems, which is a strategic conservation decision outside the scope of this report. Assuming that at least some restoration of native communities is desired on Monte Vista NWR, the paramount issue influencing future management and restoration is the need to change how management addresses the timing, distribution, and movement of water on the refuge. These future decisions clearly require a careful and deliberate focus on changing the artificial water diversion and management on the refuge. Ultimately, these considerations will help define the contribution of Monte Vista NWR to conservation throughout the larger landscape scale of the SLV and the Upper Rio Grande ecoregion.

GENERAL RECOMMENDATIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

As previously stated, this HGM evaluation is an attempt to help identify restoration and management options that will protect, restore, and sustain natural ecosystem processes, functions, and values at Monte Vista NWR. Clearly, the physical form, hydrology, and plant and animal communities at Monte Vista NWR are highly modified from the historical condition. Despite the many artificial alterations to the ecological integrity and character of the refuge, many opportunities do exist to restore at least some attributes of the native ecosystem, including restoration of natural water flow pathways, hydrological patterns, and the corresponding distribution of native vegetation community types. This HGM evaluation does not address where, or if, the many sometimes competing uses of the refuge can be accommodated, but rather it provides information to support The National Wildlife Refuge System Improvement Act of 1997, which seeks to ensure that the biological integrity, diversity, and environmental health of the (eco)system (in which a refuge sets) are maintained (USFWS 1999, Meretsky et al. 2006). Administrative policy that guides NWR goals includes mandates for: 1) comprehensive documentation of ecosystem attributes associated with biodiversity conservation, 2) assessment of each refuge's importance across landscape scales, and 3) recognition that restoration of historical processes is critical to achieve goals (Mertetsky et al. 2006). Most of the CCP's completed for NWR's to date, including the 2003 Monte Vista NWR CCP, have highlighted ecological restoration as an objective as it helps meet the authorizing purpose of the refuge. In general, historical conditions (i.e., the period prior to substantial human-related changes to the landscape, which at Monte Vista is the late 1800s) are considered the benchmark condition to guide restoration efforts (USFWS 2002, Meretsky et al. 2006). General USFWS policy, under the Improvement Act of 1997, directs managers to assess not only historical conditions, but also "opportunities and limitations to maintaining and restoring" such conditions. Furthermore, USFWS guidance documents for NWR management "favor management that restores or mimics natural ecosystem processes or functions to achieve refuge purpose(s) (USFWS 2001).

Given the above USFWS policies and mandates for management of NWR's, the HGM-approach used in this study can assist decisions about future management of Monte Vista NWR, at least where some restoration of historical communities is a goal. The HGM approach objectively seeks to understand: 1) how this ecosystem was created, 2) the fundamental physical and biological processes that historically "drove" and "sustained" the structure and functions of the system and its communities, and 3) what changes have occurred that have caused degradations and that might be restored to a less altered state within a "new desired" environment. The HGM approach also helps understand restoration opportunities for the Monte Vista NWR and can assist in helping to define the refuge's "role" in meeting larger conservation goals and needs at different geographical scales (e.g., USFWS 2010). In many cases, restoration of functional ecosystems on NWR lands can help an individual refuge serve as a "core" of critical, sometimes limiting, resources than can complement and encourage restoration and management on adjacent and regional private and public lands.

HGM evaluations are not species-based, but rather seek to identify options to restore and maintain system-based processes, communities, and resources that ultimately will help support local and regional populations of endemic species, both plant and animal, and other ecosystem functions, values, and services. Management of specific land parcels and refuge tracts should take into account the different resources needed by a variety of species throughout their life cycle. In some cases this means that relatively "artificial" habitats and structures, such as "ponds" may be important to provide critical resources to some species. The development of specific management strategies for Monte Vista NWR requires an understanding of the historic context of the Monte Vista area relative to what communities occurred in response to natural seasonal and interannual dynamics, the resources provided by these communities, and when and where (or if) species of concern actually were present and used these resources. Consequently, recommendations from the HGM evaluation in this study are system-based first, with the goal of maintaining the ecosystem itself, with the assumption that if the integrity of the system is maintained and/or restored, that key resources for species of concern can/will be accommodated. This approach is consistent with recent recommendations to manage the NWR system to improve the ecological integrity and biodiversity of landscapes (Fischman and Adamcik 2011). Obviously, some systems are so highly disrupted that all natural processes and communities/resources cannot be restored, and key resources needed by some species may need to be replaced or provided by another, similar habitat or resource.

Future management of Monte Vista NWR should attempt to attain an appropriate balance of providing critically important historical resources used and required by native animal species while simultaneously ensuring integrity of the system within the constraints imposed by local and SLV-wide land and water uses. Based on the HGM context of information obtained and analyzed in this study, we believe that future management of Monte Vista NWR should seek to:

1. Restore natural surface water flow pathways and associated hydrological regimes where possible to restore and manage wetlands and wet meadows along Spring, Rock, and Cat Creeks.

2. Restore natural topography and promote natural hydrologic regimes to restore at least some areas of historically occurring salt desert shrub and undershrub grassland habitat including its natural heterogeneity of sub-habitat components.

3. Restore natural disturbance regimes such as herbivory, fire, and drought to promote the health and quality of all habitat types and reduce noxious weeds.

The following general recommendations are suggested to meet these ecosystem restoration and management goals for Monte Vista NWR.

1. Restore natural surface water flow pathways and associated hydrological regimes where possible to restore and manage wetlands and wet meadows along Spring, Rock, and Cat Creeks.

GLO surveys and other historic information including the 1941 and 1960 aerial photographs (Fig. 18) indicate that wetland and wet meadow habitats historically present on Monte Vista NWR were located along the Rock, Spring, and Cat Creek drainage corridors. Pulses of water in the creeks following local rains and snowmelt in spring provided water that recharged and shallowly inundated off-channel wetlands. Short duration sheetflow of water overflowing from creeks into and across wet meadows provided sustained hydrological regimes for these wetland systems. Groundwater discharge from the Spring Creek "spring head" supported flows in Spring Creek (and to some degree downstream in Rock Creek) year round and created some open water and "sheet ice" even during colder winter months.

Wetlands on Monte Vista NWR historically were subject to both seasonal and long-term dynamics of precipitation, runoff, and groundwater discharge. During wetter years, creek flows likely were greater and more prolonged and probably created semipermanent water regimes in some deeper wetlands. Conversely, during dry years, inundation of creek corridor wetlands was of short duration following snowmelt and flooding regimes were seasonal at best. The combination of seasonal and long-term dynamics of creek flows through natural drainage corridors was the primary ecological process driving wetland and meadow hydrology on Monte Vista NWR. As such, availability of wetland resources and historical use by waterbirds and other wetland-dependent wildlife occurred primarily in spring and early summer with some fall migration and wintering habitat available in Spring Creek due to sustained groundwater creating some open water resources.

This report identifies the many extensive modifications and degradations to surface and groundwater availability, diversion and redistribution, water-control infrastructure, and past refuge water management and resource objectives on Monte Vista NWR. For example, natural creek and surface water flow across Monte Vista NWR now is effectively prevented by the presence of the many ditches, large canals, roads, and levees/ditches. Natural discharge of groundwater also is essentially eliminated, for example the cessation of discharge at the Spring Creek "spring head." In addition to on-refuge degradations, regional SLV-wide issues that affect surface water on Monte Vista NWR include the major valley water diversion infrastructure that exists. Collectively, regional and on-site changes to the physical and hydrological attributes of the Monte Vista NWR ecosystem has dramatically disconnected and diverted water flow away from the former Spring, Rock, and Cat Creek channels or caused them to completely cease flowing.

Certain physical and hydrological alterations on Monte Vista NWR directly interrupt and disconnect creek drainages such as the levees/dikes, ditches, and wetland sub-units constructed in former creek corridors. Specifically, artificial impoundments in management units 3, 4, 5, 6, 9, 10, 19, 20, and 24 directly disconnect and divert water from Spring and Rock Creek corridors. The small impoundments in units 22 and 23 also disconnect and redivert the former intermittent/seasonal Cat Creek channel area. Other infrastructure indirectly affects creek flows because of management decisions to move water away from the creeks to irrigate and shallowly flood former salt desert shrub areas at higher elevations. In effect these water diversions substantially reduce total and seasonal discharge capacity in the former creek corridors. Impoundments and physical modifications within former salt desert shrub areas also disrupt overland sheetwater flows, runoff to creek corridors, and water infiltration on the alluvial fan that is vital to the sustainability of the shrublands and the inherent soil chemistry of these sites. Other created wetlands in units 17, 18, 13, and 1 are not in former wetland sites and have been partly created because of canal and ditch locations as well as seepage or sub-irrigation. Further, extensive contour levees in some units such as Units 7 and 9 artificially move water into some higher elevations of the units that historically were not wetland or meadow, but rather were salt desert shrub habitats.

It is understood that past management and monitoring objectives for Monte Vista NWR have been primarily to maximize annual duck breeding pairs and production (along with supporting other waterbirds and wetland dependent species), to continue long-term nest transect surveys, and provide fall waterfowl hunting opportunity (USFWS 2003). However, continuation of consistent and prolonged flooding in impoundment units that formerly were salt desert shrub habitat, or even seasonal meadow, is not consistent with historical wetland distribution and surface water flow pathways on the refuge and continuation of water diversions and consistent annual flooding of these upland sites has the likely risk of long-term degradation of soil salinity, increased invasive species occurrence, decreased vegetation diversity, increased density and monocultures of certain emergent species such as cattail, and gradual decreases in wetland productivity. Future water and wetland management on Monte Vista NWR can restore at least some natural surface water flow pathways and corridors and more closely align water timing, depth, and duration to match soils and former wetland type distribution. For example, in areas that formerly supported mainly wet meadow communities, water management can induce short duration spring flooding as irrigation to sustain these diverse and productive meadow communities and resources that are so important for many animal species. Allowing these areas to naturally dry throughout the summer will help restore native vegetation.

The distribution of former wetland and meadow types on Monte Vista NWR based on soil type, elevation, and GLO maps provides a guide to potential future restoration of water flow pathways, more natural distribution and type of wetlands, and water management within impoundment units that are retained (Fig. 16). Four major creek corridor areas on Monte Vista NWR seem to offer the best options for restoring these creek and wetland conditions (Fig. 32). The first area is at the headwaters of Spring Creek, especially in Unit 19. The second area is the reach of Spring Creek upstream of the confluence with Rock Creek including areas in Units 14, 6, 1, and 7. The third area is in the Spring-Rock Creek confluence area, specifically in Units 3, 4, and 5. The fourth area is the former Cat Creek corridor in Units 16, 17, 22, and 23.

While the natural topography and water flow patterns at Monte Vista NWR are highly altered,

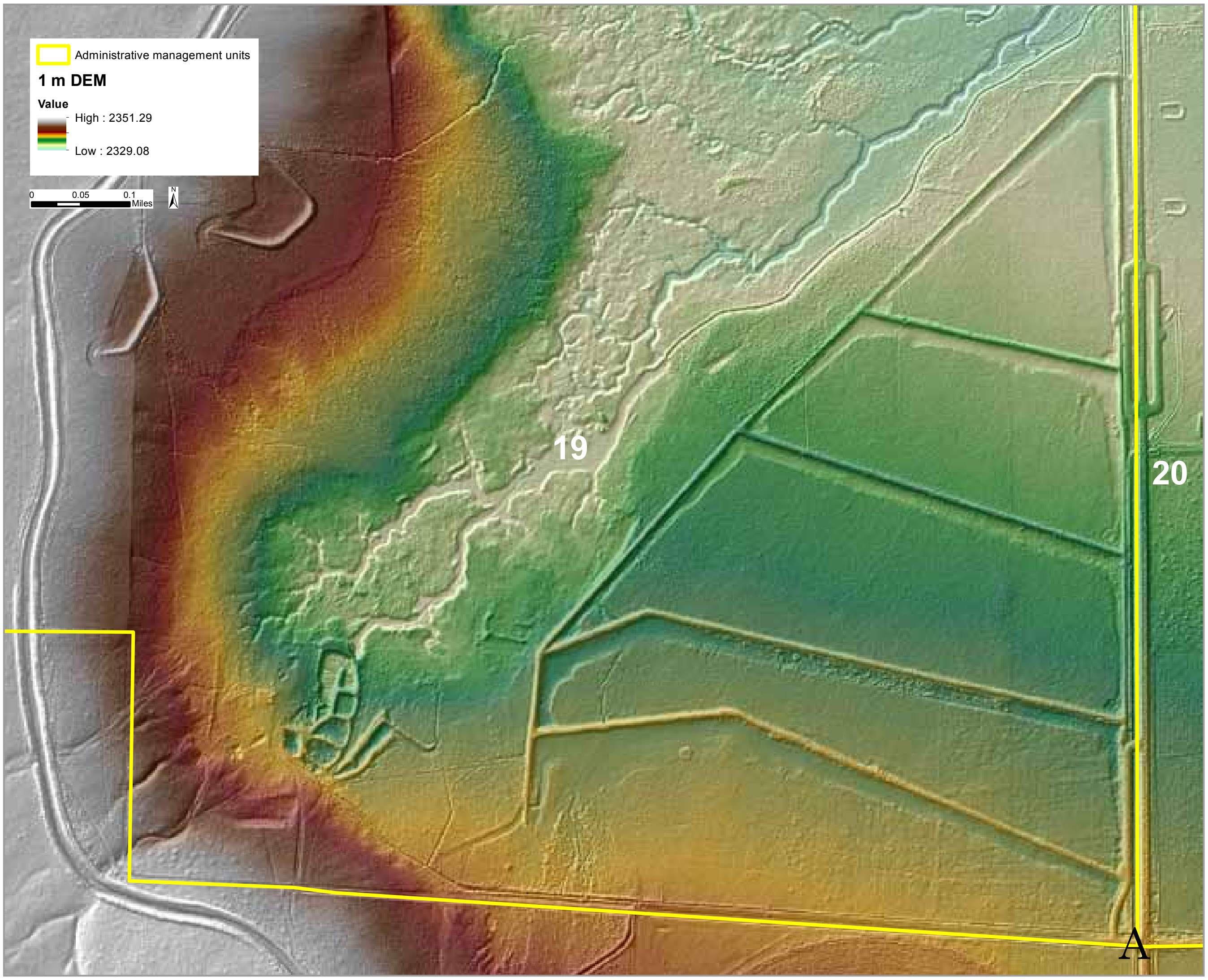

Figure 32. Potential restoration locations to restore flow patterns in former creeks channels on the Monte Vista NWR in relation to elevations changes: a) Spring Creek head in Unit 19 flowing to the northeast, b) Spring Creek prior to its convergence with Rock Creek in Units 14, 6, 7, and 1, c) the confluence area of Spring and Rock Creeks in Units 3, 4, and 5, and d) the old Cat Creek corridor in Units 16, 17, 22, and 23.

some opportunities may be available to modify existing water diversion and control infrastructure to help restore more natural patterns of surface water flow and supply to restored and managed wetland areas. The historic Spring Creek flowed from the southwest in Unit 19 to the northeast through Units 14, 6, 1, and 2 where it joined Rock Creek in Unit 3. Currently many ditches and roads impede natural flow through this system. Removal of infrastructure that impedes this flow and use of existing ditches and structures that will enhance or promote natural flow will help restore the natural hydrologic regime to this drainage. Flow through natural topographic features such as Spring Creek which allows sub-surface flow and dispersal throughout the floodplain can be increased through the correct placement of water-control structures, re-routing of roads to the edges of wet meadows, and the elimination of lead-in and lead-out ditches from water-control structures in wet meadow situations where sheetflow is desired (Zeedyk 1996). Recent LiDAR information (Figs. 8, 9) indicates that the historic creek channels exist at the topographically lowest elevations in relation to adjacent lands. The general landscape on Monte Vista NWR slopes from the west-southwest to east from about 7,732 to 7,586 feet amsl. General flow patterns follow this elevational gradient within the refuge boundaries. Rock Creek flows from north to southeast on the refuge before joining with Spring Creek and flowing along a more easterly course. Cat

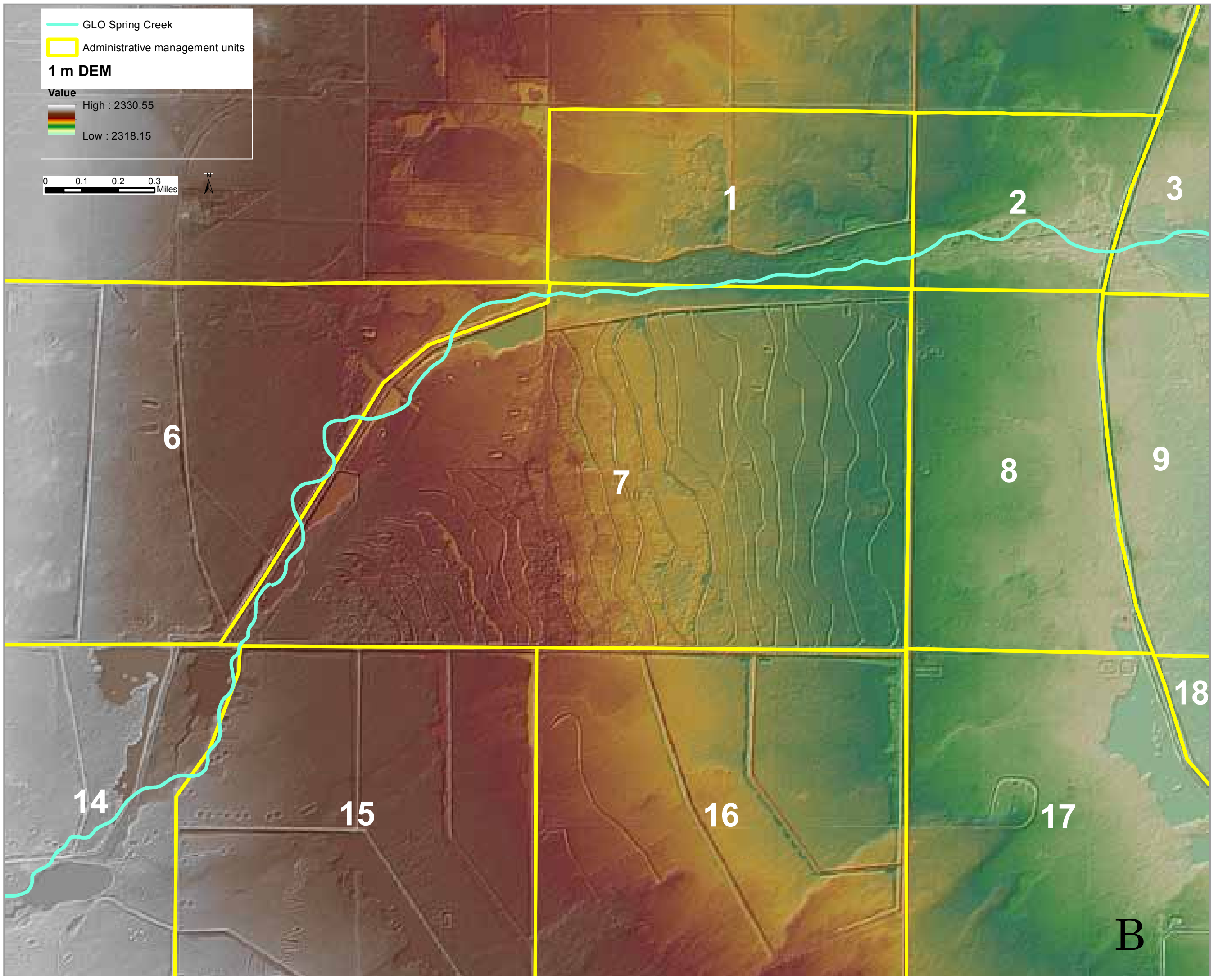

Figure 32 continued. Potential restoration locations to restore flow patterns in former creeks channels on the Monte Vista NWR in relation to elevations changes: a) Spring Creek head in Unit 19 flowing to the northeast, b) Spring Creek prior to its convergence with Rock Creek in Units 14, 6, 7, and 1, c) the confluence area of Spring and Rock Creeks in Units 3, 4, and 5, and d) the old Cat Creek corridor in Units 16, 17, 22, and 23.

Creek flows from the south to the north and east toward the Spring-Rock Creek confluence areas. Where possible, the former creek and natural elevational drainage gradients should be restored.

2. Restore natural topography and promote natural hydrologic regimes to restore at least some areas of historically occurring salt desert shrub and undershrub grassland habitat including its natural heterogeneity of sub-habitat components.

Salt desert shrub was the dominant historical community type present on Monte Vista NWR. As early as the late-1880s, areas of salt desert shrub on Monte Vista NWR were being converted to irrigated pasture and hayland using wells and water diversions. The Monte Vista Canal, which bisects the alluvial fan of Rock Creek, was built during this time, altering the surface and subsurface flow of water across and through this area to the valley floor. Crude early dikes, ditches, drains, and water-control structures were used to move and store water in desired locations, which facilitated removal of remnant shrub vegetation, irrigation of flatter areas, and conversion of salt desert shrub communities to wet meadow and mostly non-native grassland habitats and uses. By the time Monte Vista NWR was established in the early-1950s, considerable parts of the refuge area were in irrigated pasture and hayland. After the refuge

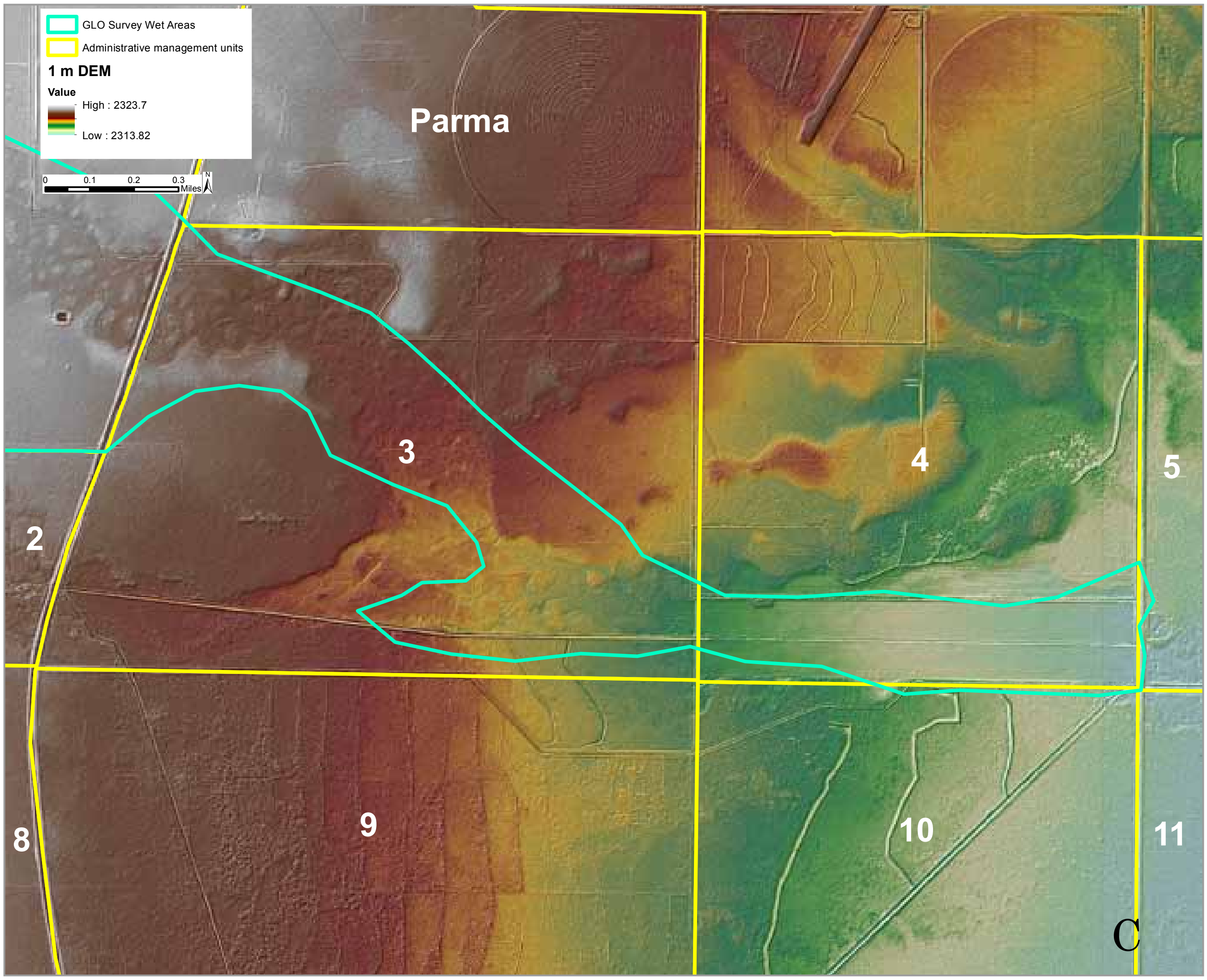

Figure 32 continued. Potential restoration locations to restore flow patterns in former creeks channels on the Monte Vista NWR in relation to elevations changes: a) Spring Creek head in Unit 19 flowing to the northeast, b) Spring Creek prior to its convergence with Rock Creek in Units 14, 6, 7, and 1, c) the confluence area of Spring and Rock Creeks in Units 3, 4, and 5, and d) the old Cat Creek corridor in Units 16, 17, 22, and 23.

was established the extensive development plan for the refuge greatly expanded the dike, ditch, drain, and water-control infrastructure and effectively compartmentalized the refuge into over 80 wetland subunits. These units were constructed mostly with the intent of creating wetlands and irrigated meadows initially for wintering waterfowl, and then eventually almost entirely to support breeding ducks and other waterbirds. The collective effect of these refuge developments and subsequent water management has been the > 50% conversion of native salt desert shrub to irrigated or seasonally flooded habitats. The conversion of former salt desert shrub habitats to meadow, wetland, and crops was done irrespective of soil type or even location on the refuge. This introduction of surface and sub-surface water to former salt desert shrub sites that often did not have soils suited for such irrigation or flooding has frequently increased soil salinity by increasing deposition of evaporative salts, which has in turn caused some sites to become highly alkaline even to the point of creating barren salt flats (SCS 1980). Construction of an efficient water delivery system moved and drained water into and through different units providing surface irrigation directly to sites as well as sub-irrigation indirectly to adjacent sites. Additionally, these former saline soils, now with greater seasonal hydration and salt deposition, have become sites of expansion and colonization of invasive plant species such as tall whitetop (Gardner 2002).

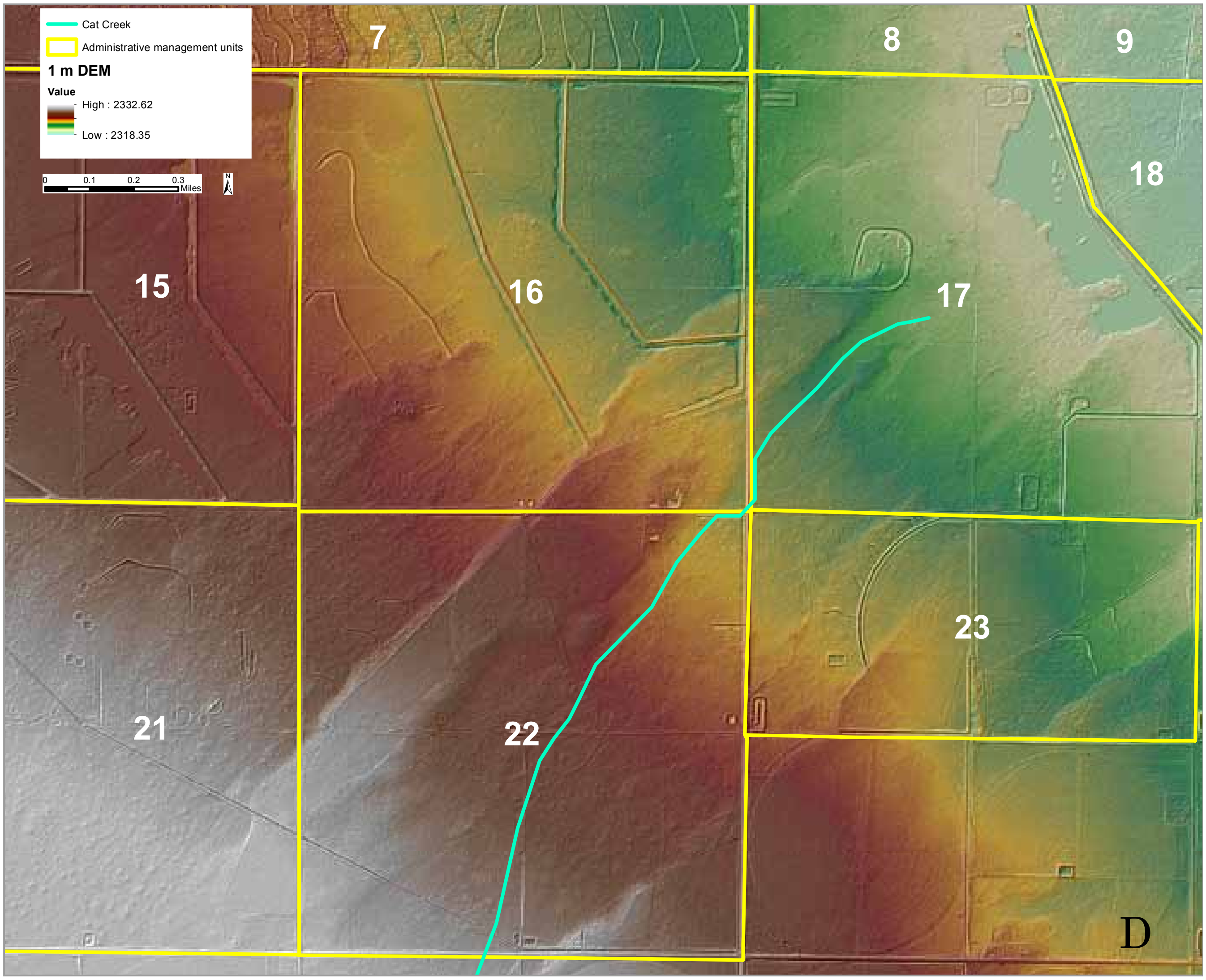

Figure 32 continued. Potential restoration locations to restore flow patterns in former creeks channels on the Monte Vista NWR in relation to elevations changes: a) Spring Creek head in Unit 19 flowing to the northeast, b) Spring Creek prior to its convergence with Rock Creek in Units 14, 6, 7, and 1, c) the confluence area of Spring and Rock Creeks in Units 3, 4, and 5, and d) the old Cat Creek corridor in Units 16, 17, 22, and 23.

The area on Monte Vista NWR that historically (and currently) supported an undershrub-grassland community is restricted to the far west part of the refuge on the bottom foothills of the San Juan Mountains. This foothill area has been altered less than other areas on the refuge, but various topographic developments such as roads, ditches, and dikes exist and native vegetation communities may be less diverse and include increasing amounts of invasive species. Undoubtedly, some of the changes in vegetation composition and distribution are the result of long-term livestock grazing prior to the refuge establishment (Hanson 1929, Fahnestock and Detling 2000, Sayre 2001). Throughout the western U.S., and certainly at the boundaries of the SLV, the loss and alteration of mountain foothill undershrub-grassland habitats has been extensive and contributed to declines in plant and animal species. Species such as fringed sage have become more dominant over time due to disturbances such as grazing and changes in hydrologic regime.

Restoration of these shrublands will require basic changes in water management strategies, removal of levees and ditches, and removal and/or relocation of water-control structures to facilitate sheetflow on Monte Vista NWR. Spring snowmelt throughout the shrub habitat would have naturally pooled water within many small depressions scattered across the area. Overland flow across the hill slopes and subsurface flow through the alluvial fans would have provided additional water resources to depressions throughout the shrub community. Surface flooding would have been of short duration, but provided resources for migrating grassland bird species and some waterbirds and waterfowl. Future management of these habitats at Monte Vista NWR should seek to sustain and restore endemic community composition, structure, and functions on select sites. This will involve allowing surface and subsurface flow across and through the alluvial fan while preventing the impoundment of water for long durations as identified in the first restoration objective stated above.

Given the former expansive distribution of salt desert shrub on Monte Vista NWR it seems desirable to restore at least some former salt desert shrub sites, at least where high soil salinity and higher elevations occur. Additionally, future prospects of more limited surface water availability and lower confined aquifer levels with corresponding decreases in artesian free-flowing wells, suggest that water management on Monte Vista NWR should attempt to prioritize water delivery and storage to former wetland sites and soils, and not attempt to flood non-wetland sites with poor water retention capability and high salinity such as exist in many former salt desert shrub areas. A comparison of current wetland and meadow distribution on the refuge with prior distribution of salt desert shrub offers guidance to the best restoration locations (Figs. 16 and 24).

3. Restore natural disturbance regimes such as herbivory, fire, and drought to promote the health and quality of all habitat types and reduce noxious weeds.

Historical communities on Monte Vista NWR previously were sustained by temporal and spatial dynamics of water amount and distribution, fire, herbivory, and other disturbances caused by seasonal and long-term variation in climatic factors. For example, Rock, Spring, and Cat Creeks meandered across the alluvial fan on Monte Vista NWR and overflowed during wet periods associated with snowmelt in the San Juan Mountains. The creek overflow inundated floodplain depressions, created shallow sheetflow across floodplains, and deposited nutrient-rich sediments and nutrients to these sites. Undoubtedly, at some unknown intervals, flow dynamics were sufficient to cause creek channel migrations, which formed the heterogeneous topography of the creek corridors including wetland depressions, ridges and swales, and natural levees. Overland flow, sedimentation and deposition were driven by climatic variation that affected amount and timing of spring snowmelt and local precipitation events. Consequently the topography, soils, and vegetation communities at Monte Vista NWR were changing at spatially and temporally different scales. Studies conducted on alluvial fans have demonstrated the sometimes drastic changes between the soils and hydrologic characteristics of semi-arid sites occupied by shrubs and interspatial barren areas. Soil structure, organic matter, and infiltration rates vary widely based on microclimate conditions created by shrubland communities (Hooke 2012, Bedford 2008, Bedford and Small 2007). With the development of water diversion infrastructure, increased extraction of groundwater aquifers, construction of roads, and the complete loss of Spring Creek and Cat Creek flows, the natural and historic hydrologic characteristics and disturbance regimes of this area have been eliminated. Also, natural herbivory from elk, deer, and antelope have been altered or eliminated and native ungulate herbivory has been replaced with cattle and sheep grazing. The natural time and duration of disturbance events in SLV wetlands especially occasional drought, fire, and herbivory were important to sustain wetland systems by recycling nutrients and biomass and regenerating communities (Cooper and Severn 2002). Reintroduction of the many important ecological disturbance mechanisms into the Monte Vista NWR system seems important.

It seems unlikely that the natural topography and hydrological dynamics of the creeks historically present on Monte Vista NWR will ever be completed restored, nor will structures such as the Monte Vista or Empire Canals be removed to allow natural surface and subsurface flow across the alluvial fan on the refuge. Consequently, to restore intrinsic values associated with the creeks and alluvial fan habitats, management strategies should seek to emulate natural processes with active water management to provide disturbances that invigorate growth, provide abiotic conditions to promote germination, and supply nutrients to the soil (e.g., Molles et al. 1998, Opperman et al. 2010). Since creek flows have been highly diverted or no longer exist and water management has shifted to more annually consistent and stabilized water regimes, the natural hydrologic flow between creeks and their floodplain has been changed dramatically. Although current vegetation communities on Monte Vista NWR have been greatly altered from former periods and many now are dominated by invasive weeds, implementation of the previous recommendations in conjunction with mimicking natural disturbance regimes, processes, or artificial manipulations will further promote the restoration of wetland and upland habitats on the Monte Vista refuge. The important historical disturbance events in SLV wetlands included creek overbank and backwater flooding, drought, fire, and herbivory; these disturbances helped recycle nutrients and biomass, regenerate communities, and volatilize salts and minerals. Reintroduction of these disturbance mechanisms into the Monte Vista NWR system will be important to restoration of native communities.

Management to provide the above disturbance events will depend on specific management objectives and the appropriate timing, periodicity, intensity, and application of the event. For example, creating conditions to mimic overbank flood events could occur during years with greater spring snowmelt in areas where sheetflow is possible and adequate water delivery systems are in place. For example, a large pulse of water could be directed through the Rock Creek drainage if water-control structures and ditches had the capacity to carry a large volume of water. Likewise, management strategies could variously incorporate fire and herbivory in wetland and grassland areas to help provide a different type of disturbance and nutrient cycling. Each of the different habitats on the refuge will require different rates and types of disturbance to achieve desired results. For example, grazing strategies in wet meadows will differ from those in seasonal wetlands or grasslands.

Natural herbivory by wildlife such as elk that potentially used lands on Monte Vista NWR probably would have been present in large herds for short time intervals as they moved to other sites with available resources, returning when the forage they consumed had recovered. Currently, this type of natural grazing by wildlife species cannot occur. Therefore, mimicking this natural process with cattle or other livestock could help remove invasive weeds and residual vegetation and promote earlier succession plant species. Livestock grazing on Monte Vista NWR has been controversial, but effective grazing strategies can incorporate rest-rotation and short duration/high intensity grazing depending on the objectives, the type of vegetation, and availability of cattle, time, and labor (Sayre 2001). Long-term grazing affects the physiology and morphology of plant species and community structure generally by promoting the growth of shorter stature plants that are less accessible to grazers (Fahnestock and Detling 2000). If livestock grazing is used, strategies should take into consideration plant community structure, phenology, and climatic conditions to promote the growth of desired native plant species. As well, elk and deer herbivory also should be assessed in relation to time of year and differences in patterns when compared with livestock grazing.

Grazing management, coupled with other treatments (e.g. flooding, fire, herbicide, etc), has been shown to assist in weed control, specifically for tall whitetop (Diebboll 1999, Gardner 2002). Rosettes and early stems may be eaten by cattle, although later growth stages are avoided. Thus, timing of grazing will dictate the type of disturbance or effect that cattle would have on this weed. Recently some landowners on the Rio Grande floodplain have changed their grazing management from one or two large pastures where cattle were held for long periods to many smaller pastures with short duration/high intensity grazing. This system appears to have been successful in decreasing invasive weeds such as wild iris (*Iris missouriensis*), Canada thistle, and tall whitetop while also increasing cover, density, diversity and the health of native plant species (pers. comm. Ruth Lewis and Cynthia Villa). A reduction in the extent and density of tall whitetop will improve the health of the wetland resources for waterfowl and waterbirds as well as the nutritional content of forage for cattle or elk grazing on the refuge in subsequent years (Young et al 1995). Selecting specific associations of age classes such as cow/calf pairs or yearlings will impact different plant species based on the time of the year and their unique nutritional needs (Leonard et al 1997).

The use of fire within various habitat types also could help restore native vegetation communities at Monte Vista NWR. Fire removes some or at times all of the vegetation and other organic matter that has built up on the soil surface. This removal and processing of biomass returns nutrients to the system and promotes growth of existing or new plants. Historical frequency of fire in the SLV is not entirely known and likely depended on dynamic climatic conditions, hydroperiods, and habitat type. Wetland areas with historically high water tables probably had a longer period of fire frequency. Fire frequency generally increases away from wetland areas such that the shrub and grassland communities with lower water tables would have a higher fire frequency (Reardon et al. 2005). Some plant species growth response is more positive than others and will depend on the intensity of the fire, season, and potential for subsequent irrigation.

SPECIFIC RECOMMENDATIONS FOR ECOSYSTEM RESTORATION AND MANAGEMENT

1. *Restore natural surface water flow pathways and associated hydrological regimes where possible to restore and manage wetlands and wet meadows along Spring, Rock, and Cat Creeks.*

Future water management at Monte Vista NWR should consider changes in water-control/diversion infrastructure and refuge management strategies to more closely emulate natural flow patterns, distribution, and seasonal/long-term dynamics of surface and subsurface water to reinstate appropriate historical distribution of communities, especially wetland and meadow types, improve native plant species diversity and productivity, reduce alkali concentrations, and increase water efficiency. Specific management actions to consider include:

- Evaluate opportunities to restore topography and natural water flow patterns through the historically intermittent Cat Creek drainage. Allow for natural drying of the creek drainage during dry years. Remove or modify levees and water-control structures in Units 16, 17, 18, 22, and 23 (excepting the large Empire Canal, which is not controlled by the USFWS) to more closely mimic the historic flow of water through this system (Fig. 33a). Currently a large east-west levee bisects the historical Cat Creek channel in Unit 22 and several levees exist in Unit 18 on the east side of the Empire Canal, which lie in the historic drainage path of Cat Creek. If possible, future restoration of this drainage could discuss possible water-control infrastructure that would allow water to pass through the Empire Canal on very wet years.
- Remove the ring dikes/ponds that occur within the Cat Creek drainage.
- Restore flow to the natural Spring and Rock Creek drainages by removing or modifying the levees, ditches, and water-control structures that impede flow and that are not useful for other strategic water diversion and management. This evaluation of ditch and levee modification will require detailed future hydrological and topography analyses and engineering, which is beyond the scope of this report. For example, some ditches and water-control structures may aid in mimicking the natural distribution of this water through the various units. While State Highway 15, County Road 3E, and the Empire Canal probably cannot be removed or extensively modified to allow a more complete restoration of the Spring-Rock Creek drainage system, some potential does exist to provide a more natural flow of water in these creek corridors. For example, current infrastructure in Units 19, 14, 6, 7, 1, 2, 3, 9, 4, 5, and 11 (listed in downstream flow progression) contain portions of these historic channels and obstructions to natural flow patterns and pathways should be removed where possible (Fig. 33b,c). Removal of levees which bisect or parallel these drainage patterns is important to promote natural surface and subsurface flow through this system.
- Evaluate options to use and/or modify existing water delivery infrastructure to reestablish overland sheetflow in wet meadows. Existing water-control structures that are located too high or low in a levee can prevent natural flow and distribution to wet meadow areas. All existing water-control structures in former wet meadow and wetland habitats should be evaluated for invert-discharge elevation setting and location to achieve restoration options.
- Restrict prolonged flooding and PEM-type wetlands to areas with Vastine soils types along the former Spring and Rock Creek drainage corridors located predominately in Units 1-5 and 11 (see Fig. 7). Manage water regimes in these wetlands to emulate seasonal inputs of water and flooding duration. While an original objective of the refuge was to provide wintering habitat for waterfowl, the inherent natural climate and hydrology at Monte Vista NWR rarely caused open surface water to be present except in creek channels.
- Manage water regimes in former wet meadow communities on Arcasco, Alamosa, Mishak, Torsido, and Typic Fluvaquents soil types in Units 3, 6, 9, 13, 17, 22, and 23 with short duration spring and early summer flooding. Subsurface flows in wet meadows adjacent to

historic creek channels may be accomplished through a combination of restoring flows in the creek channel and modification of water-control structure placement in roads and levees that increase the volume of flow, rate, and dispersal over time (USDA 1996). Use of multiple raised culvert arrays that incorporate one large capacity squash pipe for creek flows associated with multiple smaller pipes spread out across the floodplain to disperse flows mimicking overbank events have been successful (USDA 1996).

- Vary annual flooding regimes of wetland units among years to emulate periods of natural drought or more extended flooding.
- Remove wetland sub-units that are located on sites historically in saline salt desert shrub habitats (see discussion under #2 below about specific salt desert shrub restoration options).
- Prevent conversion of former wet meadow and salt desert areas to seasonal or semi-permanent wetlands through prolonged flooding, for example in Units 5 and 11. Such conversion using prolonged flooding regimes facilitates expansion of Baltic rush and seasonal wetland vegetation in soils that are unsuited to these wetter states. Diversion and impoundment of water in these upland areas carries whitetop seeds and provides conditions for establishment of the weed in these areas as roots can then grow in subsequent years to several meters dependent upon depth of the water table.
- Control invasive plant species in wetlands in part through water management mimicking a natural hydrologic regime in appropriate soils.

2. Restore natural topography and promote natural hydrologic regimes to restore at least some areas of historically occurring salt desert shrub and undershrub grassland habitat including its natural heterogeneity of sub-habitat components.

Salt desert shrub habitats historically dominated the large alluvial fan surface on Monte Vista NWR. Soil conditions and hydrologic characteristics associated with this community now have been altered greatly. Nonetheless, restoration of natural hydrologic regimes in areas that were historically occupied by salt desert shrub habitats is possible. Salt desert shrub habitat still exists in some areas on the refuge including large contiguous tracts in Units 5, 10, and 11. Remnants of this shrubland also exist in smaller patches throughout the refuge. The areas of historical, and current, undershrub-grassland habitat on Monte Vista NWR was/is restricted to the lower foothill/alluvial fan area in the far west part of the refuge. Specific management actions that could assist restoration of salt desert shrub habitats include:

- Target restoration of salt desert shrub to its former distribution especially in areas where some shrubland still exists. Units 4, 8, 16, 20, and 21 have some remnant stands of shrubland in addition to large areas of tall whitetop invasion. Targeting these areas provides a core area of native vegetation, seed source, and soils adapted for further shrub expansion. With a return of a natural hydrologic regime, native plant species should be favored rather than invasives. Levees within each of these units bisect historic shrublands and should be removed or modified because they are conduits for invasive weed seed dispersal, prevent natural sheetflow, and promote ponding of water in soils that are adapted for shrublands.
- Evaluate units that lie entirely within historic shrublands that currently are managed for short emergent wetlands. Remove water-control infrastructure and restore natural topography and overland surface sheetflow capability to these areas. For example, Unit 7 historically contained saline soils and shrub habitats, especially in the eastern side of the unit. Ideally, most, if not all, of the closely spaced contour levees in Unit 7 should be removed and the unit restored to salt desert shrub habitats. The Spring Creek historic channel lies directly adjacent and north of this unit and levees and roads that prevent natural flooding and sub-irrigation of the north portion of this unit should be removed or modified. The presence of approximately 26 parallel, north-south running levees have completely altered the natural flow of water and converted shrublands to short emergent habitat that is being invaded by tall whitetop from the east and west sides of Unit 7 (Fig. 33b).

- Remove all ring-dikes and decommission small intermittent flow artesian wells throughout the refuge. Most of the ring-dike sites occur within shrubland areas and in the past the small artificial ponds created by the ring-dikes concentrated birds and helped promote diseases (refuge annual narratives). Currently the ring-dikes prevent sheetflow, act as a drain to adjacent areas which are of slightly higher elevation, increase evaporative salt accumulations, and are sources of invasive weed expansion.
- Restore a natural hydrologic regime in shrubland areas by timing irrigation/flooding to a more natural spring runoff that increases the water table and sub-irrigates adjacent shrublands which may discharge in historic temporary wetland areas. Shrublands in Units 19, 14, 6, 7, 3, and 4 that occur adjacent to the historic Spring Creek and the confluence with Rock Creek will benefit from this type of shorter duration, spring hydrologic regime.
- Protect foothill areas from additional physical alteration caused by roads, ditches, and other potential developments. The Monte Vista Canal and parallel road have prevented natural hydrologic flow in Units 13 and 19 (Fig. 19). Creation of large levees, borrow ditches, and water delivery infrastructure

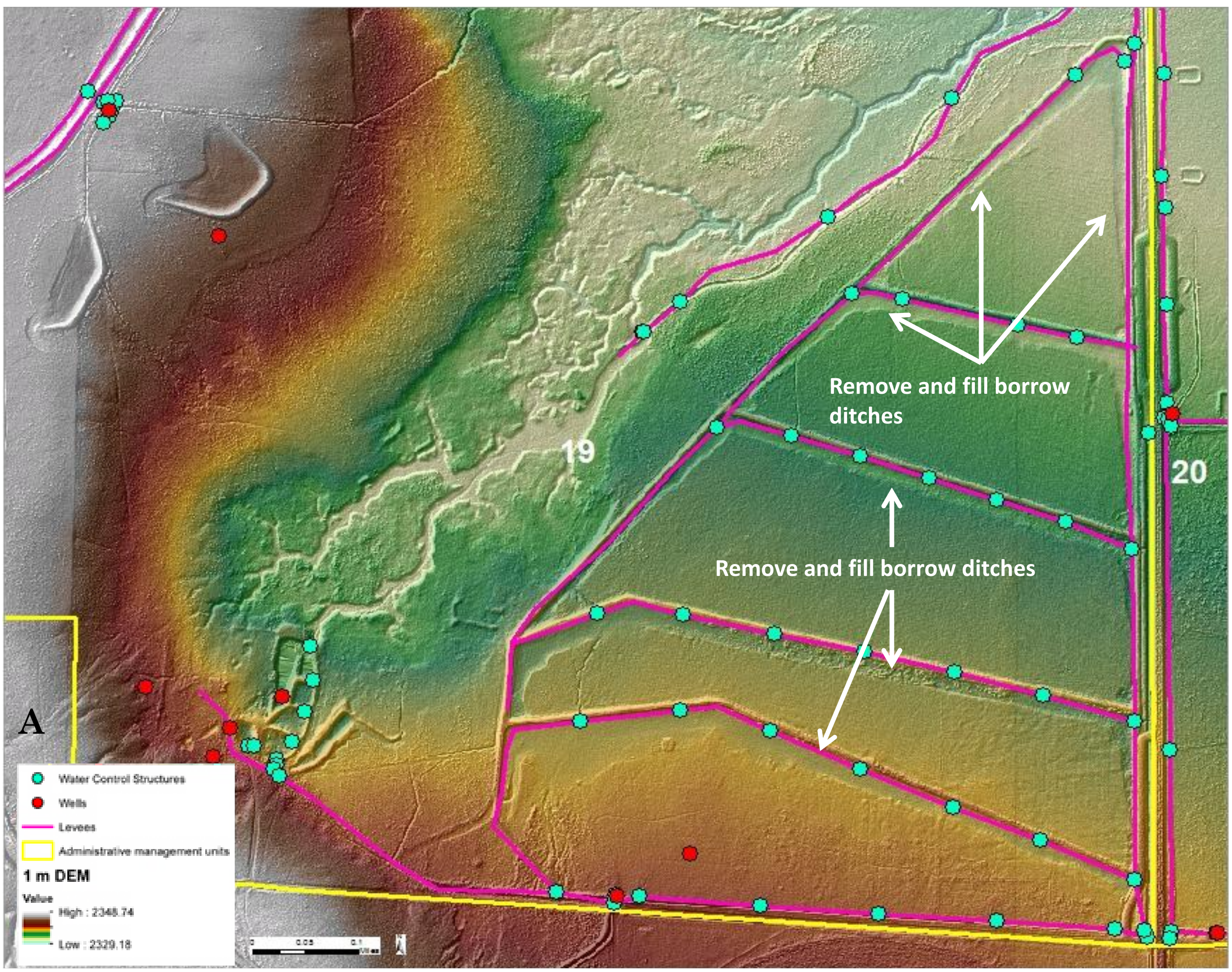

Figure 33a. Potential restoration in Unit 19 indicating elevation gradients, location of water-control structures, and the extent of spring flooding based on typical water management activities. Potential restoration options could include filling deeper borrow areas near dikes with soil to reduce the water required to provide suitable habitat for migrating sandhill cranes. Doing so would increase wetland acres while reducing overall water use in the unit.

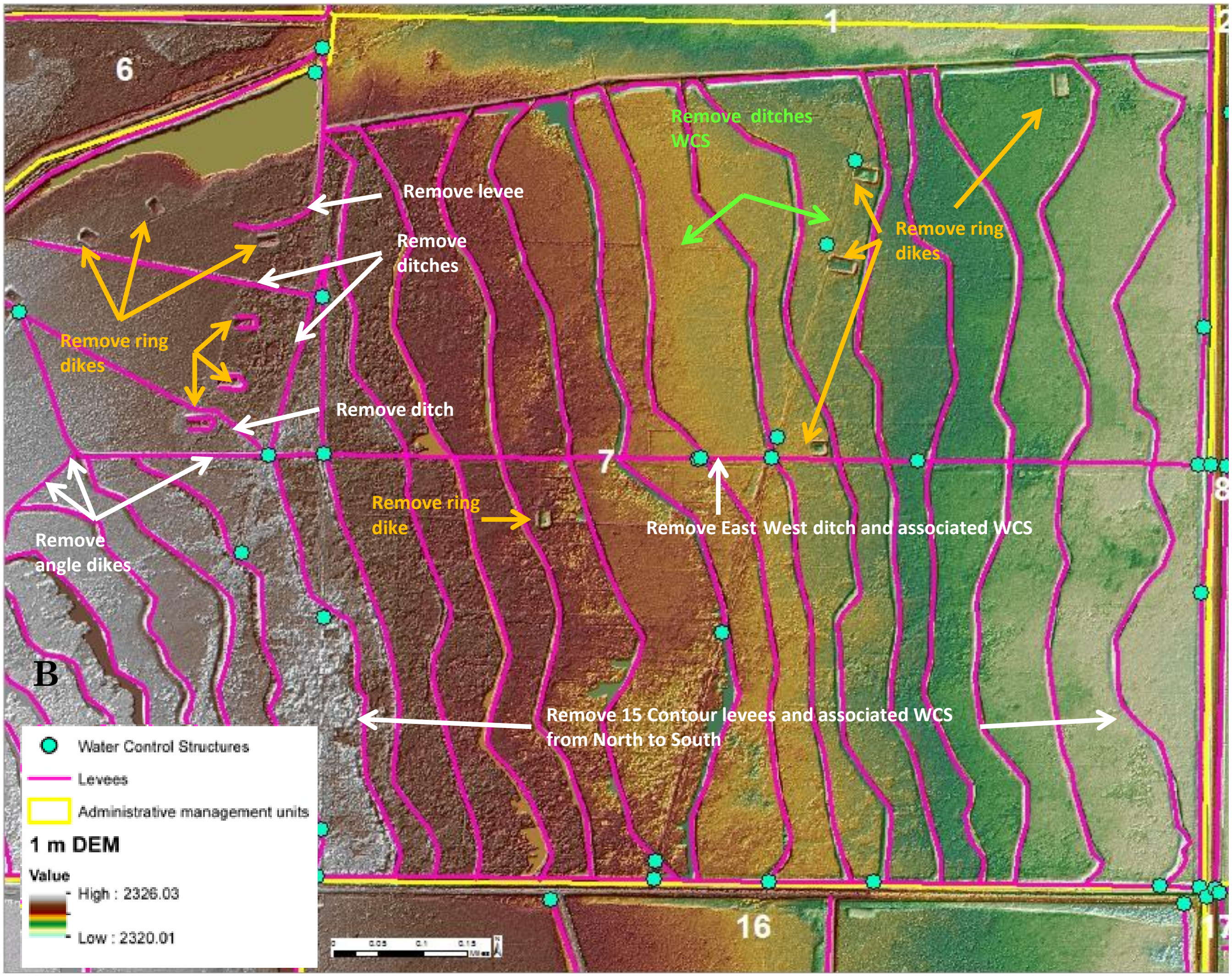

Figure 33b. Potential restoration in Unit 7 indicating locations to remove levees, ring dikes, ditches, and water control structures in order to promote the growth of native vegetation and restore natural hydrologic conditions. Unit 7 was historically dominated by salt desert shrub as indicated by soils, remnant native vegetation communities, and the invasion of weeds. The eastern third contains the most saline soils and represents an area of continued invasive weed expansion such as tall whitetop. Water historically may have overflowed from the creek and sub-irrigated some of these shrublands from the north, however prolonged flooding, tall emergent, and back flooding from east to west was not apparent.

within an historic shrubland in the south and east portions of Unit 19 have converted this area to short emergent habitat with large stands of tall whitetop (Unit 22 and 27). Further, the actual flood capacity area in Unit 19 created by the parallel angle dikes is very limited and does not justify the infrastructure, cost of water diversion and storage, or conversion of former salt desert shrub to a non-natural wetland state (Fig. 33a). The historic drainage of Spring Creek flows from the southwest corner of Unit 19 to the northeast and is north of the current impoundments. Complete restoration of Unit 19 may be complicated by desires to have surface water and public viewing sites along Highway 15, but promoting more natural flow patterns and flooding/drying regimes from southwest to northeast in Unit 19 by removing or modifying levees and borrow areas would help mimic a more natural hydrologic regime along Spring Creek and promote a more native composition of vegetation.

- Remove roads that promote impoundment of water, restore sheetflow, and emulate annual drought conditions throughout shrublands. Some roads exist that do not contain water-

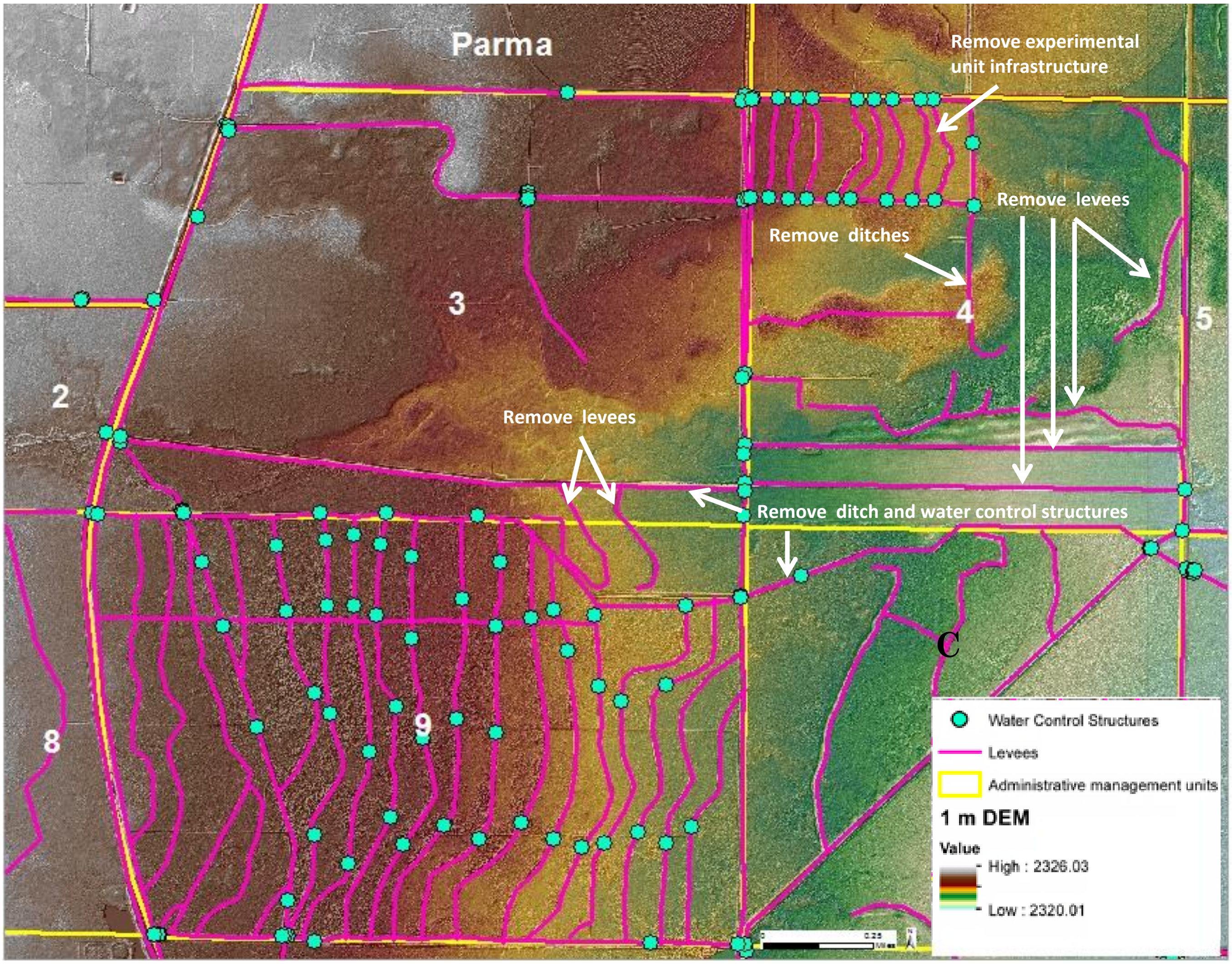

Figure 33c. Potential restoration at the confluence of Spring and Rock Creeks in Units 3, 4, and 9 indicating locations to remove levees, ditches, and water-control structures in order to promote the growth of native vegetation and restore natural hydrologic conditions. The confluence area represents the largest extent of wetland habitat historically present within refuge boundaries as indicated by soils, remnant native vegetation communities, and the GLO map. Water historically may have overflowed from the creek and sub-irrigated some of the areas to the north and south of the creek area.

control infrastructure and serve to impound water in Units 14, 21, and 24. Removal of these existing roads in former shrublands will help to improve the natural hydrology of the area and prevent impoundment of water.

- Prevent impounding water due to water delivery infrastructure which is poorly placed (vertical or horizontal), lacks the capacity to transfer water flows, or has become unusable in shrubland areas. Some sheetflow may be appropriate in late winter/early spring but should be avoided in late spring/early summer to avoid killing woody species.

- Remove water-control structures and levees in former shrublands that are no longer utilized. For example, Unit 4 historically contained wet meadow adjacent to the Rock Creek drainage and salt desert shrub in higher elevations (Fig. 16). Currently large monotypic stands of tall whitetop occur throughout the unit (Fig. 26) and smaller patches of whitetop occur in other areas. The northwest corner of Unit 4 contains approximately 20 water-control structures tied to a series of levees in former shrub habitat. Other levees throughout this unit bisect shrublands and historic drainages

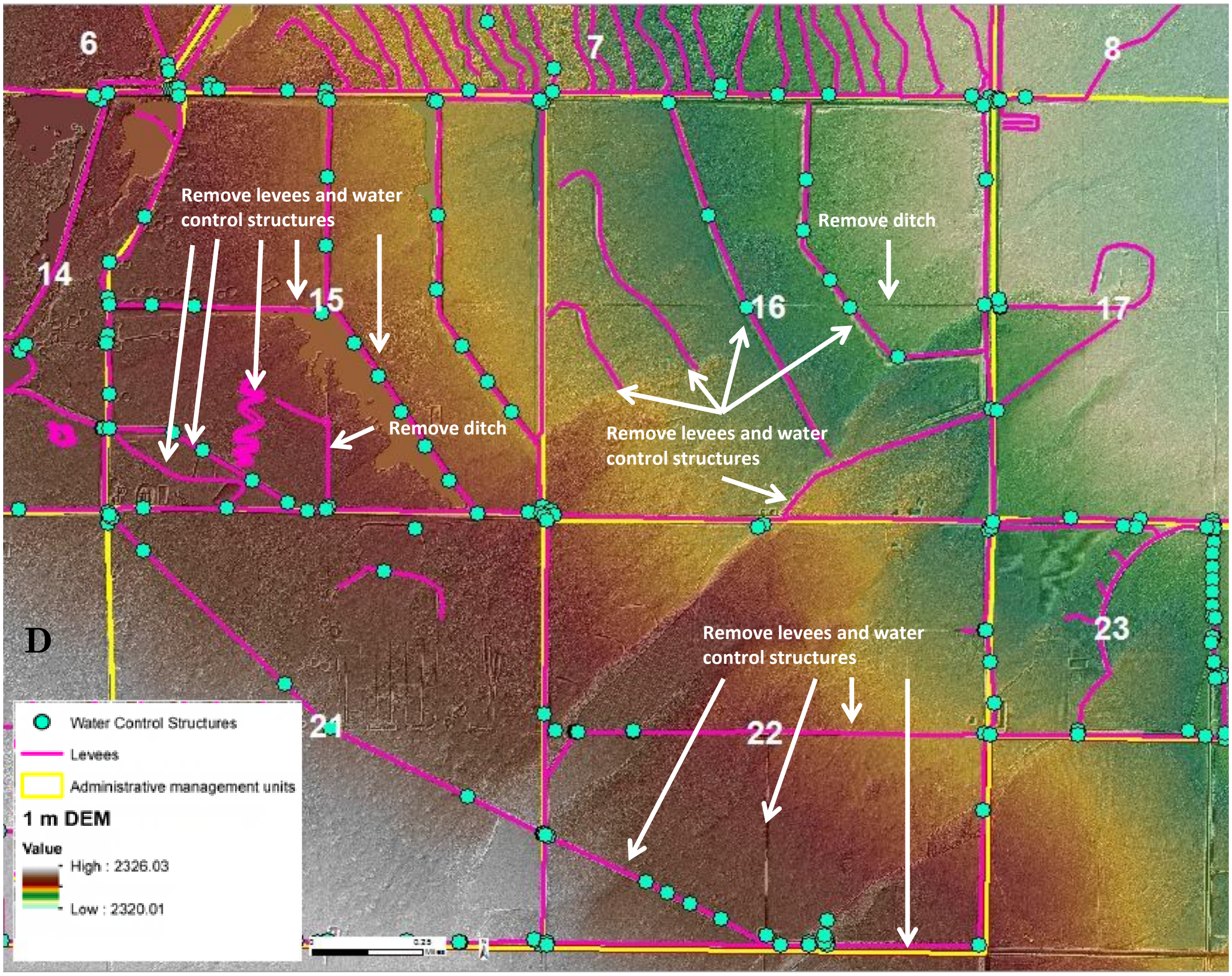

Figure 33d. Potential restoration at the confluence of the terminal portion of Cat Creek in Units 21, 22, and 16 indicating locations to remove levees, ditches, and water-control structures in order to promote the growth of native vegetation and restore natural hydrologic conditions. This area, including Unit 15, was historically a heterogeneous assemblage of wet meadow, salt desert shrub, and saline salt desert shrub as indicated by soils, remnant native vegetation communities, and historical maps and accounts. Tall whitetop is currently a dominant species throughout these units and the Cat Creek corridor. Water historically may have overflowed from the creek and sub-irrigated some of the areas to the east and west of the creek area for short periods of time.

and artificially impound water creating conditions favorable for the expansion of tall whitetop.

3. ***Restore natural disturbance regimes such as herbivory, fire, and drought to promote the health and quality of all habitat types and reduce noxious weeds.***

- Investigate further the historical natural occurrence of disturbance events such as fire and herbivory in the SLV and at Monte Vista NWR to understand the potential of using these techniques to manage vegetation or recover natural processes (such as recycling nutrients with rodent herbivory, volatization of salts and other elemental constituents through drought and fire, creation of plant regeneration sites, etc.). As an example of data uncertainty, yet management potential, the natural dynamics of historical frequency and intensity of wildfires in the SLV is not specifically known for each of the habitat types but areas with lower water tables (e.g., foothill grasslands) typically have a higher frequency of fire occurrence and could be managed as such.

- If fire can be used in grasslands, attempt late winter burns to remove residual vegetation and allow new growth of vegetation in the spring. Winter burning will allow for greater coverage of herbicide application on target invasive weeds in the summer. Spring, summer, and fall burns also may be applicable depending on the species to be controlled or promoted. For example, warm and cold season grasses typically require and respond more positively to fire prescription during different seasons e.g. spring, summer, fall, based on their respective phenologies.

- Consider managing seasonal wetland and wet meadow communities with some type of vegetation removal and recycling including fire, grazing, mowing/haying, etc. in combination with changes in water management. Promote a grazing management strategy that incorporates knowledge of different plant's life history characteristics to allow for growth and recovery in relation to the current climatic conditions. Grasses, rushes, and sedges will recover at different rates depending on the season and phenology of the plant. Therefore stocking rates and timing should be adjusted based on the response of plants relative to the management objectives.

- Mowing or haying may be done to mimic natural herbivory if grazing is not an option. Mowing of habitats that will be flooded will allow residual vegetation to provide the necessary structure for invertebrate communities. Removal of the residual structure may increase soil temperatures and promote the growth of other species. Both strategies may be utilized to help prevent the expansion of tall whitetop and Canada thistle, reduce cover and density, and allow other native species to out-compete the weed.

- Allow (or encourage) natural overbank flood events to occur by providing creeks access to their historic floodplains. Water control structures may need to be moved or replaced in order to facilitate these events (see previous recommendations).

- Promote drought conditions in shrublands on an annual basis to promote historic abiotic conditions which created micro-habitats and unique hydrologic regimes between soils occupied by shrubs and barren areas. These conditions may promote wind erosion which could help restore topography, soil chemistry, and vegetation communities. Further, small mammals may re-populate these areas and promote the microsite conditions that historically existed by burrowing and aerating the soil beneath shrubs (Bedford 2008).

- Promote drought conditions in current tall emergent wetlands that will be restored to seasonal or wet meadow habitat types in the floodplain of Spring and Rock Creeks, e.g. Units 14, 6, 7, etc. Fire, mowing, and haying can be used to remove residual vegetation and help set back succession to promote short emergent species that will thrive in a more spring/seasonal hydrologic regime.

- Control invasive species, such as tall whitetop, Canada thistle, and hoary cress utilizing a combination of treatments including drought, mowing, targeted grazing, and herbicide applications. Sites with some residual native species and potential to provide natural hydrologic regimes will probably have the greatest chance of success in terms of reducing invasive plants and restoring native communities (Baker et al 1997). Encouraging core sites such as Units 5 and 10 and 11 south of the Bowen Drain will provide a starting point from which weed control may expand annually by developing a large area with small amounts of weeds.