New Mexico Rapid Assessment Method

Manual

Version 2.0

2021

NMRAM

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Cover: Side channel of the Gila River, The Nature Conservancy Gila River Preserve near Gila, NM (E. Muldavin). **Page iii:** Amy Urbanovsky (NHNM Technical Team Member) collecting abiotic data for confined valley riverine wetlands subclass. (D. Crosley).

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LIST OF ACRONYMS

ac	acres
CBF	current basin floor
cm	centimeters
CRAM	California Rapid Assessment Method
CWMW	California Wetland Monitoring Workgroup
dbh	diameter at breast height
DPM	dynamic patch mosaic
EIA	Ecological Integrity Assessment
EPA	U.S. Environmental Protection Agency
ft	feet
GIS	geographic information system
GW	groundwater
ha	hectares
HGM	Hydrogeomorphic approach to wetland functional assessment
in	inch
IRCC	internal riparian corridor connectivity
LUI	land use index
LWD	LWD large woody debris
LUZ	land use zone
m	meters
NHNM	Natural Heritage New Mexico
NMED	New Mexico Environment Department
NMRAM	New Mexico Rapid Assessment Method
RCC	riparian corridor connectivity
REG NMRAM	Regulatory Riverine Wetlands NMRAM
RZ	riparian zone
SA	sampling area
SWQB	Surface Water Quality Bureau
TBD	to be determined
USACE	U.S. Department of the Amy Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USNVC	U.S. National Vegetation Classification
VST	Vertical Structure Type
WOI	wetland of interest

INTRODUCTION

The New Mexico Environment Department (NMED) Surface Water Quality Bureau (SWQB) Wetlands Program in collaboration with Natural Heritage New Mexico (NHNM) at the University of New Mexico has initiated the development and use of a rapid assessment framework to evaluate the ecological status of wetlands and riparian areas throughout New Mexico.[1] The New Mexico Rapid Assessment Method (NMRAM) was developed as part of the SWQB Wetlands Program's ongoing efforts to promote effective management and protection of the state's wetland resources. The overarching goal is to provide the necessary information to help prevent the continued loss and decline of New Mexico's scarce and important wetland resources.

In support of this goal, the NMRAM provides a cost-effective and consistent evidence-based tool for assessing wetland ecological condition and an associated database system to track outcomes (McGraw, Muldavin, and Milford 2018). It uses a select set of observable and relatively easy-to-measure spatial analyses and field indicators (landscape, size, biotic and abiotic metrics) to express the relative condition of a particular wetland site. NMRAM metrics are relative in that they have been developed in the context of a "reference set" of wetlands that vary along an anthropogenic-disturbance gradient. The underlying premise is that wetland condition among similar wetlands will vary along this disturbance gradient, from high quality and functionality with low disturbance to the most degraded with high disturbance. The ecological condition of a particular site is evaluated and rated as excellent, good, fair, or poor based on a preponderance of evidence from a set of landscape, biological, and abiotic metrics that are sensitive to the gradient.

Which rapid assessment metrics are used and how they are measured varies with wetland type. For consistency, the SWQB Wetlands Program classifies wetlands into broad classes and regional subclasses based on hydrogeomorphic (HGM) factors identified by Brinson (1993) and other features of regional importance (see NMRAM Wetland Classification section below). The objective of this classification is to identify groups of wetlands that are relatively homogeneous in terms of structure, process, and function. A regional wetland subclass shares similar characteristics such as hydrology, slope, physical setting, geology, climate, and vegetation. NMRAM metrics are tailored to wetland subclasses to provide consistent and reliable indicators of wetland condition at local scales. Accordingly, for each subclass separate assessment modules of relevant metrics have been developed and are described in this manual (Table 1). Field Guides for each assessment module have been developed to provide specific protocols for implementation along with field data sheets in digital and hardcopy form. Data collection using metrics tailored for a wetland subclass allows wetlands within a subclass to be compared equitably across many scales and jurisdictions, and in a variety of project contexts.

Another goal of the NMRAM is effective implementation by streamlining training, execution, and reporting. To this end, we have developed a suite of tools which include this manual with details on the method and underlying rationale; the field guides for each module provide easy-to follow

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[1] SWCA Environmental Consultants, Albuquerque, NM, contributed significantly to initial concept development and execution of the first Manual version.

protocols for rapid assessment with automated worksheets for efficient and accurate data collection. Web-based tools for uploading data to the SWQB database with report products is under construction at SWQB

Table 1. Published NMRAM Modules by HGM classes and subclasses with versioning and SWQB publication date.

Class	Subclass	Document	Published Version	Date
All		NMRAM Manual	1.1	March 2011
		NMRAM Manual	2.0	December 2021
Riverine				
	Montane Riverine Wetlands	Field Guide	1.1	May 2011
			2.5	February 2022
	Lowland Riverine Wetlands	Field Guide	1.1	November 2016
			2.4	February 2022
	Confined Valley Riverine Wetlands	Field Guide	1.3	December 2021
	Riverine Wetlands Regulatory	Field Guide	1.2	TBD 2022
Depressional				
	Southern High Plains Playas	Field Guide	1.2	April 2018
Slope				
	Headwater Slope Wetlands	Field Guide	1.1	TBD

Each subclass module of the NMRAM has been developed in collaboration with advisory teams of wetland experts assembled to review concepts and protocols (see Appendix A for team members and affiliations). In addition, a modified Riverine Wetlands NMRAM for regulatory purposes (REG NMRAM) was developed in collaboration with the U.S. Department of the Army Corps of Engineers Albuquerque District to assist them in evaluating mitigation values for projects that might impact wetlands. The development of NMRAM is an ongoing process and the status of each subclass module is indicated in Table 1. Priorities for development are based on statewide protection needs and funding availability. Furthermore, it is an iterative process where modules and this manual are updated based on sampling and analysis of additional sites across the state. Regardless, versions of this manual and the field guides will be maintained for later reference to specific site assessments and are available at the SWQB Wetlands Program website.

NMRAM APPLICATIONS

Water resources assessments and management have become a priority since the 1948 Federal Water Pollution Control Act and the 1972 amendments contained in the Federal Water Pollution Control Act. As the third-driest state in the U.S., water issues in New Mexico are significant. Wetlands, as waters of the state (20.6.4 New Mexico Administrative Code), have been largely overlooked as a resource that needs to be monitored and managed on a statewide scale to prevent pollution and degradation and to protect the many benefits and ecosystem services that wetland resources provide. Among others, these include sediment filtering, flood sequestration and reduction, erosion control, aquifer recharge, maintenance of stream temperature and stream flow, nutrient transformation and recycling, and provision of habitat and maintenance of characteristic native populations. The continued loss of wetland resources will result in both direct and indirect negative effects on environmental quality and human health and welfare. To address this, significant time and funding is expended each year to restore and protect New Mexico's wetlands and riparian areas. To support this effort, the NMRAM provides informative and defensible evaluations of wetland conditions quickly and accurately using a cost-effective approach. The results of NMRAM can inform resource management and guide wetland conservation aimed at minimizing loss and protecting wetland acreage, quality, and function. The NMRAM can be applied to a broad range of applications for management and protection of wetland resources. For example:

- prioritizing of wetlands and riparian areas for restoration and protection
- identifying suites of wetlands that are particularly impacted
- identifying drivers (stressors) of wetland resources declines
- providing profile data to facilitate restoration design
- supporting the development of restoration and mitigation performance standards
- increasing awareness of threats to wetlands and riparian areas, and
- tracking changes in ambient wetland conditions

Overall, the NMRAM has been developed to serve a broad range of users—agencies, community groups, private landowners, and other stakeholders—with an interest in best management and protection of New Mexico's wetland resources.

NMRAM FRAMEWORK

Rapid bioassessments have become standard approaches to evaluate the quality and biotic health of bodies of water and wetlands (e.g., Barbour et al. 1999), and hydrogeomorphic (HGM) assessments have become important tools for determining the hydrologic function of water bodies and wetlands (e.g., Brinson et al. 1995). Wetland rapid assessment methods have evolved to combine aspects of both bioassessments and HGM assessments, but they follow three basic principles:

1) assessments are based on current conditions measured against a reference standard;

2) the entire assessment can be completed rapidly over the course of one to two days with a small team of two to three field technicians depending on the size and complexity of the sampling area (SA); and

3) the assessment is based on observed conditions either in the field or through remote sensing (Fennessy et al. 2004, 2007).

Wetland rapid assessment methods have been developed across the United States by agencies and institutions using various approaches and levels of intensity, e.g., Ohio Rapid Assessment Method (Mack 2001), Colorado Vegetation Index of Biotic Integrity (Rocchio 2007), HGM (Hauer et al. 2002; Klimas et al. 2004); California Rapid Assessment Method or CRAM (CWMW 2013), and NatureServe's national Ecological Integrity Assessments (EIA; Faber-Langendoen et al. 2008; 2016a & b). All derive measures of wetland status against "reference standards" of the best condition and function of a target wetland type, but their approaches and objectives can differ. For example, HGM focuses on specific wetland functions in relation to ecological services and defines functions via weighted combinations of variables (metrics) of ecological conditions and processes (either direct measures or indirect indicators). CRAM also has a focus on ecological services but assesses overall wetland condition based on a restricted set of metrics that, in sum, reflects the capacity of a wetland to deliver those services. The goals of the NatureServe EIA approach were to develop strong ecological performance standards to guide wetland conservation, restoration, and mitigation. Performance standards include a range of structural and ecological condition attributes, including hydrology, vegetation, soils, and landscape context, which are hierarchically weighted to arrive at an overall ecological integrity score and rank.

Overall, the approach for NMRAM focuses on evaluating wetland condition both as a measure of ecological integrity and, by inference, the natural functional capacity of a wetland. In other words, if a wetland is in good condition, then it implies the wetland is functioning at reference standard levels.[2] Ecological *integrity* is the "ability of a system to support and maintain a balanced, integrated, adaptive community of organisms having species composition, diversity, and functional organization comparable to the natural habitat of the region" (Fennessy et al. 2007). Ecological condition has been defined as the "ability of a wetland to support and maintain its complexity and capacity of self-organization with respect to species composition, physico-

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[2] Reference standard levels or reference standard conditions are conditions that are unimpaired or minimally impaired.

chemical characteristics, and functional process as *compared to wetlands of a similar type without human alterations*" (Fennessy et al. 2007, emphasis added). The assessment of wetland condition thus describes the departure from the reference standard condition, or the condition of full ecological integrity in the context of a specific environmental framework and geographical region.

ECOLOGY AND THE NMRAM

In broad terms, the NMRAM wetland ecosystems are viewed as dynamic patch mosaics (DPM) of shifting wetland communities on a changing fluvial geomorphic template that is driven by hydrological processes (Crawford et al. 1993; Hupp & Osterkamp 1996; Crawford et al. 1999; Latterell et al. 2006; Weisberg et al. 2013; Muldavin et al. 2017). For example, riverine riparian wetlands can form complex mosaics of successional vegetation communities of herbaceous, shrubland, and forested wetlands (Figure 1) whose development is intertwined with the development of fluvial surfaces in response to flooding and channel migration (e.g., a range from small pioneer bars of herbaceous vegetation and shrublands to mature forested wetlands on elevated terraces). In playa wetlands, the patch patterns of community expression are driven by highly dynamic rainfall events, both temporally and spatially. Taken together, the community patches that make up the DPM can be viewed as an ecological system (*sensu* Comer et al. 2003) to be assessed collectively because their condition and functional capacity are linked to the same environmental drivers, mostly hydrology, in the local landscape—they cannot be viewed in isolation. Under this umbrella, the DPM incorporates many attributes of the wetland ecosystem both biotic and abiotic. The NMRAM takes advantage of this by taking a novel approach among assessment methods of mapping the DPM in a given wetland of interest SA and making it the foundation for evaluating metrics of ecological integrity with their implication for wetland functions and ecological services.

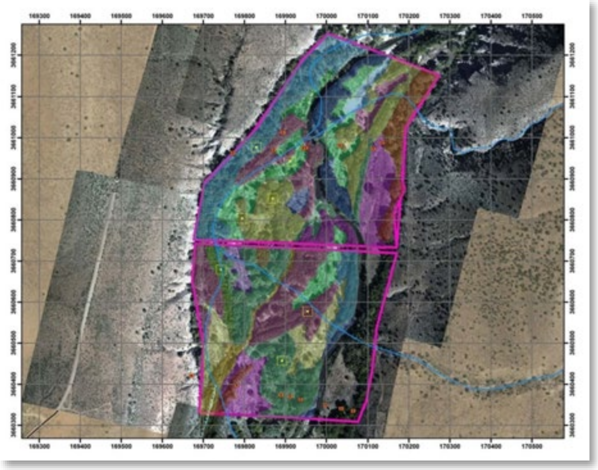


Figure 1. Example of a complex dynamic patch mosaic of forest, shrubland, herbaceous wetland stands mapped along an unregulated reach of the Gila River near Gila, NM (The Nature Conservancy Gila Preserve).

Against this backdrop of local dynamic landscapes, many of the same fundamental attributes of ecological integrity and function that other assessment methods use can be addressed: landscape context, size, and biotic and abiotic conditions (e.g., CRAM, NatureServe EIA, among others). Within these broad ecological attribute classes, key indicators of ecological integrity were identified and metrics for their assessment developed (Table 2). The landscape indicators focus on the footprint of human disturbance surrounding a SA as an indirect measure of potential adverse inputs and stresses on the target DPM. The exceptions are Internal Riparian Corridor Connectivity and Sampling Area Land Use. These landscape metrics were developed exclusively for the regulatory version of NMRAM where the SA would be located within or surrounding a project area where impacts would occur within the SA. Thus the regulatory NMRAM required a way to assess these internal landscape disruptions. Size was, and still is, commonly used

Table 2. List of NMRAM metrics by attribute class and NMRAM module. Level refers to measurement either in a GIS (1) or in the field (2) (see text).

NMRAM Attribute/Metric	**Level**			**Module**		
		Montane	**Lowland**	**Playa**	**Reg**	**Confined**
Size						
S1. Absolute Playa Size	1			x		
Landscape Context Metrics						
L1. Buffer Integrity Index	1	x	x		x	x
L2. Riparian Corridor Connectivity	1	x	x		x	X
L3. Relative Wetland Size	1	x	x		x	
L4. Surrounding Land Use	1	x	x	x	x	x
L5. Playa Configuration	1			x		
L6. Internal Riparian Corridor Connectivity	1				x	
L7. Sampling Area (SA) Land Use	1				x	
L8. Road Encroachment	1					x
Biotic Metrics						
B1. Relative Native Plant Community Composition	2	x	x		x	
B2. Vegetation Horizontal Patch Structure	2	x	x		x	
B3. Vegetation Vertical Structure	2	x	x		x	
B4. Native Riparian Tree Regeneration	2	x	x		x	
B5. Invasive Exotic Plant Species Cover	2	x	x		x	x
B6. Exotic Annual Plant Abundance	2			x		
B7. Wetland Species Index	2			x		
B8. Vertical Habitat Disruption	2			x		
B9. Riparian Zone Wetland Plant Abundance	2					x
B10. Wetland Vegetation Zone Loss	2					x
Abiotic Metrics						
A1. Floodplain Hydrologic Connectivity	2	x	x		x	
A2. Physical Patch Diversity	2	x	x		x	
A3. Channel Stability	2	x			x	
A4. Stream Bank Stability and Cover	2	x			x	
A5. Soil Surface Condition	2	x	x		x	x
A6. Channel Mobility	2		x		x	
A7. Playa Hydroperiod Reduction	1			x		
A8. Soil Condition Index	2			x		
A9. Water Source Augmentation	2			x		
A10. Playa Watershed Connectivity	1			x		
A11. Groundwater Index	2		x			
A12. Large Woody Debris	2					x
A13. Confined Channel Condition	2					x

as a surrogate for direct ecological integrity measures—large wetlands become self- buffering and endogenously functional. Actually showing those linkages in any given wetland can be difficult, particularly in riverine wetlands where the boundaries for a given wetland can be indeterminant or diffuse. Accordingly, the use of the Size attribute is restricted here to playa wetlands where there is evidence that large playas are important to bird populations (McLachlan et al. 2014) and, because playas occur in contained micro-basins, the impact of human disturbance can be directly linked and measured.

Abiotic and biotic indicators are mostly measured directly within an SA and are intended to reflect on-site ecological integrity of the community mosaic and the underlying ecological processes. Each indicator and associated metric was chosen to address a different aspect of wetland integrity and minimize overlap in concepts where possible. The definitions and rationales behind metric selection are provided in the Metric Descriptions section below. Coupled with the metrics is a stressor checklist that is used to inform users of potential drivers of the loss of ecological integrity reflected in the metrics (see Stressor Checklist section below).

Ecological assessments can be performed at multiple scales and there are generally three levels of measurement effort that have been defined (US EPA 2006). Level 1 assessment involves mapping, classifying, and evaluating wetlands using different land-feature and land-use maps (typically using geographic information system [GIS] data). The landscape context metrics fall in this group. Level 2 is a field-based rapid assessment where surveyors visit sites and quickly collect data using the metrics and stressor checklists to evaluate the condition of the wetland. Level 3 involves more direct, detailed, and time-intensive field surveys and detailed measurements. The NMRAM utilizes Level 1 and Level 2 methods to integrate both higher-level mapping metrics with field-based measurements. Some Level 3 metrics have been utilized in NMRAM development to define and scale individual metrics for rapid assessment. However, the final metrics used in each subclass module exclude the use of time- and resource-consuming Level 3 metrics.

NMRAM is designed to describe a reference set of conditions and stressors that affect similar wetlands—that is, the range from the natural condition to the most impacted condition within a reference domain. A reference domain is an area in which NMRAM can be used effectively and accurately on a wetland type. To evaluate the sensitivity and practicality of the metrics and to set the range of possible assessment scores, spatial analyses and field studies targeting specific subclasses of wetlands were conducted which defined the range of variation of ecological conditions across a disturbance gradient from those highly impacted (e.g., by urban encroachment) to the least impacted (e.g., wilderness areas). The development of the metrics and their measurement was an iterative process based on spatial analyses and field studies plus advisory committee and user input (hence, there are sequential versions of field guides and this manual).

WETLAND SCORING AND RANKING

One of the fundamental goals of the NMRAM is to provide a mechanism for efficient, trackable summarizations of wetland status that allows for consistent comparison of sites across spatial domains and wetland classes. For each metric in Table 2 there is a ratings table where the metric is scored based on the measurements and then rated into four relatively broad categorical condition classes where A = excellent, B = good, C = fair, and D = poor condition. Ratings are then further summarized by attribute class (Landscape Context, Size, Biotic, and Abiotic) based on the sum of metric scores. Finally, the attribute class scores are rolled up into a single Wetland Condition Score and categorical Wetland Condition Rank for a given wetland. This scoring framework allows for standardized comparisons and prioritization among sites for planning, mitigation, and other management activities. While overall summary scoring by design masks the details, the scoring process is transparent and structured so the underlying values can easily be accessed as necessary for further consideration.

Weighting of metrics has been applied to varying degrees among many rapid assessment methodologies across the country (e.g., Collins et al. 2008). Here, metrics are weighted within major attribute groups based on our best understanding of wetland ecological processes within a wetland subclass and metric sensitivity (see Table 2). That is, some metrics represent primary drivers of ecological condition and the measurements reflect those conditions well—these get a higher weight. Others are still important but may reflect very specific attributes or may be less robust in their measurement. Then the major attributes groups are further weighted relative to one another in the computation of the overall Wetland Condition Score. Computations are built into the digital worksheets so that individual and attribute category weighted scores can be calculated easily and then rolled up into a final numeric Wetland Condition Score between 1.0 and 4.0. Separate Wetland Condition scores are calculated for one or more SAs within a Wetland of Interest (WOI), and a site assigned a final categorical Wetland Condition Rank based on the average score as follows:

A – Excellent condition (Score: ≥3.25-4.0). Wetlands with intact functions and processes, diverse vegetative communities with almost no exotic weeds, and large relative to its historical size, with natural buffers. These wetlands are largely undisturbed and surrounded by undisturbed land (buffer), and would be considered to meet the wetland reference standard for the subclass.

B – Good condition (Score: ≥2.5-<3.25). Wetlands in somewhat degraded condition in response to environmental stressors. These wetlands have various combinations of relatively minor disturbances or factors negatively affecting condition, e.g., some alteration of the hydrological regimes; evidence of on-site anthropogenic disturbances; a reduction of vegetative community and structural diversity with the presence of some exotic weeds; and moderately reduced size relative to their historical size. The surrounding landscape may still be relatively natural. Often, these wetlands are good candidates for wetland restoration because impacts can be reversed with a high likelihood of recovery. Wetlands in good condition may be the best available for a given subclass.

C – Fair condition (Score: ≥1.75-<2.5). Wetlands that are moderately degraded in response to environmental stressors. These wetlands have one or more aspects that significantly affect condition, e.g., significantly disrupted hydrological regimes; degraded vegetative condition marked by monotypic community types often with exotic and noxious weeds; usually small size relative to their historical size. Surrounding landscape is typically significantly modified as well but may have some natural elements remaining. These wetlands may have restoration potential depending on specific wetland conditions and the stressors that are affecting that condition. However, restoration measures are expected to be more extensive (and maybe more costly) than B-ranked wetlands.

D – Poor condition (Score: <1.75). Degraded wetlands with highly disrupted hydrological regimes, poor vegetative composition and diversity, commonly dominated by exotic and noxious weeds, and typically very small size relative to their historic size. These wetlands will often have a largely disturbed surrounding landscape. These wetlands generally would require extensive rehabilitation to realize their natural potential and restore their natural functions.

Based on a multi-metric analysis, sites generally separated well along the condition gradient of each attribute class (Figure 2). That is, the overall rank classes reflected the trends in individual attribute class scores where, as scores declined for Landscape Context, Biotic and Abiotic attributes, so did the overall SA ecological condition ranks. There were occasional exceptions, e.g., some sites might score well on landscape metrics but poorly on abiotic or biotic metrics or vice versa. Accordingly, having a large suite of metrics that are designed to measure different aspects of the site engenders a robust overall assessment framework.

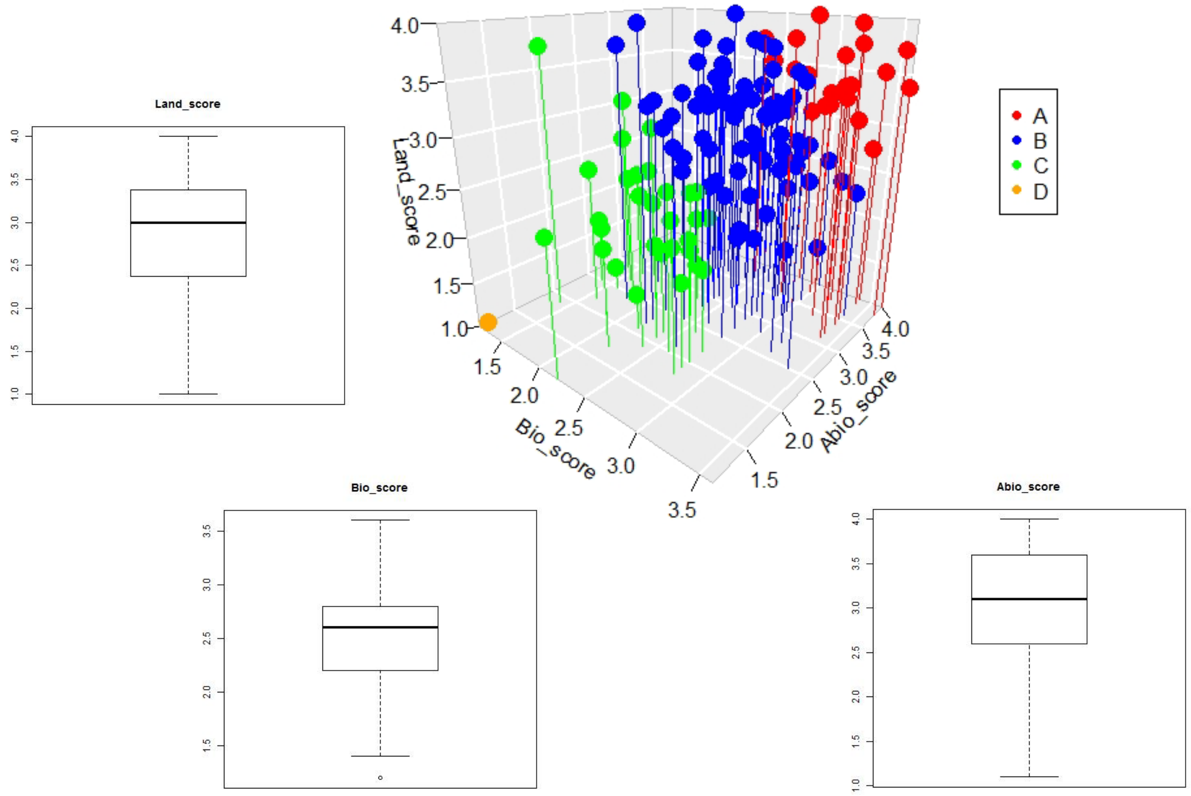


Figure 2. The distribution of site rating scores as of 2019 for ecological condition by attribute classes along the reference gradient for Montane Riverine Wetlands (Land_score= Landscape Context rating; Bio_score= Biotics rating score, and Abio_score= Abiotic rating score). The correlation of each attribute class to the overall score was relatively high (0.78, 0.74, and 0.72, respectively). Sites are coded by their overall site score where A= excellent condition, B = good condition, C= fair condition, and D= or poor condition.

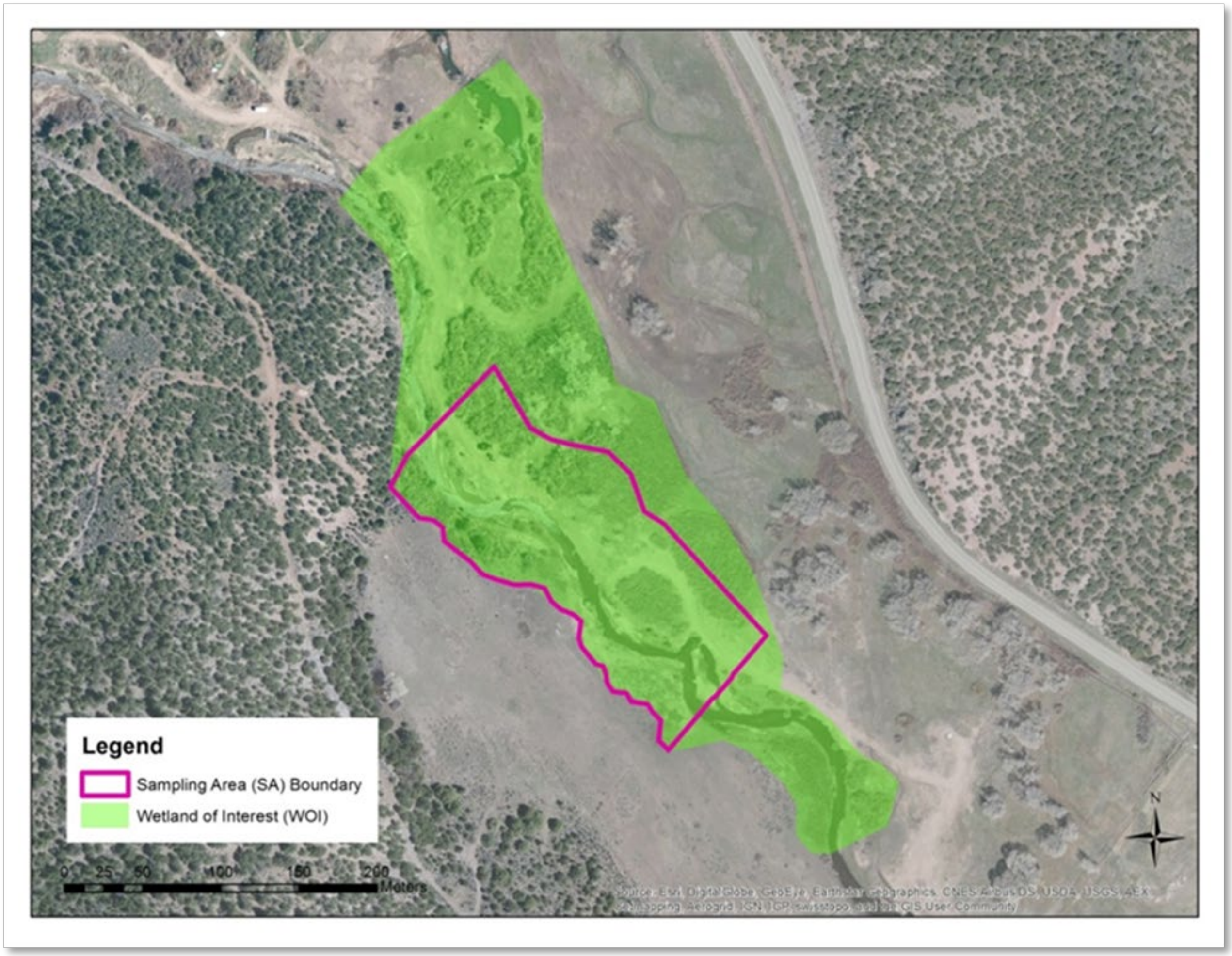
THE ASSESSMENT PROCESS

METRIC MEASUREMENTS

The NMRAM is a mapped-based process that uses GIS-based field measurements to evaluate the suite of semi-quantitative metrics that was designated by HGM subclass (see Table 2). These are organized by four attribute classes: Size, Landscape, Biotic, and Abiotic metrics. The GIS-derived metrics, Size and Landscape attribute classes, are referred to as "Level 1" metrics that use simple measurement tools available in most GIS software or can be evaluated on paper maps alone. Field metrics are referred to as "Level 2" metrics and are in turn based on field reconnaissance where various biotic and abiotic features are field mapped in combination with direct measurements of metric variables. The field survey requires teams of two to three trained practitioners depending on the HGM subclass. At least one team member should have botanical knowledge of common wetland species and invasives (Biotic team member), while one should have training in hydrology and soils (Abiotic team member). The third team member assists where needed, and is essential for some metric measurements (e.g., abiotic cross-sections and counting large woody debris).

As the first step, a target Wetland of Interest is identified and delineated on maps (Figure 3). The WOI is user-defined and based on project needs. Within a WOI, one or more SAs are identified in which the Level 2 metrics are measured during the field survey. Level 1 metrics are measured in zones extending out from the SA boundary. The exact specifications for both SA and zone delineations vary by subclass and are provided in the accompanying subclass field guides. A set of datasheets have been developed that are customized for each subclass that allows for efficient data collection and reporting. These also come in the form of interactive PDFs that can be loaded into field computers and used for data entry. Specific protocols for all metric measurements are provided in the field guides. Team members use the data collected to assign a condition score of Excellent (4), Good (3), Fair (2), or Poor (1) based on rating tables provided on the datasheets (see Wetland Scoring and Reporting below for details).

In addition to the metrics, potential stressors are identified in the watershed to provide guidance on the potential drivers of ecological condition and function of a given wetland (e.g., large forest fires, dams, flow diversions, mines, etc.). By design, they do not reflect actual ecological conditions on-site, and hence are not included in the rating and ranking system. The final step is to complete a narrative Assessment Summary based on the condition ratings and stressor information from each SA. The Assessment Summary provides a descriptive and analytical overview of wetland condition, as well as an opportunity for comments on wetland condition that may not have been captured by the metrics or a means to address specific effects of stressors based on the stressor checklists. The Stressor Checklists and Assessment Summary are completed on the datasheets for the SA.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 3. Example of Wetland of Interest (WOI) delineation (green) and the placement of an SA (pink outline) that is representative of the WOI.

Reporting Results and the New Mexico Wetlands Registry and NMED-SQUID Databases

The worksheets, maps, and photographs taken together make up the NMRAM Assessment Package, which can be used in various ways as a reporting tool. Given that the goals and objectives for using the NMRAM can vary, any of the components can be used individually in project-level reports, but the package is also designed to aid direct entry into the NMED-SQUID Database and OpenEnviroMap viewer. This database is intended as a comprehensive, central clearinghouse for information on New Mexico's wetlands to support activities such as conservation planning, mitigation, and overall status evaluation. Currently, the packages can be sent directly the Surface Water Quality Bureau Wetlands Program Coordinator (maryann.mcgraw@state.nm.us).

BIO-PHYICAL SETTING

GEOGRAPHIC DOMAINS

For development of NMRAM metrics for subclasses of wetlands and for describing their geographic application, New Mexico was divided into seven geographic domains that generally correspond to the major hydrological basins of the state (Figure 4). For each wetland subclass, metrics were developed and tested in specific “reference domains” but have application to other domains where characteristics of the subclass are met. For example, the Montane Riverine Wetland subclass (unconfined) was initially developed in the upper Rio Grande basin, then expanded and tested in the Gila and Canadian basins. While these were the reference domains, the metrics of the subclass can be applied to montane riverine reaches of the Pecos, Middle Rio Grande, Central Enclosed basins, and San Juan basins. Similarly, the Lowland Riverine Wetland subclass was developed initially in the Gila basin followed by the middle and lower reaches of the Rio Grande and Pecos. It is also applicable to the lower elevation sites of the Upper Rio Grande, Canadian, and San Juan/Little Colorado basins. The Playa Wetlands NMRAM was developed for the Playa Wetlands subclass in the Caprock Domain where a preponderance of playa wetlands with similar characteristics occur. The method will be tested on other suites of playa wetlands around the state to ensure that the metrics are representative of the conditions in other domains.

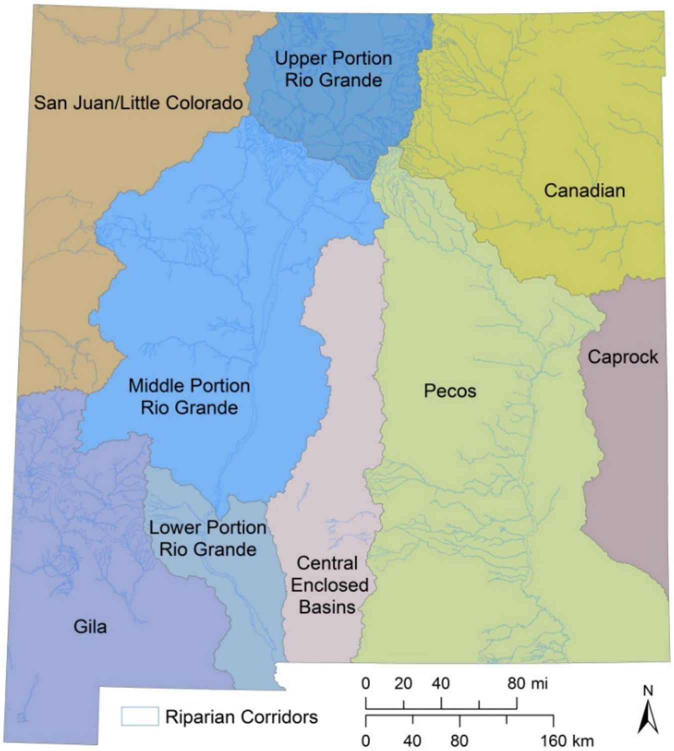


Figure 4. NMRAM domains based primarily on river basins provided the framework for developing the metrics by subclass in reference domains and for defining their applicability elsewhere in the state (developed from 4th digit USGS hydrological units).

CLIMATE AND HYDROLOGY

Climate and hydrological regimes of New Mexico played a key role in the development of NMRAM metrics. Precipitation generally follows a bi-seasonal precipitation regime. Winter precipitation (October through March) on average only accounts for about 30-40% of annual precipitation and is delivered principally by low-pressure systems that sweep from west to east across the Southwest, coalescing with moisture from the Pacific Ocean or the Gulf of Mexico (Table 3). Winter precipitation is generally followed by a seasonal dry period during May and June. This dry period is defined as much by increased potential evapotranspiration that accompanies increased day length, solar radiation, and temperatures, as by decreased precipitation. The spring dry period is usually relieved by the onset of the Mexican monsoon; this weather pattern typically delivers at least 40% of the annual precipitation during July through September, and is associated mostly with short-duration, high-intensity thunderstorms. Each summer, as high pressure becomes entrenched off the coast of Baja California, low pressure in the Southwest feeds Pacific moisture across the region, fueling the development of afternoon thunderstorms. The magnitude, frequency, and tracking of individual large, intense thunderstorm cells during this period can account for large year-to-year variability in annual rainfall and between local areas (Gutzler et al. 2016).

Hydrological regimes generally follow the precipitation regime except that since the majority of the winter precipitation is held as snow into the spring, peak flows generally occur in March and April as snowmelt and taper off in May. The unregulated Gila and San Francisco Rivers in southwest New Mexico reflect this pattern well (Figure 5). In contrast, rain events associated with large summer monsoon events may result in flow spikes of short duration during the summer and fall months. Temperatures can also play a role, particularly during winter months in the southern portion of the state where warm temperatures may cause rain on snow events that can create high peaks in the winter months. Above-average temperatures in summer months can lead to excessive evapotranspiration and effectively to less precipitation reaching streams, creating intermittent flows along channels of even major rivers.

In New Mexico, the spring and summer flood events on rivers and streams are an essential element of the natural ecological dynamics of riparian ecosystems (Figure 6). Overbank flooding connects the river to the floodplain, delivering nutrients and sediment to the riparian wetlands and on return to the channel bringing nutrients and carbon (litter and large woody debris). Large flows can remove vegetation, and reshape and renew the riverscape’s physical environment. In particular, spring floods are thought to create the fresh substrate and fluvial geomorphology necessary for germination of obligate riparian species such as cottonwoods, willows, and sycamores. Along with site creation, there is a direct link between seedling germination and subsequent survival to groundwater availability. That is, flood-driven groundwater at post-flood sites must recede slowly enough that seedling root growth can follow it down to the baseline groundwater depth before the arrival of low precipitation that typically occurs in May and June (Figure 7). Beyond this, base stream flows in the ensuing summer months must be sufficient to maintain groundwater heights to support growth and vitality of wetland and riparian vegetation along with ecological processes in the hyporheic zone that are critical to wetland function (the subsurface zone where groundwater mixes with transient incoming and outgoing surface water).

Under natural conditions, groundwater dynamics are generally in concert with surface water flows (as seen in the Gila River), but impacts such as diversions, flow regulation, and sediment retention can have significantly altered surface/groundwater interactions and the ecological integrity of riverine ecosystems. Accordingly, flooding and surface/ground water dynamics play a central role in the NMRAM metrics.

Table 3. Summary precipitation data for New Mexico across the 20th century (source: Western Regional Climate Center 2019).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1931-60	0.63	0.6	0.64	0.69	1.14	1.04	2.13	2.28	1.59	1.12	0.48	0.64	12.99
1941-70	0.56	0.5	0.64	0.63	0.93	1.03	2.28	2.37	1.49	1.11	0.43	0.68	12.65
1951-80	0.57	0.52	0.61	0.54	0.89	0.96	2.27	2.38	1.53	1.15	0.56	0.62	12.59
1961-90	0.59	0.6	0.63	0.57	0.92	1.17	2.27	2.58	1.87	1.17	0.73	0.75	13.85
1971-00	0.67	0.6	0.71	0.63	1.11	1.23	2.27	2.64	1.82	1.34	0.8	0.76	14.58
Average	0.60	0.56	0.65	0.61	1	1.09	2.24	2.45	1.66	1.18	0.6	0.69	13.33

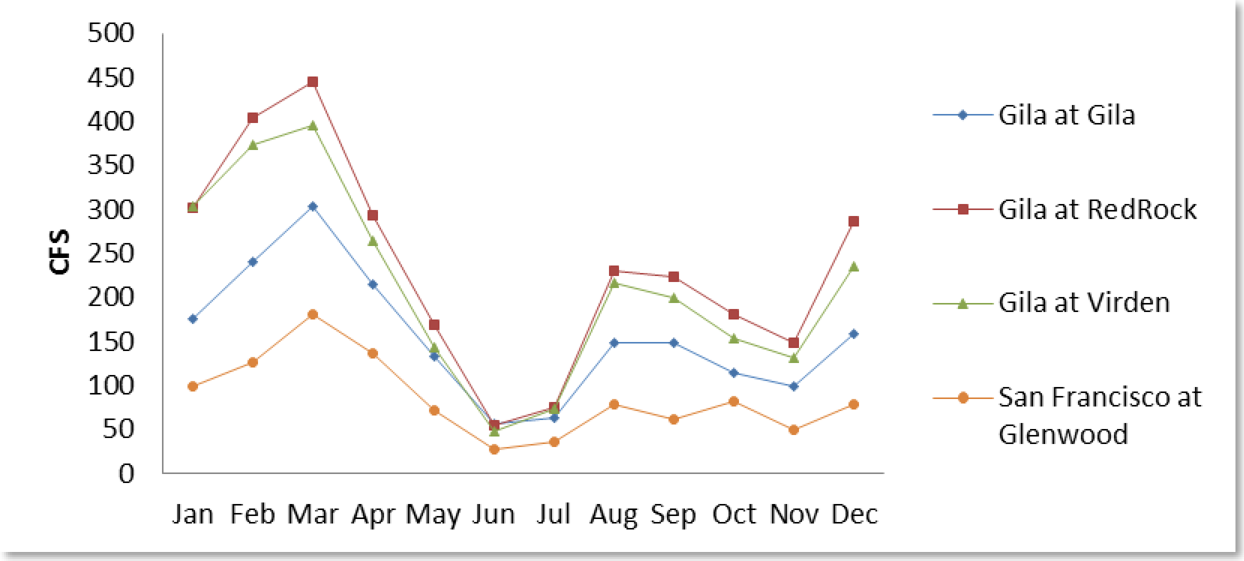


Figure 5. An example from the Gila River of how river discharges (CFS) in New Mexico peak around March in response to snowmelt with a secondary peak in August and September in response to monsoonal thunderstorms and fronts (data from USGS Waterwatch 2013).

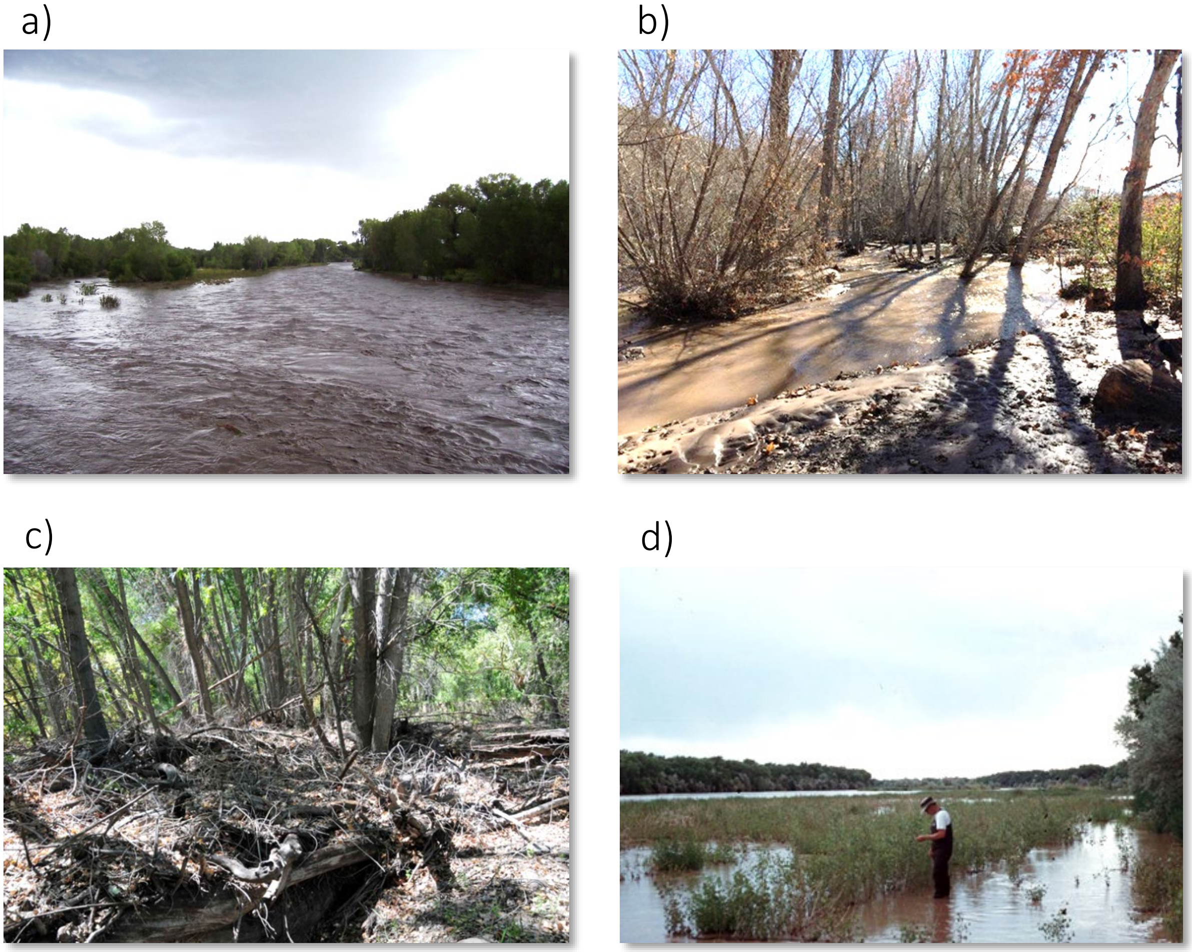


Figure 6. Flooding such as this on the Gila River in 2013 (a) can fill the floodplain with water and fresh sediments rich in nutrients (b) along with woody debris (c). Together they make for a diverse microhabitat structure for riparian wetlands. Flooding can also rework floodplains to create the required environment for the reproduction of riparian species such as these young cottonwoods along the Rio Grande (d) (Photos: NMED; NHNM).

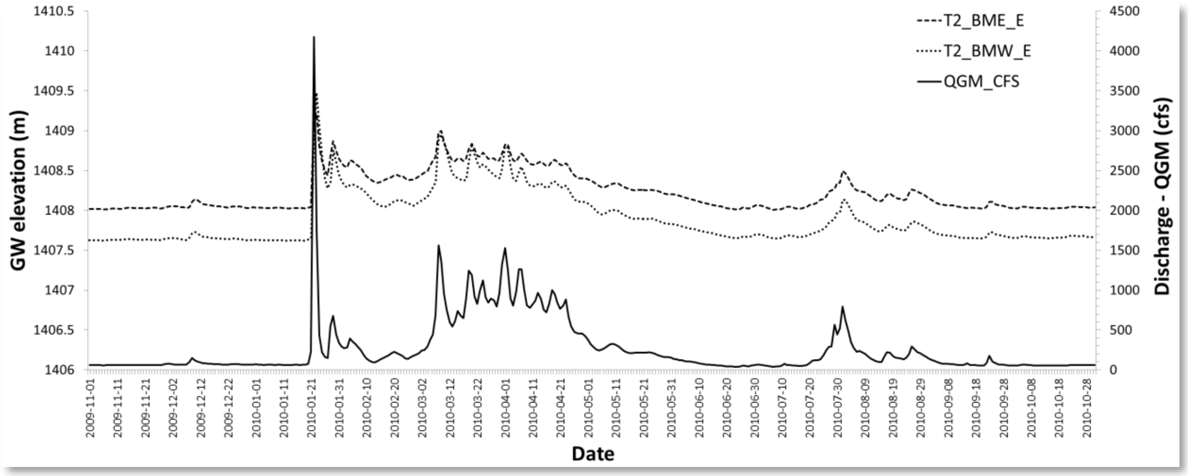


Figure 7. An example of stream flow and groundwater dynamics in water year 2010 on the Gila River near Gila, NM. Surface water flow includes discharge from the Gila River and Mogollon Creek (QGM) combined and groundwater (GW) elevations from two piezometer wells at the site (T2_BMW_E is closer to the channel and T2_BMW_E is further). Modified from Muldavin and Varani (2018).

NMRAM WETLAND CLASSIFICATION

New Mexico's wetlands vary considerably across the fifth-largest state from high-mountain headwater wetlands to montane riverine wetlands surrounded by conifer forests, to lowland riverine wetlands bordered by the Chihuahuan Desert, and isolated playas. Which rapid assessment metrics are used and how they are measured can vary with wetland type. For consistency, the SWQB Wetlands Program classifies wetlands into broad classes and regional subclasses following the hydrogeomorphic (HGM) classification factors identified by Brinson (1993) along with other biophysical factors of importance. The objective is to identify groups of wetlands that are relatively homogeneous in terms of structure, process, and biotic composition. In the HGM framework, a regional wetland subclass shares similar characteristics such as stream discharge, slope, physical setting, geology, climate, and vegetation. For each subclass, we have developed relevant metrics and measurement protocols tailored to the subclass conditions. Metrics developed by subclass provide consistent and reliable indicators of wetland conditions at the local level and which can be compared consistently across a region. Some metrics apply across two or more subclasses that allow for direct comparisons among types.

The NMRAM follows the Hydrogeomorphic (HGM) Classification hierarchy of Brinson (1993) and its updates including Brinson et al. (1995), Smith et al. (1995), and Wilder et al. (2012). The top tier of wetland classes is defined in terms of geomorphic setting, water source, and hydrodynamics. Lower-level Subclasses within these classes are based on characteristics such as hydrology, slope, physical setting, geology, climate, and vegetation per the U.S. National Vegetation Classification (USNVC)[3]. The USNVC provides a hierarchy of recognized vegetation types across the United States that serves to guide multi-agency land management as directed by the USNVC Standard 2.0 of the U.S. Federal Geographic Data Committee Subcommittee on Vegetation Classification. In this context, there are five HGM classes relevant to New Mexico: Riverine, Depressional, Lacustrine Fringe, Slope, and Mineral Soil Flat. The SWQB Wetlands Program has identified several subclasses of wetlands through a Level 1 effort to map and classify all wetlands in New Mexico exclusive of tribal lands (see Table 1). To date, four subclass modules within two classes (Riverine and Depressional) have been developed (Montane Riverine Wetlands, Lowland Riverine Wetlands, Confined Valley Riverine, and Depressional Playa Wetland). These are summarized in Table 4 and described below.

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[3] See http://usnvc.org/

Table 4. NMRAM class and subclass characteristics.

Riverine Wetlands Class

Wetlands of floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow from the channel or subsurface (hyporheic) hydraulic connections between the stream channel and wetlands.

Montane Riverine Wetlands (unconfined) Subclass

- Riparian wetlands of unconfined valley floodplains.
- Stream gradient 1-4%.
- Mid-elevations between 6,000 and 8,500 ft in the northern part of the state and dipping to lower elevations around 4,800 ft in the southern portion.
- Mid-order streams between mainstem lowland rivers and streams of subalpine zones.
- Predominantly perennial flows but intermittent segments can occur seasonally or during dry years.
- Generally mobile, meandering or step-pool single-channel systems with direct overbank flooding or high-flow side channels.
- Vegetation a mosaic of riparian forested and shrubland wetlands along with herbaceous wetlands dominated by montane species. Key indicator species: narrowleaf cottonwood, bluestem willow, thinleaf alder, Arizona alder, and water birch.
- USNCV Groups: Rocky Mountain-Great Basin Montane Riparian Forest (G506); Western Montane-Subalpine Riparian & Seep Shrubland (G527); Vancouverian-Rocky Mountain Montane Wet Meadow & Marsh (G521).

Lowland Riverine Wetlands (unconfined) Subclass

- Riparian wetlands of unconfined valley floodplains.
- Stream gradient <1%.
- Elevations below 6,000 ft in the north and 4,800 ft in the south.
- Mainstem, fourth- or fifth- order streams below montane riverine streams.
- Predominantly perennial flows but intermittent segments can occur seasonally or during dry years.
- Generally mobile, meandering single- or multi-channel braided systems with direct overbank and side-channel flooding.
- Vegetation a mosaic of riparian forested and shrubland wetlands along with herbaceous wetlands dominated by lowland species. Key indicator species: plains and Fremont cottonwood, Gooding's willow, peachleaf willow, coyote willow, seep willow.
- USNVC Groups: Western Interior Riparian Forest & Woodland (G797); Rocky Mountain-Great Basin Lowland-Foothill Riparian Shrubland (G526); North American Warm Desert Riparian Low Bosque & Shrubland (G533); Arid West Interior Freshwater Marsh (G531).

Confined Valley Riverine Wetlands Subclass

- Riparian wetlands of naturally confined canyons with a v-shaped cross-sectional profile.
- Cobble, boulder, and/or bedrock controlled with little channel mobility and floodplain development.
- Stream gradient >1% and commonly > 5%.
- Mid-order streams between main-stem lowland rivers and streams of subalpine and alpine zones.
- Channel morphologies include cascades, step-pool, and drops over boulders with extended pools.
- Elevations generally above 6,000 ft in the north and 4,800 ft in the south.
- Predominantly perennial flows but intermittent segments can occur seasonally or during dry years.

Table 4 (cont.). NMRAM subclass characteristics for Playa Wetlands

Depressional Wetlands Class
Wetlands that occur in topographic depressions with a closed-elevation contour that allows accumulation of surface water from adjacent uplands.
Playa Wetlands Subclass
• Shallow, ephemeral freshwater wetlands of enclosed micro-basins typically between 1 acre and 10 acres but can be smaller or larger on occasion. • Filled by direct precipitation and runoff from the micro-basin and then dried by evaporation, transpiration, and infiltration into the local aquifer over the course of a dry period. • Restricted to the basin floor and the immediate slope up to the annulus as defined by the visual edge. • Not groundwater-fed. • The basin floor or pan is typically composed of shrink-swell clay soils (vertisols) that seal with water inputs and prevent direct drainage. • Elevations range from ~ 4700 ft in the north to 3,000 ft in the south. • USNVC Groups: Great Plains Playa & Rainwater Basin Wetland (G136)

RIVERINE CLASS

The Riverine Wetland Class refers to those wetlands that occur in floodplains and riparian corridors in association with stream channels (Brinson et al. 1995)(Figure 8). The NMRAM Riverine Wetland Class per HGM is inclusive of the areas that are seasonally or temporarily flooded that support forested wetlands and shrublands along with emergent wetlands (US EPA 2006). Dominant water sources are overbank flow or side-channel flow from the main channel coupled with subsurface hydraulic connections between the stream channel and a shallow groundwater hyporheic zone. Additional water sources may be overland flow or interflow from adjacent uplands, tributary flow, and precipitation. Surface flows down the floodplain may dominate riverine wetland hydrodynamics during high flow events.

Rivers and streams associated with riverine wetlands are generally perennial but can include intermittent segments, particularly during drought years. For the purposes of NMRAM, also included in this class are ephemeral systems that are characterized by alluvium and dominated by precipitation flooding and flow events of short duration.

In New Mexico, the hydrological regime of the class is characterized by peak flows in April through June in the north and March through May in the south driven by snowmelt runoff, followed by extended periods of low to moderate base flows (see Figure 7). Rain events associated with large summer monsoon events beginning in July through September may result in flow spikes of short duration during the summer and fall months that can inundate riverine wetlands for generally brief periods. During spring runoff and storms, riverine wetlands can become saturated by shallow groundwater and then lose subsurface water by discharge back to the channel, movement to deeper groundwater, and evapotranspiration. There can be off-channel depressions and abandoned channels (oxbows) that have become isolated from direct riverine processes yet subjected to long periods of saturation from groundwater sources (Brinson et al. 1995, Hauer et al. 2002). These off-channel elements that are still linked to the riverine system via hyporheic connections are considered part of the riverine system.

The NMRAM HGM-based definition of "riverine" approximates that of "riverine" of the channel plus palustrine habitats of the floodplain as described by Cowardin et al. (1979) and used by U.S. Fish and Wildlife Service (USFWS 2009) in its national wetlands inventory. The focus of the NMRAM assessment is on palustrine floodplain habitat or riparian zone that is temporarily or seasonally flooded. Regardless, the critical element of riverine wetlands that distinguishes them from adjacent uplands is their dependence on a channel connection to surface or subsurface water.

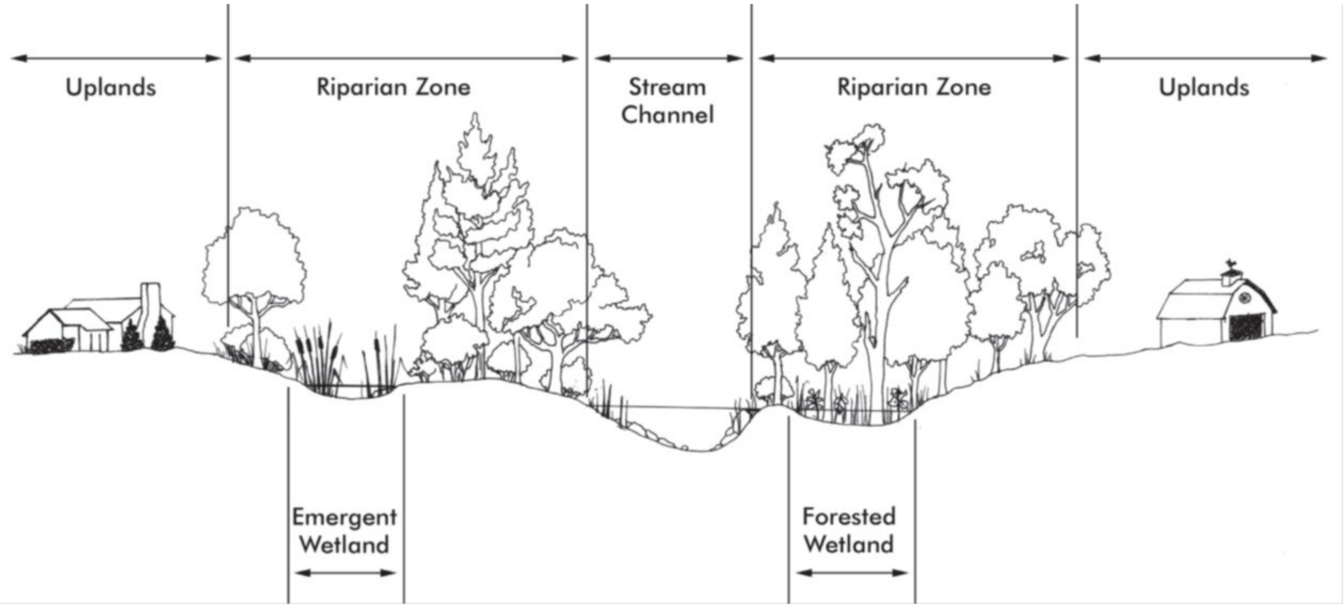

Figure 8. The NMRAM Riverine Class per HGM is inclusive of the areas that are seasonally or temporarily flooded that support forested wetlands and shrublands along with emergent wetlands (US EPA 2006).

MONTANE RIVERINE WETLANDS

Montane Riverine Wetlands occur along unconfined mountain streams and rivers at elevations between 6,000 and 8,500 ft and in the southern part of the state at elevations as low as 4,800 ft (Figure 9). They generally lie between the subalpine riverine and lowland riverine subclasses. The subclass includes mid-elevation, second- to fourth-order stream segments where valley widths generally exceed 80 m (262 ft) and have a channel width ranging from two to 10 m (6.6-33 ft). Accordingly, channels have a low degree of confinement from the surrounding landscape and have room for lateral movement leading to moderate sinuosity. Channels have moderate slopes of about 1% to 4% and channel features that may include point bars, runs, riffles, and pools. Gravel and cobble dominate streambeds and banks, but sand and silt may be present in the banks or on floodplain surfaces. Under normal conditions, channels are relatively shallow with an entrenchment ratio exceeding 2.2 and a corresponding channel width-to-depth ratio greater than 12. Overbank flooding during peak flows plays a major role in developing and sustaining complex floodplains composed of point bars, terraces, and backwater channels that support the wetland communities. Overall, these are mobile, meandering single-channel systems with direct overbank and side-channel flooding that corresponds to Rosgen (1996; 2006) C-channel types.

Some montane riverine channel reaches exhibit steeper channel slopes (2-4%), still within a wide valley as a result of their geomorphic context. The channel and its riverine wetlands display Rosgen B-channel characteristics. However, a lower entrenchment ratio (<2.2-1.4) is normal for the reach. Other Rosgen B-channel types fit into the Confined Valley Riverine subclass when the river valley is too narrow to accommodate the full width of the flood-prone area, and the attendant suite of Montane Riverine wetlands plant communities (Rosgen 1996; 2006).

Figure 9. Typical montane unconfined riverine wetlands along the Red River in northern New Mexico with a relatively small channel of moderate gradient and an adjacent depositional floodplain in a valley bounded by mountain slopes. (Photo: NHNM stock)

The vegetation of the Montane Riverine Wetlands subclass can be broadly characterized as a complex mosaic of montane riparian forests, shrublands, and emergent herbaceous wetlands. Following the U.S. National Vegetation Classification (USNVC) system (Federal Geographic Data Committee 2008), these communities can be classified at the USNVC Group level as Rocky Mountain-Great Basin Montane Riparian Forest (G506); Western Montane-Subalpine Riparian & Seep Shrubland (G527); and Vancouverian-Rocky Mountain Montane Wet Meadow & Marsh (G521). Each group is characterized by a suite of plant associations defined by dominant and/or diagnostic species (see Muldavin et al. 2000 or the USNVC for detailed descriptions).

Briefly, the forest and shrubland communities are dominated by a mix of obligate or facultative wetland deciduous trees and shrubs which include narrowleaf cottonwood (*Populus angustifolia*), bluestem willow (*Salix irrorata*), thinleaf alder (*Alnus incana* ssp. *tenuifolia*), Arizona alder (*Alnus oblongifolia*), and water birch (*Betula occidentalis*). At the lower elevations of the subclass, *P. acuminata*, the hybrid between narrowleaf cottonwood and the broadleaf cottonwoods, *P. deltoides* or *P. fremontii*, may be common along with boxelder (*Acer negundo*) and coyote willow (S. exigua). Conifers such as blue spruce (*Picea pungens*) may also be common. The herbaceous wetlands and woodland understories vary, but typically obligate or facultative wetland species prevail (e.g., sedges [*Carex microptera* or *C. utriculata*]; rushes [*Juncus arcticus*], or grasses [*Calamagrostis canadensis*]. While exotic invasive trees and shrubs are relatively uncommon, the herbaceous understory may be dominated by mesic but exotic European pasture grasses, (e.g., redtop [*Agrostis stolonifera, A. gigantea*], bluegrass [*Poa pratensis*], or quackgrass [*Elymus repens*].

LOWLAND RIVERINE WETLANDS

Lowland Riverine Wetlands lie along fifth order or greater streams (>1300 cfs bankfull discharge) occurring at elevations below montane riverine wetlands (below 6000 ft) in broad alluvial valleys where the grade falls below 1% to nearly flat (<0.02-0.0001) (Figure 10). Lowland streams may be perennial or intermittent, particularly in desert reaches or during droughts. Channels have a low degree of confinement from the surrounding landscape and have room for lateral movement often leading to a high degree of channel sinuosity or multi-channel systems. In contrast to montane streams, lowland rivers are larger systems with higher bankfull discharge rates, often with naturally higher fine sediment bedloads, and species that are adapted to these hydrologic and geomorphic characteristics.

Figure 10. An example of the Lowland Riverine Subclass along the Gila River near Gila, NM. Note the broad floodplain and broadleaf Fremont cottonwoods that characterized the subclass. (Photo: E. Muldavin)

The primary configuration is single-thread meandering systems with a main channel having a defined bank and bed that is indicative of overbank flows that help support a riparian zone. Channel features may include point bars, island bars, side channels, oxbows, wide shallow runs, pools, and back waters. Cobble may underpin the floodplain surface of sand beds, and silt and clay layers deposited on the floodplain. Over time, the unconfined river channel displays lateral migration of meanders across the floodplain, influenced by the presence and condition of riparian vegetation. Alternatively, streams may be naturally multi-threaded (braided or anastomosing) caused by deposition and distribution of high-sediment loads that encounter a sudden reduction in flow velocity as the gradient declines. In a braided stream, there may be a main low-flow channel along with side channels that carry flow during bankfull and higher flow events instead of overbanking. The side channels provide pathways to riparian zone inundation and infiltration. Braided stream systems also can be characterized by the channel divided into a number of smaller, interlocking channels by longitudinal bars and high system mobility. Braided channels tend to be wide and shallow and bedload materials are often dominated by non-cohesive coarse sands and gravels. Under normal conditions, channels are relatively shallow with a bankfull to flood-prone valley-width ratio exceeding 2.2 and a corresponding channel width-to-depth ratio greater than 12. Overall, these are mobile, meandering single or multi-channel braided systems with direct overbank and side-channel flooding (Rosgen (1996; 2006) C or D channel stream types).

The vegetation of the Lowland Riverine Wetlands subclass can be broadly characterized as a complex mosaic of lowland riparian forests, shrublands, and emergent herbaceous wetlands. Following the U.S. National Vegetation Classification System (Federal Geographic Data Committee

2008), these communities can be classified at the USNVC Group level as: Western Interior Riparian Forest & Woodland (G797); Rocky Mountain-Great Basin Lowland-Foothill Riparian Shrubland (G526); North American Warm Desert Riparian Low Bosque & Shrubland (G533), and Arid West Interior Freshwater Marsh (G531). Each group is characterized by a suite of plant associations defined by dominant and/or diagnostic species (see Muldavin et al. (2000) or the USNVC for detailed descriptions). Briefly, the forest and shrubland communities are dominated by a mix of obligate or facultative wetland deciduous trees and shrubs which include plains and Fremont cottonwood (*Populus deltoides* and *P. fremontii*), Gooding's willow (*S. gooddingii*), peachleaf willow (*S. amygdaloides*), coyote willow (S. exigua), and seep willow (*Baccharis emoryi, B. salicifolia*, and *B. salicina*). Exotic tree species can also be present as co-dominants, especially at lower elevations and include Russian olive (*Elaeagnus angustifolia*), tamarisk (*Tamarix chinensis*), Siberian elm (*Ulmus pumila*), and tree of heaven (*Ailanthus altissima*). The herbaceous wetlands and woodland understories vary, but in areas with higher water tables obligate or facultative wetland species prevail, e.g., sedges such as *Carex emoryi* or *C. nebrascensis*; common spikerush (*Eleocharis palustris*), rushes such as *Juncus balticus*, bulrushes such as *Scirpus pungens* or grasses such as saltgrass (*Distichlis spicata*). In the herbaceous understory, as in the woody overstory, introduced species are relatively common. Herbaceous stands may be dominated by mesic but exotic European pasture grasses (e.g., redtop [*Agrostis stolonifera*, *A. gigantea*]), tall fescue, [*Festuca arundinacea*], and naturalized ruderal species (e.g., kochia [*Kochia scoparia*]), Russian thistle [*Salsola* sp.] and other non-native invasive species.

CONFINED VALLEY RIVERINE WETLANDS


Figure 11. An example of a confined valley channel from Lake Fork Cabresto Creek above Cabresto lake.

Confined Valley Riverine Wetlands are those wetlands found along stream and river channels that are cobble, boulder, and/or bedrock controlled and typically constrained within narrow v-shaped valleys (Brinson 1993; Wilder et al. 2012). Accordingly, lateral migration of channels is limited and stream channel morphologies range from cascades with small or no pool development to a step-pool configurations with intermixed drops over boulders and extended pools (Rosgen 2006 steam type A; Figure 11). This subclass typically occurs in mountainous regions but can extend down into ravines that cut through plateaus (e.g., tributaries to the Rio Grande Gorge). Elevations range from 4,500 ft to 9,000 ft. Stream channel gradients are >1% and commonly >5%, and hence confined streams have relatively high velocities and stream power that leads to scouring the channel of sediments at high flows, and preventing significant sediment storage (the development of alluvial bars or the collection of fine materials in the interstitial spaces between boulders and cobbles is very limited). Large woody materials such a downed logs can be important in channel structure, sediment capture, habitat diversity and stream velocity. Water sources are primarily flow-through surface flows with limited associated near-surface ground waters, and occasional lateral slope inputs are possible.

Specifically, a confined valley width is limited to less than six times the average channel width when stream channel slope exceeds 1.5% (valley width defined by break to increasing slope associated with uplands). When channel slope approaches 1.5% or less, slope valley width to channel ratio is <3. Channels tend have limited sinuosity or are straight (1.2 or less sinuosity ratio).

Lowland "box canyons" of low gradients, which often have significant fluvial sediment accumulations, are not considered part of this subclass but rather a special case of the lowland unconfined subclass. In addition, entrenched channels that are the result of historical (post-Columbian) deep incision of larger fluvial floodplains are not part of this subclass regardless of the constraining old terrace walls (e.g., Rio Puerco).

Riparian and wetland vegetation communities of the Confined Valley Riverine Wetlands are predominantly willow (e.g., *S. exigua* or *S. irrorata*), alder (e.g., *A. tenuifolia*), dogwood (*Cornus sericea*), and birch (Betula occidentalis) shrublands that line the channel. Trees are very limited except for an occasional cottonwood (*P. angustifolia, P. deltoides,* and *P. fremontii*) in a protected site or adjacent overhanging upland conifer forests. Narrow bands or small pockets of herbaceous wetlands can also occur along the channel which are dominated by facultative and obligate wetland grasses and sedges. With respect to the USNVC, these communities belong to the Rocky Mountain-Great Basin Lowland-Foothill Riparian Shrubland (G526) and Western Montane-Subalpine Riparian & Seep Shrubland (G527). The herbaceous wetlands fall under Vancouverian-Rocky Mountain Montane Wet Meadow & Marsh (G521). While the herbaceous communities may have a significant component of exotic species, the shrublands are strongly native-dominated.

DEPRESSIONAL WETLANDS CLASS

Depressional wetlands occur in topographic depressions with a closed-elevation contour that allows accumulation of surface water. Dominant sources of water are precipitation, groundwater discharge, interflow, and runoff from adjacent uplands. The direction of water movement is from the surrounding uplands toward the center of the depression.

PLAYA WETLANDS

The Playa Wetlands of the Southern High Plains are a subclass of Depressional Wetlands found within the Llano Estacado (plateau) or "Caprock" region of southeastern New Mexico (specifically Curry, Roosevelt, Quay, and Lea Counties). Elevations range from about 4,700 ft (1,400 m) in the north to 3,000 ft (900 m) in the south. These are shallow (<2m), ephemeral fresh-water wetlands at the bottom of relatively small, enclosed basin watersheds without outlets (typically 50 to 800 ha; 125 to 2,000 ac). The wetlands are typically circular, ellipsoid or teardrop in shape and between 1 acre (0.4 ha) and 10 acres (4 ha) in size, but they can be smaller or larger on occasion. The playa basins are formed by a combination of wind, wave, and dissolution processes and they often occur in clusters along geologic fracture zones. The wetlands are restricted to the basin floor and the immediate slope or annulus (whose upper boundary is defined by a visual edge reflecting the general high water mark for the wetlands; Figure 12). The basin floor or pan is composed of shrink-swell clay soils (vertisols) that seal with water inputs and prevent direct drainage. The wetlands are formed by precipitation and runoff from the immediate basin slopes (they are not groundwater-fed) and then dried by evaporation, transpiration, and downward infiltration into the local aquifer over the course of the dry period. Herbaceous obligate and facultative wetland plant species are usually present and often form concentric bands of vegetation of differing compositions.

Figure 12. Example of a playa wetland of the Caprock region of New Mexico showing the ephemeral lake margin and annulus (Photo: E. Muldavin).

The hydroperiod of a playa is critical to natural playa functions. The natural flora and fauna of a playa are dependent on the flooding and periodic drying of playas seasonally and from year to year. Drying and flooding allows vastly different communities to exist on the same site increasing diversity of the wetland (Smith and Haukos 2002). Changes in the moisture regime affect the types of communities that exist within the playa. Sedimentation and filling of playa wetlands are a significant threat to naturally functioning playa wetlands (Smith 2003). Because playas are situated at the bottom of their watershed, they naturally accumulate some sediment. Under normal circumstances on the Southern High Plains, prevailing winds are able to scour the playa bottom after playa inundation when playas are dry and vegetation has decomposed. A number of sources can increase the accumulation of sediment in a playa beyond the functional capacity of the playa wetland. As sediment accumulates over time, the volume of the playa is reduced which in turn reduces the volume of water that a playa can store. Sediment from uplands that enters a playa normally has a different soil and chemical composition than the clay bottoms typical of playa wetlands, which in turn alters plant and faunal communities.

Playa vegetation communities are predominantly made of herbaceous grasses, sedges, and forbs that in respect to the USNVC belong to the Great Plains Playa & Rainwater Basin Wetland Group. These communities commonly form ring-like zonal patterns around the playa that are driven by the degree of inundation and water persistence in the playa. For example, the annulus shown in Figure 12 is a mix of annual and perennial forbs and grasses that can tolerate periodic but not sustained flooding (facultative wetland species) such as frogfruit (*Phyla cuneifolia*), pink smartweed (*Persicaria bicornis*), knotweed (*Polygonum ramosissimum*), vine mesquite (*Panicum obtusum*), barnyardgrass (*Echinochloa crus-galli*) and bearded sprangletop (*Leptochloa fusca* ssp. *fascicularis*). Upslope are upland grasslands of the Shortgrass Prairie typically dominated by blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*). Downslope into the playa bottom where water may persist for extended periods, herbaceous wetland species such as pale spikerush (*Eleocharis macrostachya*), hairy waterclover (*Marsilea vestita*) and Southwestern annual saltmarsh aster (*Symphyotrichum subulatum* var. *parviflorum*), may predominate or even aquatic species such as roundleaf mudplantain (*Heteranthera rotundifolia*) or longbarb arrowhead (*Sagittaria longiloba*) may be present in ponded areas. However, as the playa dries, the playa bottom can become barren of vegetation, particularly as the clay pan cracks. When the playa has been dewatered, upland grassland species, most notably, buffalo grass and ruderal annual species like common kochia (*Kochia scoparia*) and prickly Russian thistle (*Salsola tragus*) will often encroach and persist (see Smith 2003 for details on playa floras).

METRIC DESCRIPTIONS

Descriptions of all NMRAM metrics follow, grouped by attribute classes of Size, Landscape Context, Biotic, and Abiotic. For each description, the subclass module the metric is applicable to is listed followed by a brief definition, the background for the development of the metric, the rationale for its use in rapid assessment, and a metric scoring and rating explanation. Full protocols for measuring metrics are provided in the field guides for each module and the rating tables are in the associated field sheet packets (see Table 3 for cross-references regarding which metrics apply to which subclass module).

SIZE

Traditionally, the total size of a wetland has been important as an overarching measure of ecological integrity and function, but its role is complex (Faber-Langendoen et al. 2008). Size can be important for maintaining plant and animal populations and the overall biodiversity of a wetland. That is, there can be minimum dynamic and resource area requirements for supporting a full suite of biota. Larger wetlands tend to support more diverse mosaics of vegetation communities and microhabitat features. Larger wetlands are likely to be more resistant to hydrologic stressors and land-use impacts from the surrounding landscape. Thus, size can serve as a readily measured proxy for some ecological processes and the diversity of interdependent assemblages of plants and animals.

Yet, determining size can be context and definition dependent. That is, the size of a wetland of interest is likely dependent on the wetland type and decision rules used to define the limits of that type. For example, the size defined based on jurisdictional wetland criteria could be considerably smaller than wetlands defined in terms of wildlife habitat or conservation of species of concern. In addition, wetlands found along high-order versus low-order streams or in depressions likely have different relationships between size, and integrity and function. That is, size can vary widely for entirely natural reasons (e.g., a smaller valley may naturally restrict the size of a functioning floodplain wetland). *Given these caveats, the NMRAM applies size as a rated condition metric only to playa wetlands because they have clearly delineated basin size limits that set wetland size ranges that can be easily evaluated.*

S1. ABSOLUTE PLAYA SIZE

Modules: Playa Wetlands

Definition: An assessment of current size of a playa wetland including the annulus and basin floor.

Background: The identification of large, isolated playas is one of six metrics used by Playa Lakes Joint Venture to prioritize playas for conservation (McLachlan et al. 2014). They consider playas greater than 1.2 ha (3 ac) to be large; 0.4 to 1.2 ha (1 ac) medium, and less than 0.4 ha small.

Rationale: Because playa wetlands are inherently shallow, isolated, and self-maintained within their own micro-basin (watershed) within relatively flat terrain, playa size is important in maintaining its ecological integrity (Figure 13). Larger playas are generally associated with and drain larger basin areas. Precipitation on the Southern High Plains can be localized, filling a playa in one location while a playa nearby will be dry. Having a larger drainage basin can preferentially capture runoff that fills the larger playa more often and, accordingly, extend roosting and foraging habitat for migrating waterfowl and other wildlife species (McLachlan et al. 2014). Larger playas are also able to absorb more impacts while retaining a portion of their ecological integrity, biodiversity, and natural functions, where a smaller playa would be more susceptible to functional loss or complete obliteration. Numbers of animals or plants may be higher in larger occurrences than in small occurrences that are otherwise similar (Smith 2003). Larger playas are likely more resistant to hydrologic stressors. Thus, size can serve as a readily measured proxy for some ecological processes and the diversity of interdependent assemblages of plants and animals (Faber-Langendoen 2012a).

Scoring and Rating: Size classes were derived from classes developed by Playa Lakes Joint Venture for their Playa Decision Support System (McLachlan et al. 2014) but with refinements based on field studies associated with Playa Wetlands NMRAM development. The needs of area-sensitive species and the data on wetland size requirements for population sustainability for such species are elusive. Accordingly, size requirements are conservative, and the ratings are scaled based on the distribution of sizes within the sampling reference domain.

Figure 13. Larger playas offer greater biological diversity and buffering capacity against land use impacts (photos: Y. Chauvin and E. Muldavin).

LANDSCAPE CONTEXT ATTRIBUTES

Landscape Context metrics are formulated as indicators of ecological condition of the landscape surrounding the SA and their implications for potential impacts on ecological condition of a site. These metrics are based on the concept that significant anthropogenic modification of a landscape and degraded condition around the wetland can impart stress on and influence biotic and abiotic conditions within the wetland itself (Brooks et al. 2004; Tiner 2004; Weller et al. 2007). Accordingly, Surrounding Land Use measures the broader human footprint and its intensity around the wetland while the Buffer Integrity Index evaluates the degree of natural or semi-natural buffer immediately adjacent to the wetland that can potentially offset the stress imposed by surrounding landscape conditions (Figure 14; CWMW 2013). Riparian Corridor Connectivity specifically examines the intactness of the riverine corridor adjacent to an SA. As a measure of overall functional capacity reduction (or loss of ecosystem services) at a landscape scale, Relative Wetland Size estimates the change in a riverine wetland's size that is due to direct human development, while Playa Configuration is a similar measure that estimates this anthropogenic alteration for the playa subclass.

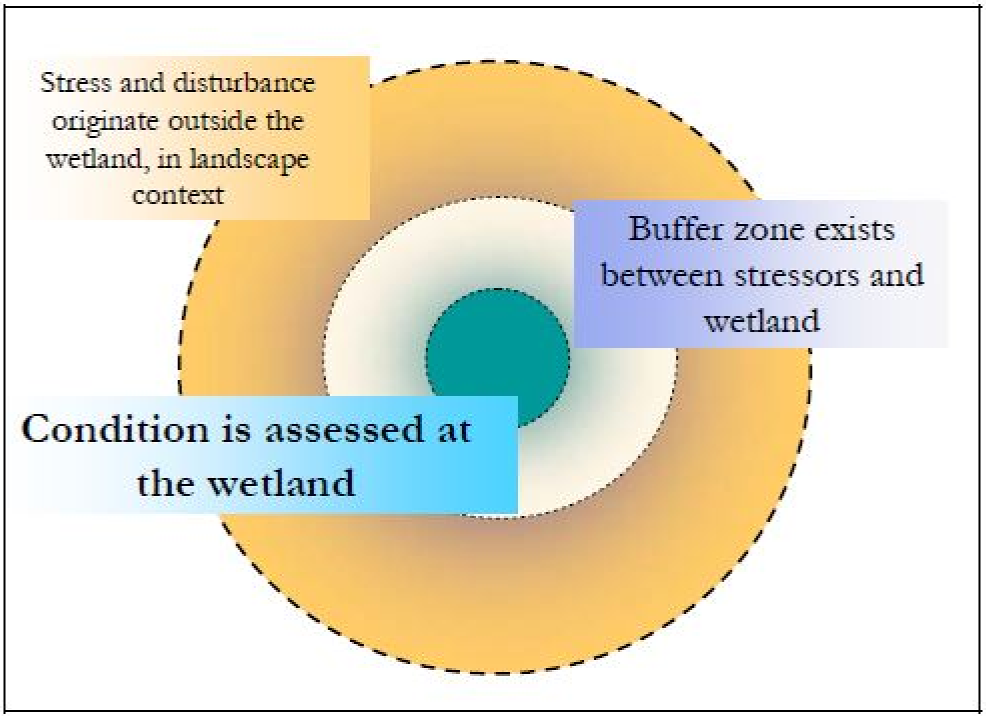

Figure 14. Landscape context attributes can be viewed hierarchically where land use stress surrounding a wetland can be ameliorated to some degree by the quantity and continuity of immediate natural buffer surrounding the wetland (source: CWMW 2013).

L1. BUFFER INTEGRITY INDEX

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory; Confined Valley Riverine

Definition: The Buffer Integrity Index is a measure of the amount of natural and semi-natural vegetated buffer adjacent to the SA and is composed of two sub-metrics:

- *Buffer Percent*: the percentage of the lateral perimeter of a wetland SA that is considered natural or semi-natural buffer
- *Buffer Width*: the average width of the extant buffer lateral to the SA

Background: The Buffer Integrity Index is originally a non-riverine metric rating developed by McIntyre and Hobbs (1999); the riverine version used here was adapted from CRAM (CWMW 2013) and its modifications for NatureServe Ecological Integrity Assessment (Faber-Langendoen et al. 2012b). For NMRAM Manual Version 2.0, the sub-metric Buffer Condition has been removed because of the limited field capacity to evaluate it effectively.

Rationale: Buffers are important components of the wetland in that they enhance function and protect the wetland from anthropogenic environmental stressors. Buffers are transitional zones between the margins of a wetland and its surrounding environment that are in a natural or relatively natural state and not greatly affected by anthropogenic stressors or disturbances. The buffer can protect wetlands from anthropogenic stressors by filtering pollutants, reducing nutrient loads, reducing erosion and stream sedimentation, providing habitat and/or corridors for wetland wildlife, and acting as barriers to disruptive anthropogenic incursions (CWMW 2013; Faber-Langendoen et al. 2012a). Buffers can also reduce the risk of invasion by non-native plants and animals either by obstructing terrestrial corridors of invasion or by helping to maintain the integrity and therefore the resistance of wetland communities to invasion. The Environmental Law Institute (2008) summarizes extensive data on the rationale for the role of buffers in maintaining ecological integrity of wetlands.

The extent along the perimeter of a wetland buffer is thought to increase wetland protection by preventing focal entry by carnivores, herbivores, and invasives that can affect the plant community (CWMW 2013). Similarly, greater buffer width can help reduce inputs of non-point source pollutants and reduce sediment influx, and buffers that exceed 100 m are optimal. Those that exceed 250 m are optimal for animal habitat buffering. To accommodate the latter, the Buffer Integrity Index is measured in an area extending 250 m from the SA and is based on identifying a suite of non-buffer land-cover elements that limit the extent of buffers.

Scoring and Rating: Originally, there were four equal-value rating classes for each sub-metric following CWMW (2013). However, following analysis of data collected during the development of the NMRAM we found that equal-value ratings classes for Buffer Percent were not sensitive to conditions in NM. Accordingly, the ranges for the Buffer Percent sub-metric rating classes were restructured to reflected field conditions in New Mexico (See field guides for details.) The Buffer Integrity Index score is the average of the two sub-metric scores and the final score is weighted such that only very pristine sites can get an “A.”

L2. RIPARIAN CORRIDOR CONNECTIVITY

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory, Confined Valley Riverine

Definition: Riparian Corridor Connectivity (RCC) measures the disruption of natural land connectivity upstream and downstream from the SA with an emphasis on detecting intervening obstructions that might inhibit wildlife movement, disrupt floodplain connectivity, and impact plant populations.

Background: Adapted from CRAM (CWMW 2013). For NMRAM Manual Version 2.0, definitions of the RCC measurement area vary by subclass per field protocols but the concept remains the same.

Rationale: High-quality riverine wetlands areas are typically composed of a continuous corridor of intact natural riparian vegetation made up of forested, shrub, and herbaceous wetlands along the stream channel and floodplain (Muldavin et al. 2000; Smith 2000; Faber-Langendoen 2012b). These corridors allow uninterrupted movement of animals throughout the riparian zone as well as access to adjacent uplands (Gregory et al. 1991; Hilty and Merenlender 2004). Intact corridors can allow for unimpeded movement of surface and overbank flows, which is critical for the distribution of sediments and nutrients as well as the recharging of local alluvial aquifers. This connectivity of process is also key to the creation and maintenance of healthy riverine and native riparian habitats (Crawford et al. 1993; Blanton and Marcus 2013). Additionally, connectivity of width and length of riparian habitats may be a powerful indicator of water quality (Gergel et al. 2002). Hence, connectivity among riparian wetlands in a corridor is key to the function and integrity of a riverine ecosystem.

Not only is the longitudinal connectivity important for the movement of wildlife, lateral extent of riparian zones is also necessary for the maintenance of healthy and diverse animal populations. Bird diversity and species richness are significantly correlated with riparian belts of 50 to 150 m or wider (Arcos et al. 2008; Croonquist and Brooks 1993; Darveau et al. 1995; Hodges and Krementz 1996; Keller et al. 1993). Riparian woody vegetation corridor width and height are significantly correlated with bird species richness (Blanton and Marcus 2013; Cooke and Zack 2009). Riparian zone widths of 300 to 1,000 m may be required for some sensitive species of birds, reptiles, and amphibians (Burbrink et al. 1998; Gaines 1974). Large, native mammalian predators also show a marked preference for wide and intact riparian corridors (Hilty and Merenlender 2004). Overall, continuous and wider corridors are better than fragmented or narrow corridors (Fischer and Fischenich 2000).

Fragmentation and the breaking of connectivity of the riverine corridor can be caused by human alterations, such as roads, power lines and pipeline corridors, agricultural activities, and urban/industrial development (Smith 2000). Hence, RCC assessment is based on measuring non-connectivity land-cover elements that reflect fragmentation of the corridor (the same elements used for the Buffer Integrity Index above). These elements were derived from CRAM (CWMW 2013) with modification to include unpaved roads in active use and functioning vegetated levees as non-connectivity elements. Many levees in New Mexico are topped with unpaved roads. Unpaved roads and levees with roads become vectors for the introduction of invasive weed species, and provide easy access to the riparian zone for a variety of human uses that damage connectivity, such as dumping of waste, off-road vehicle use, fires, unmanaged domestic animals, excessive visitation, etc.

The area assessed for the RCC metric is both wider and longer for large rivers than for small rivers (Table 5). First, bottomland riparian zones were historically larger and often supported a faunal community that required larger intact patches (Kilgo et al. 1998). Secondly, larger systems become self-buffering if the area assessed for impacts is not appropriately scaled with the system, and significant impacts may be missed entirely. Finally, the degree of impact of a single disruption scales in reverse with the size of the system. A single house within the riparian zone of a small river may represent a major loss of connectivity for that small riparian zone, but a single house on a large river would be a less significant loss of connectivity because the riparian zone is also larger. Thus, for large river systems a larger area is assessed for percentage of lost connectivity.

Table 5. Lengths and widths to assess for Riparian Corridor Connectivity for each riverine subclass.

Riverine Subclass	RCC Length	RCC Corridor Width (plus channel)
Montane	500 m (1,640 ft)	100 m (328 ft)
Lowland	1000 m (3,281 ft)	200 m (656 ft)

Scoring and Rating: We suggest that the effects of fragmentation within a riparian corridor are not likely to be linear. That is, even minor breaks in connectivity can have an adverse effects on the functions of a corridor. Accordingly, “A” sites have no fragmentation, “B” sites up to 15%, “C” having an additional 25%, but once disruptions reach a threshold of 40%, the site is considered dysfunctional with respect to connectivity leading to poor condition “D” category. At that point there are likely significant barriers to wildlife movement and loss of functional habitat overall.

L3. RELATIVE WETLAND SIZE

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory

Definition: An index of reduction of the current wetland relative to its estimated historical size.

Background: This metric is derived from the Change in Size metric of NatureServe’s Ecological Integrity Assessment methodology (Faber-Langendoen et al. 2012b; 2016b).

Rationale: Relative size is a generalized measure that focuses on the degree of a wetland’s reduction from its historical natural size as a function of human-induced disturbances, particularly land-use conversions (e.g., urbanization and agriculture) and major channel controls (e.g., levees). This metric assumes that large reductions of area indicate alteration of hydrology or ecosystem processes and may indicate ecological instability, reduced viability, and tendency to lose diversity in the future. As such, relative size is an indicator of potential stress on the remaining extant wetland.

Scoring and Rating: Scaling criteria are derived from Rondeau (2001) and NatureServe EIA (Faber-Langendoen et al. 2016a) but modified to reflect a different measurement technique. Sites that are little changed from their historical extent (<10%) are considered fully intact and providing expected ecosystem services, other elements being equal ("A" site). At the other end of the scale, a "D site, is a wetland than has been significantly reduced with the expectation that ecosystem services have accordingly been reduced (>70% reduction). This is less conservative then Faber-Langendoen et al. (2016a) who's threshold was 30%, but we consider riverine wetlands that have a modicum of functionality in other characteristics such as hydrological connectivity to be reasonably robust despite reduction. We grant that smaller wetlands may be more susceptible to impacts brought on by changes in size and may become dysfunctional at some minimum size regardless of the percentage reduction, but further analysis will be needed to determine if this element of absolute size should be integrated into the metric.

L4. SURROUNDING LAND USE

Modules: Lowland Riverine; Montane Riverine; Playa Wetlands; Riverine Regulatory, Confined Valley Riverine

Definition: The amount and intensity of human land-use in the landscape surrounding the SA.

Background: Surrounding Land Use is based on an HGM metric developed by Hauer et al. (2002) and adapted by EIA (Faber-Langendoen et al. 2012b). Here, the list of land uses has been modified to exclude those elements that cannot be mapped explicitly as cover types (e.g., grazing). See also Mack (2006) for a related version of this metric. The measurement area, the Land Use Zone (LUZ), varies by subclass, but otherwise the metric is the same for all riverine and playa versions.

Rationale: Land use in the landscape surrounding a wetland can be correlated to wetland condition (Weller et al. 2007), and the intensity and type of land use has a proportionate impact on ecological processes (Faber-Langendoen et al. 2016b). That is, not all land uses are equal in how and what they promulgate through the buffer into the SA, nor in their impact on ecological patterns and processes that they may cause. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., haying of native grassland), while other activities (e.g., permanent crop agriculture) may replace native vegetation with non-native or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter ecological processes. Accordingly, a suite of land-use types that might occur in the surrounding landscape area of an SA have been assigned coefficients indicating their relative impact on the ecosystem (from 1.0 indicating no impact to 0.0 indicating high impact). The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002; Mack 2006; Faber-Langendoen, personal communication 2008). Then a Land Use Index (LUI) is calculated based on the proportionate amount of each land use in the measurement area weighted by the coefficients. The list used for riverine wetlands varies from that used for playas.

The playa subclass list reflects potential effects on playa sedimentation, water supply, hydroperiod, and water quality—factors considered most crucial for playa ecological condition. The list for the riverine subclasses has a broader spectrum of potential impacts across hydrologic, geomorphologic, chemical, and biologic factors.

Scoring and Rating: The LUI ranges from 0 to 100. The final rating classes are weighted with relatively low tolerance for disturbance in surrounding landscapes, i.e., “A” sites have a range of only five points (>=95 and <=100); “B” sites 15 (>=80 and <95); “C” and D” sites 40 (>40 and <80) and < 40, respectively). However, because the impacts of land use can decline with distance from the SA, the contribution of Surrounding Land Use to the overall Landscape Context attribute score is less than that of the Buffer Integrity Index and RCC.

L5 PLAYA CONFIGURATION

Modules: Playa Wetlands

Definition: Playa configuration evaluates the departure of the current playa wetland shape and size from the historical configuration as a function of direct anthropogenic alterations, particularly fill from accelerated erosion and artificial sources.

Background: This is a novel metric for playa wetland assessment.

Rationale: Playas are typically naturally circular, elliptical, or oval in shape, reflecting the shape of the micro-basin they occupy. Accordingly, departures from the natural shapes are typically caused by human disturbance that alters the configuration, both internally and along the boundary, and reduces the size of the playa wetland, leading to a loss of ecological integrity.

Scoring and Rating: Playa shapes and associated impacts were evaluated in a GIS across the reference domain to characterize the range of variation in playa configuration. Where a playa remained more or less circular, elliptical, or oval relative their micro-basin shape, and wetland area loss was minimal the wetland was rated a 4 or “A.” In contrast, where a large portion of the original playa wetland area has been lost to the surrounding, now upland, area, and the playa is highly modified in shape, the wetland is considered likely to have significant loss of ecological services and biodiversity and is rated 1 or “D.”

L6 INTERNAL RIPARIAN CORRIDOR CONNECTIVITY

Modules: Riverine Regulatory

Definition: Internal Riparian Corridor Connectivity (IRCC) measures the disruption of natural land connectivity within the SA with an emphasis on detecting intervening obstructions that might inhibit fluvial processes and wildlife movement, and impact plant populations.

Background: This is a novel metric for the Riverine Regulatory module. Unlike other riverine versions of the NMRAM, the Regulatory NMRAM SA’s include areas of disruption (Project Area) that would normally be external to the SA, thus a metric to measure that change in disruption internal to the SA was needed. This metric is based on the Riparian Corridor Connectivity metric used for all riverine modules, but adapted to assess connectivity within the SA due to existing or planned construction and mechanical manipulation.

Rationale: This metric addresses the riparian corridor connectivity within the SA. Riverine connectivity is essential for the maintenance of wetland habitat that allows for uninterrupted movement of animals throughout the riparian zone as well as access to adjacent uplands (Gregory et al. 1991). Intact corridors can allow for unimpeded movement of surface and overbank flow, which is critical for the distribution of sediments and nutrients as well as the recharging of local alluvial aquifers. This connectivity of process is also key to the creation and maintenance of healthy riverine and native riparian habitats (Pickett and White 1985; Crawford et al. 1993; Blanton and Marcus 2013). Additionally, connectivity of width and length of riparian habitats may be a powerful indicator of water quality (Gergel et al. 2002). Hence, connectivity among riparian wetlands in a corridor is key to the function and integrity of a riverine ecosystem.

Fragmentation and the breaking of connectivity of the riverine corridor can be caused by human alterations, such as roads, bridges, power lines and pipeline corridors, agricultural activities, and urban/industrial development (Smith 2000). Hence, the Internal Riparian Corridor Connectivity assessment is based on measuring non-connectivity land-cover elements that reflect fragmentation of the corridor within the SA (the same elements used for the Riparian Corridor Connectivity and Buffer Integrity Index above). These elements were derived from CRAM (CWMW 2013) with modifications specific for conditions within New Mexico. The Riverine Regulatory Module was developed for use in pre-and post-construction wetland assessments. Therefore, by overlaying the SA with the proposed project construction footprint it can be rated for expected changes in riparian corridor connectivity impacts and compared with the rating of the current IRCC pre-construction. The area assessed for the Internal RCC metric is wider for large rivers than for small rivers (100 m for montane; 200 m for lowland), as in the external RCC metric.

Scoring and Rating: Internal RCC is focused on the of degree disruption of the riparian corridor within the SA and is measured as the percentage of anthropogenically altered length of the connectivity corridor within the SA. The final rating classes are weighted with extremely low tolerance for disruption within the SA as an “A” site, as reference condition for a riverine wetland excludes non-natural corridor interruption. A “D” rating is earned when more than a quarter of the internal corridor has been disrupted.

L7 SAMPLING AREA (SA) LAND USE

Modules: Riverine Regulatory

Definition: The amount and intensity of human land use in the designated SA.

Background: This is a novel metric for the Riverine Regulatory module. This metric is based on the Surrounding Land Use metric used for all riverine modules but adapted to assess land use within the SA due to existing or planned construction and mechanical manipulation.

Rationale: SA Land Use addresses the intensity of human activity inside the SA. The Riverine Regulatory Module is developed for use in pre-and post-construction wetland assessments. Therefore, by overlaying the SA with the proposed project construction and land alteration footprint it can be rated for expected land use changes and compared with the rating of the current SA pre-construction. The SA can be impacted differentially by land uses. That is, not all land uses are equal in how and what they promulgate through the SA, nor in their contributing impact on ecological patterns and processes. This metric uses the same suite of land-use types from the Surrounding Land Use metric that might occur surrounding an SA to assess within the SA. As with Surrounding Land Use (L4) the land uses assessed with this metric are those that have a distinctive footprint. Each land-use type has been assigned coefficients indicating their relative impact on the ecosystem (from 1.0 indicating no impact to 0.0 indicating high impact). The coefficients were assigned according to best scientific judgment regarding each land use's potential impact on ecological condition (Hauer et al. 2002; Mack 2006; Faber-Langendoen, personal communication 2008). The SA Land Use Index (LUI) is calculated based on the proportionate amount of each land use within the SA weighted by the coefficients. Although some land uses may be aimed at improving wetland condition, such as treatments to earthwork to remove invasive exotic weeds or designed to increase floodplain connectivity, if they produce a disturbance footprint on the landscape they may lower the SA Land Use score, as least in the short term.

Scoring and Rating: The SA LUI score ranges from 0 to 100. The final rating classes are weighted with low tolerance for disturbed area within the SA (an "A" site essentially excludes all non-natural features), but broader ranges for lower ratings.

L8. ROAD PROXIMITY

Modules: Confined Valley Riverine

Definition: Road Proximity is a measurement of the juxtaposition and impact of roadways to confined riverine wetlands.

Background: This is a novel metric for the Confined Valley Riverine subclass where roadways are one of the most common and significant impacts on condition and are often placed either immediately adjacent to or directly on top of the wetland.

Rationale: The placement of a road in a confined valley can directly alter a riverine wetland's natural size and has the potential to affect its hydrological and ecological processes (Zaimes 2007). This metric assumes that a road within the historic wetland and/or adjacent to the current wetland has the largest impact on wetland size, condition and function, while one higher upslope from the wetland has a smaller impact (Figure 15). Significant reduction of the historic wetland area indicates alteration of hydrology and ecosystem processes and may indicate instability, reduced viability, and a loss of functionality due to potential stress on the remaining extant wetland.

Additionally, roads are potential vectors for sediment, non-point source pollution, trash, and introduction of noxious species (Parendes and Jones 2000; National Research Council 2002). Roads can negatively affect wildlife that use wetlands both indirectly through disturbance and directly through collision mortality (Spellerberg 1998).

Scoring and Rating: Any paved or graded road, railroad, or paved hiking trail is considered a road when evaluating this metric. The rating is based on the presence or absence of a road within the canyon slope, the road's proximity to the wetland, and any visual evidence of direct sediment and runoff impacts. The closer a road is to the SA, the greater the potential impact and the lower the rating.

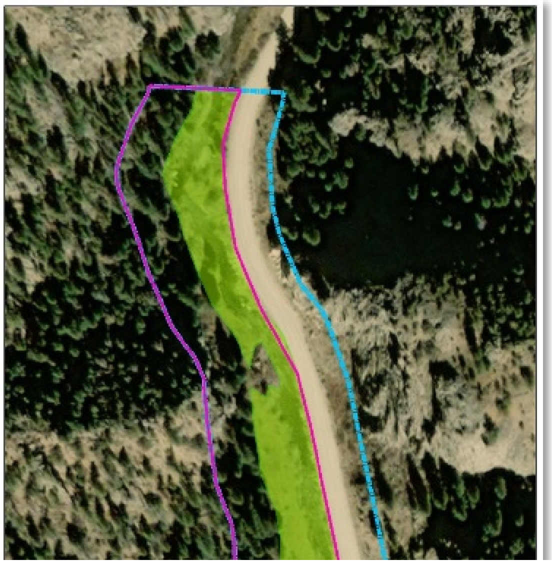

Figure 15. Roads can have direct and severe impacts on riverine wetlands, particularity in confined canyons where roads are commonly near the stream channel.

BIOTIC ATTRIBUTES

Fundamental to ecological health of riparian and wetland areas is a diverse and dynamic mosaic of vegetation communities that are sustained by natural hydrological processes (Crawford et al. 1993; Muldavin et al. 2017). Such diverse riverscapes tend to increase habitat for wildlife, reflect functional hydrological conditions (Latterell et al. 2006), and enhance overall ecological services. Accordingly, the evaluation of NMRAM biotic metrics relies on mapping the vegetation pattern of the SA that reflects the complexity of the patch mosaic, and describing the compositional and structural characteristics within and among the mapped patches (i.e., native versus introduced plant species composition and invasives, vegetation vertical structure for wildlife, and riparian forest regeneration (Figure 16).

Figure 16. Biotic metrics focus on introduced and invasive species (left), vegetation structure for wildlife habitat (center), and reproduction of riparian trees, the future wetland forests (right). Photos: NHNM stock.

B1. RELATIVE NATIVE PLANT COMMUNITY COMPOSITION

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory

Definition: A measure of the abundance of native-dominated wetland vegetation communities versus exotic-dominated communities.

Background: This metric is similar to Native Plant Species Cover of Faber-Langendoen et al. (2012b) which addresses relative percent cover of native plant species. The ratings table of Montane Riverine 1.0 was modified in Version 2.0 to be more sensitive to incursion of non-native species.

Rationale: Faber-Langendoen et al. (2012b) suggest that those ecosystems that are dominated by native species reflect high ecological integrity. High native plant species diversity can indicate higher biotic diversity, stability of wetland biotic communities, increased wildlife habitat and species diversity, and overall higher resilience and resistance to environmental disturbance. In contrast, high numbers of exotic plant species indicate degraded or disturbed wetlands (Houlahan and Findlay 2004).

Scoring and Rating: The rating classes are weighted with relatively low tolerance for non-native incursion into a wetland. That is, while most wetland/riparian areas in the Southwest will have some non-native component (woody or herbaceous), in our judgement the best sites will have less than 10% and the lowest performing sites will have more than half their vegetation cover in non-native species. The metric is also weighted such that woody non-native species have a greater impact on the rating, since the assumption is that most practitioners will be most accurate in their identification of woody species.

B2. VEGETATION HORIZONTAL PATCH STRUCTURE

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory

Definition: The Vegetation Horizontal Patch Structure metric is an assessment of general vegetation patch diversity and complexity of the patch pattern (interspersion among vegetation patch types) within an SA.

Background: The Vegetation Horizontal Patch Structure metric is derived from CRAM Horizontal Interspersion (CWMW 2013).

Rationale: This metric is intended to help evaluate the degree of complexity of the riparian vegetation patch mosaic as a measure of functional riparian and wetland ecosystems (Latterell et al. 2006); Muldavin et al. 2017). Multiple horizontal plant community patches across the SA reflects greater ecosystem heterogeneity that generates more diverse habitat structure for wildlife and high biotic diversity in general. A patch mosaic of different vegetation types suggests intact hydrological regimes with associated ecological processes. In contrast, riparian wetlands dominated by one community type likely reflect highly altered hydrological regimes or other impacts to ecosystem function and processes (*see* Ecology and the NMRAM section above).

Scoring and Rating: The rating of this metric is based on CRAM (2013) graphic examples of idealized riverine vegetation patch patterns from complex to simple in combination with a narrative describing the landscape complexity of each ratings class. In addition, to support the rating there is a table that provides a numerical description of the schematic vegetation pattern with respect to the number of unique patches and their aerial extent.

B3. VEGETATION VERTICAL STRUCTURE

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory

Definition: An assessment of the overall vertical structural complexity of the vegetation canopy layers across the SA, including presence of multiple strata and age/size classes.

Background: The concept of Vegetation Vertical Structure is derived from CRAM Vertical Biotic Structure (CWMW 2013) and EIA Vegetation Structure (Faber-Langendoen 2012b). However, the vertical-structure class types used here were based on the riparian vegetation structural type classification for the Rio Grande created by Hink and Ohmart (1984) and further elaborated on by Callahan and White (2004). This system was originally formulated to characterize stand structure of dominant woody species for vegetation mapping and biotic inventory, but it has since been adapted to many uses within the Rio Grande, including wildlife habitat potential. The structural types have been modified for application in the NMRAM (termed Vertical Structure Types (VST)), but the ability to crosswalk the NMRAM types back to the Hink and Ohmart (1984) types has been maintained. The largest modification for the NMRAM was an expansion of the short-stature cover types to distinguish between short-woody (VST 5 and VST 6S), wetland herbaceous (VST 6W), and non-wetland herbaceous (VST 6H) vegetation (Figure 17).

Rationale: Vegetation Vertical Structure is an integral part of habitat structure and associated processes. Wetland vertical vegetation structure is correlated with overall biodiversity, which can positively affect hydrological functions through rainfall interception and reduction of evaporation (CWMW 2013). Vegetation structure influences the distribution of water and sediment within wetlands, with different specific vegetation types increasing the wetland’s ability to hold water and sediment, or ameliorate flood flows (Faber-Langendoen 2012b). Increased vertical structure indicates multiple plant life forms, more habitat complexity for wildlife, and higher overall biotic diversity for the SA. Bird species richness is positively correlated to woody riparian vegetation height (Cooke and Zack 2009) and high vegetation structure is thought to be a particularly important component of bird habitat (Willson 1974; Rotenberry and Wiens 1980). Although Hink and Ohmart (1984) vegetation structural classifications were developed for riparian communities along the Middle Rio Grande, the NMRAM structural class types developed based on them are appropriate for the riverine class throughout the state.

Scoring and Rating: The diversity of vertical vegetation structural types present at an SA (per Hink and Ohmart (1984) structural classes) determines the rating. Because some structural types provide more overall vertical structure than others, the seven structure types are grouped and weighted differently. High Structure Forests (VST 1) provide more vertical structure than any other type individually, and thus are weighted more heavily in the scoring. Low Structure Forests (VST 2), Tall Shrublands (VST 5), and Wetland Herbaceous (VST 6W) patches all provide less structure individually than a High Structure Forest but are desirable structure for many riparian and wetland species and thus are weighted intermediately. Short shrublands (VST 6S), non-wetland herbaceous (VST 6H) patches, and sparse vegetation/bare ground (VST 7) are given the lowest weight individually. In addition, the relative abundance of structure types is incorporated into the rating such that the highest vertical structure scores are attained by sites that combined a number of relatively abundant high-value structure types together. High scores represent highly complex and tall vertical structure, which should support a higher diversity of wildlife species than low stature, low vertical complexity vegetation. Different species of wildlife have different structural needs. Weighting Vertical Vegetation Structure scores for a complexity of vertical structure across multiple vegetation patches within the SA, as well as within-patch structural complexity, accounts for this aspect of vertical vegetation complexity and runs in parallel with Vegetation Horizontal Patch Structure.

Multiple-Story Communities (woodlands/forests)

VST 1 – High Structure Forest with a well-developed understory. Trees (>6 m) with canopy covering >25% of the area of the community polygon and woody understory layer of tall shrubs or short trees (1.5–6 m) covering >25% of the area of the community (polygon). Substantial foliage is in all height layers.

VST 2 – Low Structure Forest with little or no understory. Trees (>6 m) with canopy covering >25% of the area of the community polygon and minimal woody understory layer (1.5–6 m) covering <25% of the area of the community (polygon). Majority of foliage is over 7 m above the ground.

Single-story Communities (shrublands, herbaceous, and bare ground

VST 5 – Tall Shrubland. Young tree and shrub layer (1.5–6 m) covering >25% of the area of the community polygon. Stands dominated by tall shrubs and young trees, may include herbaceous vegetation underneath the woody vegetation.

VST 6S – Short Shrubland. Short stature shrubs or very young trees (< 1.5 m) covering >25% of the area of the community (polygon). Stands dominated by short woody vegetation, may include herbaceous vegetation among the woody vegetation.

VST 6W – Herbaceous Wetland. Herbaceous wetland vegetation covering >10% of the area of the community polygon. Stands dominated by obligate wetland herbaceous species. Woody species absent, or <25% cover.

VST 6H – Herbaceous vegetation. Herbaceous vegetation covering >10% of the area of the community polygon. Stands dominated by herbaceous vegetation of any type except obligate wetland species. Woody species absent or <25% cover.

VST 7 – Sparse Vegetation, Bare Ground. Bare ground, may include sparse woody or herbaceous vegetation, but total vegetation cover <10%. May be natural disturbance in origin (e.g., cobble bars) or anthropogenic (e.g., roads).

Figure 117. Guide to vertical structure types (VST).

B4. NATIVE RIPARIAN TREE REGENERATION

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory

Definition: This metric assesses the abundance and spatial distribution of native riparian tree reproduction across the SA (tree seedling, saplings, and poles under 12.7 cm (5 in) diameter at breast height (dbh).

Background: The Native Riparian Tree Regeneration metric is derived from Woody Regeneration of Faber-Langendoen et al. (2012a) and is addressed in Winward (2000) and Burton et al. (2008).

Rationale: Healthy functioning riverine wetlands should consist of a mosaic of woody vegetation stands that include stands of both mature and young regeneration trees (Figure 18). Absence of young trees may indicate ecological dysfunction. Generally, native riparian trees reproduce (seedling recruitment) in patches on disturbed, usually recently flooded moist ground. Because reproduction is closely tied to natural disturbance cycles (Crawford et al. 1993), the presence of numerous patches of differently aged native tree species acts as a surrogate measure for a functional natural-disturbance regime that includes flooding and sediment transport. Hence, the limited presence or absence of patches of young trees within a riverine wetland system is of particular concern.

Figure 18. An example of young cottonwood stands from along the Gila River near Gila, NM (photo:E. Muldavin).

Scoring and Rating: The rating is based on the estimated cover of target juvenile native riparian tree species and the number of patches as derived from values of the reference gradient. Healthy and regenerating riparian woodlands should have a large number of stands of young native poles, sapling, and seedlings trees well represented and high scores. In contrast, sites with little flooding and those that are entrenched will have little or no reproduction and low scores.

B5. INVASIVE EXOTIC PLANT SPECIES COVER

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory; Confined Valley Riverine

Definition: The Invasive Exotic Plant Species Cover is a measure of the total percent cover of a set of exotic plant species that are considered invasive based on the New Mexico list of noxious weeds (http://www.nmda.nmsu.edu/apr/noxious-weed-information/). This includes Class C weeds such as saltcedar, Russian olive, and Siberian elm, which are considered invasive and widespread. Species of specific concern for a given project or those that are not yet on the New Mexico list of noxious weeds could be included in this measure on a project-specific basis but are not included in the roll-up scores

Background: Based on EIA "Invasive Plant Species Cover" of Faber-Langendoen (2012b) derived in part from Tierney et al. (2009) and Miller et al. (2006). This metric is also similar to the CRAM "Percent Invasion" submetric within Plant Community (CWMW 2013)

Rationale: Invasive, non-native species can have a significant impact on community diversity and function. High levels of invasive exotic species within a riparian plant community are a direct threat to maintaining wetland function and biodiversity (Stenquist 2000; Bailey et al. 2001). While the mechanisms underlying the "invasive" character of some species is an active area of research, there are indications that riparian sites that have been altered or significantly impacted by human activity may be more prone to invasion. Invasive exotic species tend to thrive in riparian systems when natural hydrologic and geomorphic functions have been disturbed, particularly where the hydrological regime has been altered and is controlled (Di Tomaso 1998; Nagler et al. 2009). Thus, this metric is both a measure of current vegetation condition and an indicator of the status of the hydrological regime.

Scoring and Rating: Ratings are based on the total percent cover of exotic invasive species across the SA. The scaling is similar to Faber-Langendoen et al. (2012a), but NMRAM has lower tolerance thresholds that reflect the severe impact that aggressive invasive species can have on wetland sites in the southwestern U.S., and that are reflected in our reference gradient data.

B6. EXOTIC ANNUAL PLANT ABUNDANCE

Modules: Playa Wetlands

Definition: An index of the relative abundance of exotic annual plant species cover relative to the overall herbaceous plant cover within the playa wetland driven by local and landscape-scale impacts versus natural plant diversity in unimpacted playas.

Background: This is a novel metric for playa wetland assessment. Bartuszevige et al. (2012b) used a Floristic Quality Index that incorporates annual exotic species into its framework.

Rationale: Playa wetland vegetation communities are typically dominated by native annual species emerging from the local seedbank (Haukos and Smith 1994; Smith 2003). The incursion of annual introduced exotic species likely reflects both land use changes, particularly agriculture, in the surrounding landscape as well localized human disturbance that encourage non-native species proliferation into novel habitats within the wetlands (berms, roads, development, etc.). Smith and Haukos (2002) report a greater incidence of non-native species incursions in playas surrounded by cropland versus those surrounded by rangeland.

Scoring and Rating: Rating classes are based on the range and amount of exotic annual incursions as sampled along the reference gradient. Highly functional "A" playas should have no exotic annuals, whereas on poor sites exotic annuals have become dominant in one or more vegetation patches and can be persistent.

B7. WETLAND SPECIES INDEX

Modules: Playa Wetlands

Definition: An index of wetland condition based on the presence and abundance of dominant or co-dominant wetland species in the current playa basin floor.

Background: For playa wetlands, this is a novel metric.

Rationale: Wetland species, even in the ephemerally wetted playas, are thought to be a key component of playa vegetation communities (Smith 2003). An intact hydrological regime combined with limited or no new human-generated sediment inputs leads to a dynamic natural cycle of wetting and drying of the playa wetland where wetland species can come and go seasonally, but by and large reappear or persist during wet precipitation periods. In contrast, when perennial upland species, particularly grasses, become prevalent or dominant, this reflects a long-term drying of the wetland and a departure beyond the natural range of variation.

Scoring and Rating: To best take advantage of wetland species values as indicators of wetland condition, relative cover of obligate and facultative wetland species is calculated by vegetation patch, weighted by the relative patch size, then summed across the current basin floor (CBF). Scoring was based on the range of cover values of wetland species across the reference gradient. For highly functional playas, wetland species dominate the overall plant cover (>50%), but once relative wetland cover is low or absent and the majority of the playa is dominated by upland species, the playa is considered to have low ecological integrity.

B8. VERTICAL HABITAT DISRUPTION

Modules: Playa Wetlands

Definition: An assessment of the impact of vertical structures and woody vegetation that have encroached on the playa due to habitat alterations by humans, including both constructed features and the presence of tall woody species not historically associated with playa habitat.

Background: The distance to vertical structures is one of six metrics used by Playa Lakes Joint Venture to prioritize playas for conservation (McLachlan et al. 2014).

Rationale: Prior to settlement, playas of the Southern High Plains were embedded in a flat landscape mostly devoid of trees or any other tall vertical structures or landscape elements. As a result, predators such as hawks or coyotes had few perches or hiding spots from which to stalk prey. With settlement, the landscape now contains a wide variety of vertical structures including trees, houses, telephone lines, fences, etc., that put smaller fauna at greater risk of predation. In addition, wind turbines and oil and gas structures have become more prevalent, potentially creating new hazards for wildlife and waterfowl attracted to playa wetlands. Also, increased woody encroachment into playas and surrounding landscape has created nesting habitat for non-grasslands birds not typically found in the playa environment (Smith 2003).

Scoring and Rating Rationale: Site ratings are based on the number and types of vertical structures that occur within the playa or within a 100-m buffer of the playa wetland. Beyond 100 m, the impacts on prey within the wetland are expected to be significantly diminished.

B9. RIPARIAN ZONE WETLAND PLANT ABUNDANCE

Modules: Confined Valley Riverine

Definition: An index of wetland condition based on the presence and abundance of dominant or co-dominant wetland species in the riparian zone within confined riverine wetlands and channels.

Background: This is a novel metric for the Confined Valley Riverine subclass.

Rationale: The abundance of wetland plant species is core to the ecological integrity of a wetland. Wetland herbaceous species and phreatophyte shrubs provide a unique habitat resource that is vital to a variety wildlife (Gray et al. 2013; Perron and Pick 2020) and are a key attribute of functional riverine wetlands (Brinson et al. 1995).

Scoring and Rating Rationale: The rating is based on the percent cover and extent of the most abundant obligate and facultative wetland species within the channel and riparian zone. The higher the cover and the greater the area of wetland species reflects more abundant wetland habitat for wildlife and overall ecological integrity.

B10. WETLAND VEGETATION ZONE LOSS

Modules: Confined Valley Riverine

Definition: Wetland Vegetation Zone Loss assesses the presence or absence of expected wetland and riparian vegetation zones as a measure of overall biotic habitat availability.

Background: This is a novel metric for the Confined Valley Riverine subclass. Wetlands in the confined subclass are very narrow by definition, and when they are altered by development that alteration often completely obscures the former extent of the wetland. This metric was developed as an objective measurement of former wetland size that does not require determination of the historic boundary.

Rationale: Riparian zones create essential habitat, act as buffers between the adjacent uplands and steam channels by capturing sediment from hillslopes, processing nutrient inputs, and sequestering contaminants. (Mayer et al. 2007; Lind et al. 2019). The ability of riparian zones to act as buffers is enhanced where wider widths provide increased functionality (Sweeny and Newbold 2014) and various riparian widths have been suggested to maintain riparian ecosystem processes (Hawes and Smith 2005; Lind et al. 2019). In narrow confined systems, the loss of riparian zone width represents a significant loss of overall wetland function, diversity, and habitat. In addition, the narrowing of the floodplain in confined systems due to anthropogenic encroachment increases streambank erosion and disrupts channel flow which may result in further riparian zone loss.

The width of riparian wetland zones within confined canyons can be highly variable due to natural abiotic factors such as cliffs, substrate and slope, but loss of riparian zone due to development within the floodplain is a condition issue that can be measured via presence of development and/or development fill within the expected riparian vegetation zones. In the presence of water, fill adjacent to the channel may become colonized with riparian vegetation relatively rapidly. However, the overall natural riparian floodplain and attendant vegetation suite will likely have been reduced from its former size.

Scoring and Rating Rationale: This metric is assessed based on the proximity of development, if present, to the current riparian zone (RZ) along with the total extent of development relative to the lateral SA boundaries. To avoid the ambiguity of making a subjective assessment of how much historic riparian zone was lost to development, this metric is rated solely on the proximity and linear extent of development and/or fill to the outer edge of the current RZ. This method of rating also provides a consistent rating of scores between different users. The wider the area of unaltered vegetation from the riparian zone edges for a greater linear extent, or the absence of development within the floodplain, the higher the rating. As development encroaches on the RZ, the ratings are lower.

ABIOTIC ATTRIBUTES

Abiotic condition metrics address factors affecting the hydrology, fluvial geomorphic processes, and direct physical anthropogenic disturbance that influence wetland function and condition. Their evaluation depends on a combination of feature mapping and description of the site along with direct physical measurements. In keeping with the importance of the status of the hydrological regime, three of the five metrics address channel and floodplain indicators of a functional regime (Figure 19). That is, indicators of connectivity of flood waters to the floodplain, the status of the ground water in sustaining riparian vegetation, and channel stability as it affects the dynamic capacity of the river to migrate, reshape, and revitalize the riverscape. The other two metrics look at the physical attributes: the riparian zone floodplain surface in terms of complexity (micro-habitats for biota) and anthropogenic disturbance.

Figure 19. Three of the abiotic metrics focus on hydrological factors such as evidence of recent flooding (left), phreatophyte health as an indicator of ground water status (center), and degree of channelization of the river that limits it mobility and the dynamic character of river ecosystem (right). Photos: NHNM stock.

A1. FLOODPLAIN HYDROLOGIC CONNECTIVITY

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory

Definition: Floodplain Hydrologic Connectivity is an assessment of the ability of the water to flow into or out of the wetland or to inundate adjacent floodplain areas.

Background: This metric is derived from CRAM (CWMW 2013) which has its foundation in Rosgen (2006). EIA also developed a narrative version for riverine systems based on CRAM (Faber-Langendoen 2012b). HGM has a similar frequency of surface flooding metric (Hauer et al. 2002).

Rationale: The adjoining floodplain of an unconfined river is constructed in the present climate by overbank flooding at times of high discharge (Dunne and Leopold 1978). The hydrologic connectivity between the river and riverine wetlands formed on its floodplain supports ecologic function and plant and wildlife habitat diversity by promoting exchange of water, sediment, nutrients, and organic carbon (CWMW 2013). Periodic flooding is integral to developing habitat complexity across the floodplain (Hupp and Osterkamp 1996; Figure 20).

Figure 20. Overbank flooding in the floodplain of the Gila River near Gila.

Scoring and Rating: For the Montane subclass, Floodplain Hydrologic Connectivity is an assessment of the relationship of the river channel to its floodplain at the bankfull stage (the channel-forming flow recurring approximately every one to two years). Operationally, this reflects the degree of entrenchment of the channel and the potential for high river discharges to flood the adjacent floodplain. Ratings are based on degree of entrenchment per Rosgen's (2006) entrenchment ratio and stream type. For example, Rosgen Stream Type C (Rosgen 1996; 2006) is characterized as meandering streams with overbank flooding, the Rosgen-based entrenchment ratio of the flood-prone width to channel depth should be greater than 2.2 under the best of conditions. A lower ratio is indicative of entrenchment increasing disconnection of the stream from its floodplain (i.e., less frequent floodplain inundation).

Where the entrenchment ratio cannot be measured directly, such as where beaver have significantly altered flow patterns, or across channels that are too large or multi-channel configurations, a narrative approach with on-site indicators of recent flooding is used. Rating are based on a qualitative estimate for a series of flooding indicators on the floodplain and within back channels which are rated based on the magnitude of the most recent peak flow (a method to estimate recent peak flows from USGS gage data is provided in the Lowland field guide).

A2. PHYSICAL PATCH COMPLEXITY

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory

Definition: This metric describes the physical structural richness of riverine wetlands and associated channels that foster habitat complexity and biotic diversity.

Background: Physical Patch Complexity is adapted from CRAM Structural Patch Richness (CWMW 2013) and HGM Macrotopographic Complexity (Hauer et al. 2002), but rescaled following EIA Physical Patch Type, which emphasizes condition rather than functional complexity (Faber-Langendoen et al. 2012b). The NMRAM also adds indicators representative of this subclass based on findings from reference site visits and those included in CRAM (Collins et al. 2008).

Rationale: Rivers act as conveyor belts of both water and sediment, the movement of which occurs linearly in the direction of flow and horizontally as rivers periodically overflow their banks and spill onto the floodplain. Under optimal hydrological conditions, these flood pulses will generate varied and complex habitats that can supports high biological diversity and create multiple pathways for the operation of ecological processes (Odum 1978; Gregory et al. 1991; Bayley 1995; Tockner et al. 2002)

Scoring and Rating: For each wetland subclass, scoring and rating is based on patch richness and distribution across the floodplain. Hence, the rating uses a combination of the number of patches along with a narrative description of conditions (which varies between subclasses) with highly complex sites rating the highest. Absence of these features indicates reduction of the influence of natural fluvial and biological processes, or anthropogenic alteration of the channel or floodplain removing key features and reducing ecological integrity.

A3. CHANNEL EQUILIBRIUM

Modules: Montane Riverine; Riverine Regulatory

Definition: Channel Equilibrium is the assessment of the degree of channel aggradation or degradation resulting from the departure from flow patterns associated with the characteristic pattern, profile, and dimension of the stream or river.

Background: The Channel Equilibrium metric is derived from Hydroperiod/Channel Stability of CRAM (CWMW 2013) and its EIA derivative (Faber-Langendoen et al. 2012a).

Rationale: Riverine systems are driven by the long-term trends in peak flow, base flow, and average flows and the types and kinds of sediment deposits that form the floodplain and control ecological functions. Riverine systems are dynamic, reacting to processes within the watershed. Changing patterns associated with climate, seasonal variations in rainfall, diversions, releases from dams, and land use determine the timing and duration of flow patterns and sediment availability. Large, persistent changes to the flow or sediment regime caused by upstream land-use changes, alterations of the drainage network, or climatic changes tend to destabilize the channel and cause it to change form (Collins et al. 2008). Hence, channel equilibrium is generally dependent on watershed-scale drivers and, as a result, the expression may be at larger grain than that of the SA. Since the metric is assessed based on local field indicators of channel equilibrium, degradation, and aggradation, localized transient impacts may affect the scores (e.g., dredging and fill).

Degrading channels exhibit downcutting of a stream into its bed materials, often leading to channel entrenchment, eroding banks and abandoned floodplains. Aggrading channels result from the accumulation of bed materials resulting in an increase in the streambed elevation, an increase in width-to-depth ratio, and a corresponding decrease in channel transport capacity (Gordon et al. 2004). Degrading and aggrading streams display general instability of the system and the inability to maintain its current ecological functions. Stable channels or those in "dynamic equilibrium" condition display geomorphological resilience and do not exhibit progressive, rapid changes in slope, shape, or dimensions in response to changes in water and sediment. These can include braided systems where aggradation is the norm.

Scoring and Rating: Channel Equilibrium is rated based on the field indicators of departure from optimal conditions for given Montane Riverine stream types (Rosgen C or B types). Sites with little observable degradation or aggradation out of natural range are considered the best sites and are given high ratings, while those with highly altered sediment supply and/or flow regimes are poor sites and rate lower.

A4. STREAM BANK STABILITY AND COVER

Modules: Montane Riverine; Riverine Regulatory

Definition: This metric is a measure of stream bank soil/substrate stability and stream bank erosion potential that reflect overall stream bank stability.

Background: The Stream Bank Stability and Cover metric was derived from Burton et al. (2008). The metric has been modified to incorporate additional measurements of bank soil stability and erosion potential loosely following the U.S. Forest Service's General Aquatic Wildlife System (Slade et al. 1988).

Rationale: The resistance of a stream bank to erosion is important to the integrity and stability of associated riverine wetlands. This metric provides a classification and ranking of stream bank stability. Stable stream banks should support more perennial vegetation (greenline) and more stable and healthy wetland communities (Winward 2000). Unstable stream banks and those with the potential for erosion are likely suitable candidates for restoration. Less stable stream banks, and banks with greater potential for accelerated erosion generally indicate channel instability and associated channel adjustment (vertically and laterally) that could lead to loss or dewatering (abandonment) of adjacent riparian habitat, riverine wetland vegetation mortality, and decline and loss of the physical and biological functions that riverine wetlands provide.

Scoring and Rating: This method has two qualitative measures of bank condition: bank soil stability and stream bank erosion potential. The former is a measure of active, ongoing erosion and consists of an estimation of the percentage of the bank that is stable. The latter relates to the stability generated by vegetative cover and large bank material capable of limiting bank erosion as a measure of erosion potential. Both are scaled from 1 to 4 based on narratives of on-site indicators and then averaged. The final score range is weighted to favor the inner two ranks—"C" and "B" sites, respectively.

A5. SOIL SURFACE CONDITION

Modules: Lowland Riverine; Montane Riverine; Riverine Regulatory; Confined Valley Riverine

Definition: The Soil Surface Condition metric is a measure of anthropogenic disturbance of wetland and riparian soils that results in modification of soil characteristics.

Background: The Soil Surface Condition metric is derived from NatureServe (Faber-Langendoen et al. 2008), which in turn was based on Mack (2001). NatureServe (Faber-Langendoen et al. 2008) scales Soil Surface Condition on a qualitative continuum from undisturbed to highly disturbed and has been modified to document impervious surfaces and potential modification to soil chemistry, such as changes in salinity. In addition, Soil Surface Condition differs from the NatureServe metric in that it does not ask assessors to predict restoration potential or site recovery.

Rationale: This metric evaluates disturbance to the soil and surface substrates that affects biological, physical, and chemical processes that ultimately define broader wetland ecological condition, such as plant establishment and vegetation communities. In this capacity, the understanding of soil condition whether natural or modified via land use is critical to setting restoration goals and developing restoration strategies. Examples of soil surface disturbance include filling and grading, plowing, livestock disturbance, vehicle use (motorbikes, off-road vehicles, and construction vehicles), dredging, and other mechanical disturbances to the surface substrates or soils. Layers of ash and fine sediment after a recent fire or fire pits on site can change the ability of soils to absorb water (Larsen et al. 2009) Soil disturbance can potentially negatively impact soil nutrient cycling, moisture, chemistry, biodiversity, and structure.

Scoring and Rating: The metric is assessed by noting human-dominated land uses and the overall extent of disturbed land (e.g., all-terrain vehicle use or grazing, or indicators of natural processes exacerbated by surrounding land uses, e.g., increased soil salinity or rill development). Ratings used in the NMRAM include more detailed descriptions of anthropogenic disturbance as well as a semi-quantitative estimate of the area of disturbance. These area estimates are conservative in that sites rating a “4” have virtually no degradation and less than 1% total disturbance, including erosion, impervious surfaces, fill, or other anthropogenic degradation to the soil surface in the SA=; a rating of “3” has some disturbance between 1% and 5% of the SA.; a “2” rating indicates between 5% and 10% soil disturbance, while apparent, is limited to specific areas and not found across the majority of the SA ; and “1” soil disturbance aerial extent exceeds 10% disturbance across the SA.

A6. CHANNEL MOBILITY

Modules: Lowland Riverine; Riverine Regulatory

Definition: Channel Mobility is an assessment of the dynamic capacity of a channel to laterally migrate or avulse, leading to the development of a dynamic patch mosaic of fluvial landforms that support wetland and riparian communities.

Background: This is a novel metric developed to address artificial channelization due to anthropogenic activities and non-native species in lowland rivers.

Rationale: A guiding principal of underlying riverine ecosystem health is the maintenance of a dynamic riverscape of shifting ecological communities on a changing fluvial geomorphic template that is driven by hydrological processes (Crawford et al. 1993; Hupp and Osterkamp 1996; Stanford et al. 2005; Latterell et al. 2006; Weisberg al. 2013). Critical to maintaining this dynamism is ensuring a capacity for lateral channel migration and avulsions that lead to the development of new sites for vegetation development and tree regeneration.

Scoring and Rating: This metric is assessed based on the percentage of channel banks that are stabilized by artificial elements such as riprap or jetty jacks, and by woody non-native shrubs as measured at three sampling points along the river bank of the SA.

A7. PLAYA HYDROPERIOD REDUCTION

Modules: Playa Wetlands

Definition: The degree to which the natural playa hydroperiod has been reduced by the existence of a pit excavation(s) in the playa floor that concentrates water and lowers flood height and aerial coverage.

Background: For playa wetlands, this is a novel metric.

Rationale: Playa hydroperiod is affected when pits are dug in playa bottoms to increase water storage for a variety of purposes (e.g., irrigation and livestock watering). The outcome, based on pit size, is the overall reduction in hydroperiod outside the pit. The water stored in the pit is removed from the remaining playa surface allowing the playa bottom and annulus to dry out faster and more frequently, which can favor upland species. Accordingly, playas that lack pits are more likely to support wetlands and to maintain ecological functions. Other factors that affect the playa watershed hydrology and decrease natural sheet flow into the playa are covered by the Playa Watershed Connectivity metric.

Scoring and Rating: The metric is based on the size of the pit relative to the playa basin floor and the depth of the pit from field measurements. The size of the pit relative to the basin floor is the primary driver of rating, but size is modified by the pit depth where deep pits (>2 m) are scored lower compared to shallow pits of the same size. Playas with no pits or shallow pits that are relatively small in comparison to the current basin floor (CBF) rate a 4. In contrast, playas with deep pits or pits that are relatively large in comparison to the CBF rate a 1.

A8. PLAYA SOIL CONDITION INDEX

Modules: Playa Wetlands

Definition: A soil-based index that assesses the alteration of the playa-bottom soils due to anthropogenic impacts within the playa and in the surrounding watershed.

Background: This is a novel metric for playa wetlands.

Rationale: Increased sedimentation of playas driven by human disturbance is considered a primary threat to ecological integrity of playa wetlands because it leads to altered hydroperiods and functionality (Tsai et al. 2007; 2012; Daniel et al. 2015; Tang et al. 2016). New sediment is typically loamy and not composed of shrink-swell clays that characterize the basin floor (Luo et al. 1997). They tend to absorb water, not seal the basin floor and thus reduce hydroperiod and alter the hydric soil characteristics of playa wetlands.

Scoring and Rating: The degree of impact of increased sediment is directly related to the depth of new sediment packages on the playa basin floor (reflected by a change in soil texture with depth) and the loss of hydric soil characteristics indicated by soil color (Figure 21). The scoring takes into account both of these features to arrive at a metric score.

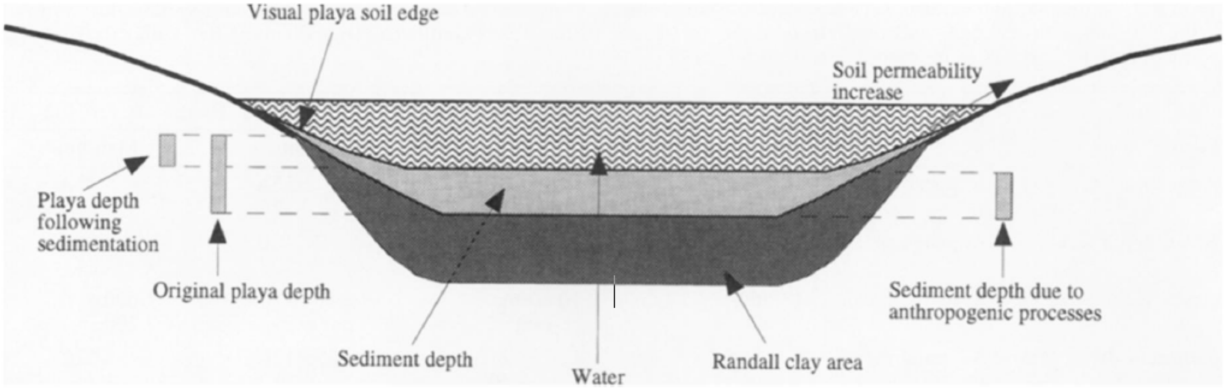

Figure 19. The Playa Soil Condition Index is measured from three soil pits augured or dug to 50 cm in depth in the playa bottom. The thickness of the sediment layer above the clay pan is determined by texture and color (from Luo et al. 1997).

A9. PLAYA WATER SOURCE AUGMENTATION

Modules: Playa Wetlands

Definition: Water-source modifications that augment playa water supply and that may extend the hydroperiod, increase the frequency of wetting, or alter the extent of the playa when filled with water.

Background: Water sources encompass the forms, or places, of direct inputs of water to the wetland. The metric is adapted from Collins et al. (2006) where water source is considered direct if it supplies water mainly to the SA rather than via dispersed overland flow (e.g., storm drains that empty directly into the SA or into an immediately adjacent area).

Rationale: While natural inflows of water into a wetland are important to its ability to persist as a wetland, additional flows can lead to extended hydroperiods that alter ecosystem structure and function (Smith 2003). For playa wetlands, in the most extreme conditions permanent lakes form that transform the wetland from the playa subclass to the lacustrine subclass.

Scoring and Rating: Rating is based on direct observation of artificial water sources and a qualitative rating of their significance.

A10. PLAYA WATERSHED CONNECTIVITY

Modules: Playa Wetlands

Definition: An assessment of the degree of hydrologic connectivity of surface water flows from the watershed surrounding into the playa as measured by physical features in the landscape that interrupt, hold back, store, or otherwise deplete natural water flows to the playa, causing a shortening of the hydroperiod, a lowering of the wetting frequency, and an overall reduction in playa size and function.

Background: Playa Watershed Connectivity is a variant of Hydrologic Connectivity used for riverine wetlands that is applied within the playa wetland basin.

Rationale: Historically, land-use practices, restoration, and direct land-use modifications have been implemented in playa micro-basins to limit soil erosion that have had the effect of reducing playa inundation and the overall hydroperiod of the playa wetland (Tsai et al. 2010; Bartuszevige et al. 2012a). Accordingly, wetlands in unmodified landscapes are expected to have higher watershed connectivity and the free flows of water to the basin floor that maintains the ecological integrity of the playa wetlands.

Scoring and Rating Rationale: Rating is based on the percentage of landscape features that are known to interrupt natural water flows into a playa. Playas without any alterations in their surrounding watershed rate a 4 while those that have a major portion of their surrounding watershed altered rate a 1.

A11. GROUNDWATER INDEX

Modules: Lowland Riverine

Definition: An index of floodplain water table status based on phreatophyte riparian and wetland species presence and condition.

Background: Coles-Ritchie et al. (2007) developed a community-level Wetland Index based on species wetland status to evaluate livestock grazing impacts in riparian zones.

Rationale: Detecting the effects of the growing-season high-water table (average position of the top of the hyporheic zone under base flow conditions) on wetland and phreatophyte vegetation is an indicator of the degree of functional impairment. That is, the hyporheic zone should have the capacity not only to support phreatophytic and hydrophytic vegetation but also maintain subsurface processes that sustain ecological services such as water quality, water storage and maintenance of base flow (Stromberg et al. 1996). Here, the Groundwater Index is a measure of the amount of floodplain surface/groundwater connection in an area as indicated by vegetation composition and stress. This metric assumes that an increase in depth to the water table will result in a change in vegetation vigor of deep-rooted, woody phreatophytes, and a loss of herbaceous facultative and obligate wetland species supported by near-surface groundwater. Additionally, this metric relies on the supposition that significant increases in depth to the water table will result in woody phreatophytes loss and replacement by upland woody or herbaceous species.

Scoring and Rating Rationale: Rating is based on the prevalence of phreatophytes and wetland species by strata across a site weighted by their apparent health (leaf loss and tree death in a stand). Accordingly, rating range from “Excellent health” (4) with little to no dead foliage or dead limbs across the site <5% of potential phreatophyte cover impacted and few standing dead trees to “Poor health or standing dead” (1) where greater than 50% loss of limbs and leaves and standing dead are common.

A12. LARGE WOODY DEBRIS

Modules: Confined Valley Riverine

Definition: The measurement of the average amount of large woody debris (LWD) available to create habitat complexity within confined riverine wetlands and channels.

Background: This is a novel metric for the Confined Valley Riverine subclass where LWD has a significant effect on channel and wetland morphology and wildlife habitat potential, and serves as an indicator of disturbance within and surrounding the wetland.

Rationale: LWD can be important in structuring the riverine wetland environment (Triska 1984; Webster et al. 2002). LWD can be a significant factor in formation of pools and overhead cover that are major needs for coldwater fish habitat within montane wetlands (Richmond and Fausch 1995). It can serve to alter the geomorphology of the river channel by contributing to pool formation, sediment retention, and channel migration (Wohl et al 2019). It also contributes to habitat complexity, both in the channel and riparian zones. Lack of LWD within high-elevation watersheds, where mature forests should cover the surrounding landscape, is an indication of disturbance due to landscape alteration and human activity.

Because LWD source material decreases as rivers descend from tall evergreen forests of high mountain elevations to the pinyon/juniper woodlands of the foothills, the rating for this metric is adjusted based on the upland community surrounding the SA. SAs in the Pinyon/Juniper woodland zone (generally below 7,500 ft elevation), where less LWD source material is available, are rated more leniently than those surrounded by tall conifer forests (generally above 7,500 ft elevation) as these SAs would be expected to have less LWD even without disturbance.

Scoring and Rating Rationale: LWD is rated based on the average sampled amount of dead and down woody stems that lies within the active channel and adjacent RZ. Stems must be greater than 10 cm in diameter to qualify as large debris that has the potential to alter channel conditions.

A13. CONFINED CHANNEL CONDITION

Modules: Confined Valley Riverine

Definition: Degree of excessive sediment accumulation in confined channels and riparian zones resulting from streamside to watershed disturbances.

Background: The Channel Equilibrium metric is derived from Hydroperiod/Channel Stability of CRAM (CWCM 2012a) and its EIA derivative (Faber-Langendoen 2012a). This Confined Valley Riverine variant is a further modified version of the Channel Equilibrium metric found in Montane Riverine Wetlands.

Rationale: In montane confined valley riverine systems, under normal hydrological conditions bedload transport rates exceed sediment supply leading to naturally scoured channels and little floodplain development from sediment aggradation. Degradation in the short term may apply when there has been significant alteration of the channel by development or fill, but generally does not apply given that these channels have inherent high channel resistance whereby only extreme and relatively infrequent events will alter channel configuration (Wohl 1998). Accordingly, the Confined Valley Riverine variant of Channel Equilibrium focuses on specific and recent indicators of aggradation along mountain streams which occur most often during monsoon-driven high-flow events and may follow major watershed-scale disturbance events that accelerated erosion (e.g., catastrophic fires, roads, timber harvest, mining, grazing, and drought, etc.; see Wohl (1998)). Changes can be obvious with recent excessive sediment deposition over boulders and bedrock that obscure the original confined canyon channel form and associated riparian zone—temporarily changing a v-shaped canyon into a u-shaped seemingly unconfined reach. The expectation is that there will be subsequent incision of these temporary sediments and a return to a confined canyon channel morphology once the associated disturbance events dissipate. Changes may be subtle with the accumulation of sediment films, the partial obscuring of boulder and bedrock exposures, modest bimodal sediment deposits that reflect the alteration of clear-water channel where bedload is consistently transported out under typical bankfull conditions. Determining when sediment is adverse is dependent on ascertaining that the reach was historically confined and now altered by human disturbance (e.g., indicated by overall canyon form, relict exposures of large boulders and bedrock associated with the channel, overall longitudinal channel slope, direct alterations of channel form caused by road building and other construction).

Scoring and Rating Rationale: Rating is based on visual indicators of sediment deposition in the channel and adjacent riparian zone that is beyond the natural range of variation for confined valley channels.

STRESSOR CHECKLIST

Stressors are anthropogenic disturbances that are potential drivers of declining ecological conditions of a wetland. We developed a Stressor Checklist to help identify those that might be affecting a WOI's condition and that can be informative in wetland management or restoration to improve wetland status (Figure 22). The checklist is primarily focused on factors that can impact the hydrological regime and associated ecological conditions of an SA at a landscape scale, but it does include some localized impacts that have an indeterminate footprint such as grazing and recreation. By design, the checklist excludes elements that are already incorporated into NMRAM metrics (e.g., Surrounding Land Use).

Figure 22. The Stressor Checklist examples of landscape-scale alterations that may affect ecological conditions at a local site (e.g., dams, large fires, and effluent discharge).

Stressor checklists do not contribute directly to assessment rankings but may help evaluate trends in ecological condition. For example, given a site that is at the break between an "A" or "B," the stressor checklist may provide guidance of possible drivers of condition decline and offer insights for mitigation or alternative management.

Stressors can be evaluated by ground reconnaissance, interpreting aerial and satellite imagery, and public records and databases (e.g., the Monitoring Trends in Burn Severity (MTBS) database may have data on recent fires in the watershed).

Stressors are grouped into the following six major elements:

Adverse water management. Water regulation from dams and reservoirs affects water availability and timing of flows to wetlands and the overall natural hydrological regime (i.e., an altered hydrograph).

Key stressors are:

1. Extended low-flow releases from reservoirs that may severely impact water table depth and significantly stress riparian and wetland vegetation;
2. Timing of flow releases not concordant with natural riparian ecosystem processes, particularly phreatophyte tree and shrub regeneration;
3. Extended high-flow dam releases that may submerge riparian and wetland vegetation and create adverse growing conditions, particularly if an anoxic environment is created; and
4. Agricultural or urban flow diversions upstream of a site that may significantly deplete surface and ground water supplies to riparian and wetland communities.

Adverse sediment management. Sediment management can affect channel equilibrium in terms of degradation and aggradation that can lead to adverse changes in floodplain connectivity and shallow groundwater conditions of a wetland.
Key stressors are:

1. Adverse sediment retention by dams that leads to significant downstream sediment depletion and potential channel incision and dewatering of the riparian zone;
2. Sediment loss by dredging of stream channels or extensive barrow pits in the floodplain upstream; and
3. Adverse sediment inputs from roads and urban development upstream, or channel accumulations as streams enter reservoirs (deltas).

Artificial water additions. Artificial water additions can adversely alter the natural hydrograph and groundwater conditions at a site and contribute significant contaminants.
Key stressors are:

1. Treatment effluent from water treatment facilities;
2. Point-source urban runoff that does not flow through water treatment facilities;
3. Uncontrolled factory or feedlot outfall to the stream system;
4. Agricultural irrigation ditch returns; and
5. Mining waste waters

Groundwater pumping. Groundwater pumping can lead to significant shallow aquifer loss that disrupts the hyporheic processes and impacts ecological conditions.
Key stressors are:

1. Urban and exurban depletions;
2. Fracking water use; and
3. Agriculture irrigation from wells.

Watershed alteration. Large landscape-scale disturbances in a watershed such as fire and logging can lead to accelerated erosion and water runoff into streams that can impact downstream wetland resources. Such alterations are often easily seen in aerial or satellite imagery.
Key stressors are:

1. Extensive recent fires in the watershed;
2. Extensive recent timber harvest;
3. Extensive open pit mining in watershed; and
4. Upland livestock and wildlife grazing exceeding recommended stocking rates.

Local biodiversity impacts. Some local dispersed activities such as grazing and recreation, which can have an impact on wetland vegetation condition and wildlife populations.
Key stressors are:

1. Evidence of excessive grazing (local); and
2. Excessive noise (construction, vehicle and air traffic) affecting wildlife.

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