MADREAN ARCHIPELAGO
RAPID ECOREGIONAL ASSESSMENT

PROCESS MODELS DIAGRAMS AND DESCRIPTIONS

REA Memorandum for:
Department of the Interior
Bureau of Land Management
Rapid Ecoregional Assessments

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This document is provided to BLM as a Phase II, Task 2 deliverable.

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1 Introduction

This document culminates Phase II Task 2 of the REA by detailing the results of investigation into available data and proposed processing steps to conduct the assessments identified in Work Plan. For context, the REA began with the Pre Assessment Phase I tasks 1 & 2 which conducted stakeholder workshops and investigations into the management issues of the ecoregion. Also during that Phase the conservation elements (CEs) and change agents (CAs) were identified and conceptual models were built for the ecoregion and each of the 19 CEs. This information was presented in the Pre-Assessment Report (PAR). In Phase II Task 1 the REA Work Plan (REAWP) was developed to propose the remaining assessment work that guided the Task 2 work presented here. In the following task (3), the geospatial analysis work will be conducted according to the process models presented here and the project will conclude with Task 4 to develop the final report and final data submissions.

1.1 Process Models: Overview

Process models are graphic depictions, using box and arrow diagrams, of the steps needed to conduct specific assessments that address identified REA analyses. Process models are intended to communicate the inputs, geospatial analysis (and other) steps, and resulting outputs to clarify these components of the assessments for REA advisors and reviewers prior to conducting the actual geoprocessing work. They form the bridge between the ecoregion and CE conceptual models, and the actual geoprocessing steps by taking into account available data, potential surrogates for data gaps, foundation ecology, and the KEAs developed for each conservation element. In addition, for questions outside of the CE status assessments, the special assessments, they go through a similar data/surrogate identification process to convey how these questions can be answered. Key terminology, acronyms, and abbreviations are described in the Glossary and Abbreviations at the end of this document.

1.2 Assessment Types

The fundamental goal of the REAs is to provide an understanding of the current ecological status of resources values (CEs) in the ecoregion, which CAs are impacting them and where, and the potential future status of CEs in relation to projections of CAs into the future. The REA Pre-Assessment report (Harkness et al. 2013) and work plan addressed how these REA information needs can be further distilled into the following broad and inter-related categories of assessments:

- Where do CAs overlap with CEs? This is the most basic type of assessment that simply looks at coincidence between these features rather than an evaluation of CA effects on CEs. Such intersections are a precursor for conducting the next category of assessments: ecological status of CEs.
- What is the condition or ecological status of ecosystem and species CEs? (Ecological status is in part determined by the effects of CAs on CE extent and condition.)

- What is the ecological integrity of the ecoregion as a whole?
- Special assessments that do not easily fit into any of the above categories

The MAR REA Work Plan described seven key assessment questions. Here, those questions are grouped under three Assessment Types (retaining the assessment questions numbering per the work plan). The Assessment Type descriptions then reference the Process Models that will be used to answer these questions.

1.2.1 Ecological Status Assessment

1. **Where are Change Agent-related features and activities in relation to ecosystems and species?**

   The first part of this assessment addresses questions about the locations of Change Agents (CAs). The location or geographic extent of the Change Agents are compiled and represented spatially in "scenarios;" their current extent is represented in a current or baseline scenario and their future extent is represented in one or more future scenarios. The compilation and aggregation of the CAs' extents into current and future scenarios is illustrated in the Scenario Generation Process Model. Note that some scenarios include features that are not strictly CAs but act as surrogates for CA effects that cannot be directly assessed. The term CA is used, however, as shorthand for all scenario features.

   The second part of this assessment addresses the relationship between the location of the Change Agents and the geographic extent of each of the CEs. The assessment of the CAs in relation to Conservation Elements (CEs) is illustrated in the CA-CE Intersection Process Model.

   The results of these two process models are the key inputs into the Ecological Status Assessment Process Models.

2. **What are the effects of Change Agent-related features and activities on the status of ecosystems and species?**

   This assessment is addressed through the ecological status assessment. Ecological status assessments require the results of the above two Process Models (Scenario Generation and CA-CE Intersection) to use as inputs in the Status Assessment Process Models (terrestrial and aquatic).

3. **Where are Change Agent-related features and activities expected to be constructed or taking place in the future, and what will their effects on the status of ecosystems and species be in the future?**

   This assessment uses the series of three Process Models listed above – Scenario Generation, CA-CE Intersection, and Status Assessment. The key difference between this and question 2 is that it will utilize the Scenario Generation results for the future scenario (rather than current) –

showing the expected future distribution of CAs – as an input for the CA-CE Intersection and Status Assessment Process Models.

4. **How will synergies between these features and activities and other CAs (climate change, invasive species, fire) affect the status of ecosystems and species?**

   This REA does not attempt to model synergies between CAs in terms of modeling how one CA can change the distribution or intensity of another CA. The Status Assessment Process Models do incorporate cumulative effects of CAs on the CEs by calculating each CA effect on each CE independently, then multiplying the effects where CAs overlap (or, where appropriate, their offsite effects as well).

5. **Where are ecosystems and species most vulnerable to these impacts, both now and in the future?**

   This assessment requires interpretation of the Status Assessment results for both current and future scenarios. The Process Models above can be applied to individual classes of CAs (e.g., Development) to isolate the effects of one class of CA from the effects of other CAs in the consolidated Status Assessments.

1.2.2 Ecoregional Ecological Integrity Assessment

6. **What is the ecological integrity of the ecoregion?**

   Ecological integrity has been interpreted in various ways in the REAs. This assessment utilizes the Ecological Integrity Process Model to produce results that offer measures of current ecological integrity throughout the entire ecoregion (instead of just within CE distributions that do not cover the entire ecoregion area).

1.2.3 Special Assessments

7. **Special Assessments**

   This series of assessments address questions that cannot be answered through the standard assessments described above. Each special assessment is unique, requiring individual Process Models, but they may incorporate results of some of the above Process Models or use them as inputs. The special assessments include such topics as the interaction between climate change and hydrologic regimes, water resources availability, and where might mesquite –invaded grasslands be restored, where has fire regime altered so as to impact ecosystems and increase sedimentation.

1.2.4 Process Model Structure

The treatment of process models begins with Ecological Status Assessment and a summary model that illustrates the relationship among its component process models. From there process models for

Ecological Integrity and Special Assessments are described. Each process model contains the following information:

- The model purpose (i.e., what assessment/question it addresses)
- The process model diagram (a graphic box and arrow diagram that illustrates the work flow from source data inputs, through analytical processes, to delivered outputs)
- Inputs
- Analytical process description
- Issues or limitations (including data gaps)

The first model to involve CE distributions in the CA-CE Intersection Process Model and this is where geospatial processing of the CE distributions can be found.

All datasets proposed for use as inputs to the geo-processing are evaluated for fit to the assessment purpose and technical data quality (completeness, currency, spatial and thematic resolution or accuracy, redundancy with other datasets, metadata, and more). Each evaluated dataset (data quality evaluation or DQE) has evaluation attributes and other attributes provided to BLM including a description of the dataset, associated reports, from whom it was obtained, the date it was created, and other pertinent information. This is known as a data inventory tracking form (DITF), and both the quality evaluation and tracking form are required by BLM for the REA. Because detailed information on the data is provided in the DITF, it is not repeated here for brevity but key data gaps are identified.

2 Ecological Status Assessment

Ecological status assessment is the process for calculating the current status/condition of indicators throughout the distribution of each CE currently and, when data is available, for the near term future scenario (2025); the 2060 scenario will only address climate change (as described later). Status assessment links indicators for Key Ecological Attributes (KEAs) as described in the CE conceptual models to geospatial data for CAs and other information via a model of expected effects on the CE. The most accurate measure of ecological condition requires field-based measurement of many factors that are infeasible in an ecoregional assessment. Instead, the REA that must rely on existing, primarily remotely-sensed data on CAs and other factors as indication of status. For example, presence of roads can fragment the size of CE patches/occurrences; presence of invasive species reduces biotic diversity, and dams on streams reduce aquatic connectivity. The lack of such features suggests, without other evidence, that status should be high. This approach is then testable with field observation (which may be used to calibrate models) and updates with new or improved data.

The proposed approach uses a raster-based spatial model that begins with a theoretically perfect condition score of 1.0 for each pixel of a CE distribution (with zero being lowest condition). From there, it applies a CE response model for how each CA is expected to reduce that condition score onsite and in some cases, offsite where the response is drawn from the CE conceptual model. Where multiple CAs overlap, the resulting condition scores are multiplied to approximate a cumulative CA effect. This model is called the Landscape Condition Model (LCM) (Comer and Hak 2009, Comer and Faber-Langendoen 2013) and draws conceptually from similar prior work (Brown and Vivas 2005, Theobald 2001) and has similarities to other contemporary modeling approaches (Leu et al. 2008, Sanderson et al. 2002, Theobald 2010). The LCM was approved and used in three previous REAs (Central Basin and Range, Mojave Basin and Range, Seward Peninsula) (Comer et al. 2013a, b, and Harkness et al. 2014).

The LCM application is based on the concept of a scenario of features that can affect ecological status of a CE's KEA indicators for a particular timeframe and or set of assumptions. These features are primarily composed of maps of the distribution of CAs but may also include other features that can act as surrogates for CAs' effects that have not been directly mapped. For the MAR, the scenarios represent current actual features and a 2025 timeframe of expected changes in features (assuming sufficient data to represent those features in 2025). In cases where existing source data provides indices that indicate low to high status of a particular component such as fire regime or native biotic composition, these indices can be utilized such that high values will contribute to that theoretical perfect status while low values will be treated as a reduction in status. Therefore, all inputs to status modeling can either indicate maintenance of status or reduction in status but not an improvement in status (except if say invasives removal was introduced in a scenario to remove the effect of an invasive species CA).

Once a scenario of CA features is created, a response model is needed to tell the LCM how the CA affects the CE indicator status. The response model is constructed using information from the CE conceptual models for how a CE is expected to respond in the presence of the scenario features (and in some cases, a distance out from the feature) for a particular CE indicator and is represented in a simple table (presented later with the LCM details). The geospatial implementation of the response model intersects the CE distribution with the scenario and the response model is applied to those intersecting pixels to derive a raster map of the calculated remaining condition for each pixel in the CE distribution. The workings of the model are described later in the CE Status Assessment Process Model section. An overall scenario and cumulative status map are generated to provide overall CE status but such products typically beg the question about what indicators are driving the status at different locations. Therefore "KEA scenarios" that represent relevant indicators are also assessed individually to illuminate their effects and inform understanding and potential management action.

The following CE Ecological Status Assessment Summary Process Model (Figure 2-1) is provided to illustrate the overall ecological status assessment process. It depicts the key components of the assessment which are further broken down and explained in the component process models that follow. Nearly all of the status assessment process is conducted with the NatureServe Vista™ (Vista) extension to Esri's ArcGIS 10.x platform (which includes the LCM described above). In cases where other modeling is needed (e.g., pre-processing of inputs to the scenarios) these are indicated in the component process models either in the diagrams or in the Analytical Process Descriptions in narrative for simple processes.

The Vista tool was selected because it contains the primary functions necessary for this modeling and is being assessed for general BLM application by the National Operations Center. Additionally, as opposed to a custom tool, Vista is a commercial grade tool that contains graphical user interfaces, a detailed integrated user manual, and available technical support and training to support replication of results and later updating. Specific relevant Vista functions include:

- Unique capabilities to assemble scenarios by importing and characterizing data for scenario features. Vista facilitates this by providing a crosswalking function to import data from many different sources and translate their various attributes into a common classification of CAs and other scenario features. The scenario tool also provides the ability to rectify overlapping data to specify whether one feature “overrides” another (e.g., a development would override most other co-occurring features) or combine features to indicate that they are co-occurring and thus have cumulative effects. This can be especially useful to depict the status benefits of protected areas that have a conservation land use but may also contain certain CAs that will impact status.
- Integration of NatureServe’s Landscape Condition Model (LCM) such that Vista provides a user interface and supporting functions and reporting for the LCM.
- Multi-resolution assessment and reporting. Vista allows the user to set the pixel size for assessment as well as a reporting unit for summarizing results. These settings can be changed each time an analysis is run.
- Post-REA application support. Vista is a powerful project assessment and overall planning tool. Use of Vista for REA status assessment provides the ability for later users to integrate other data with REA data and results to support a variety of typical land use, project assessment, and management applications.

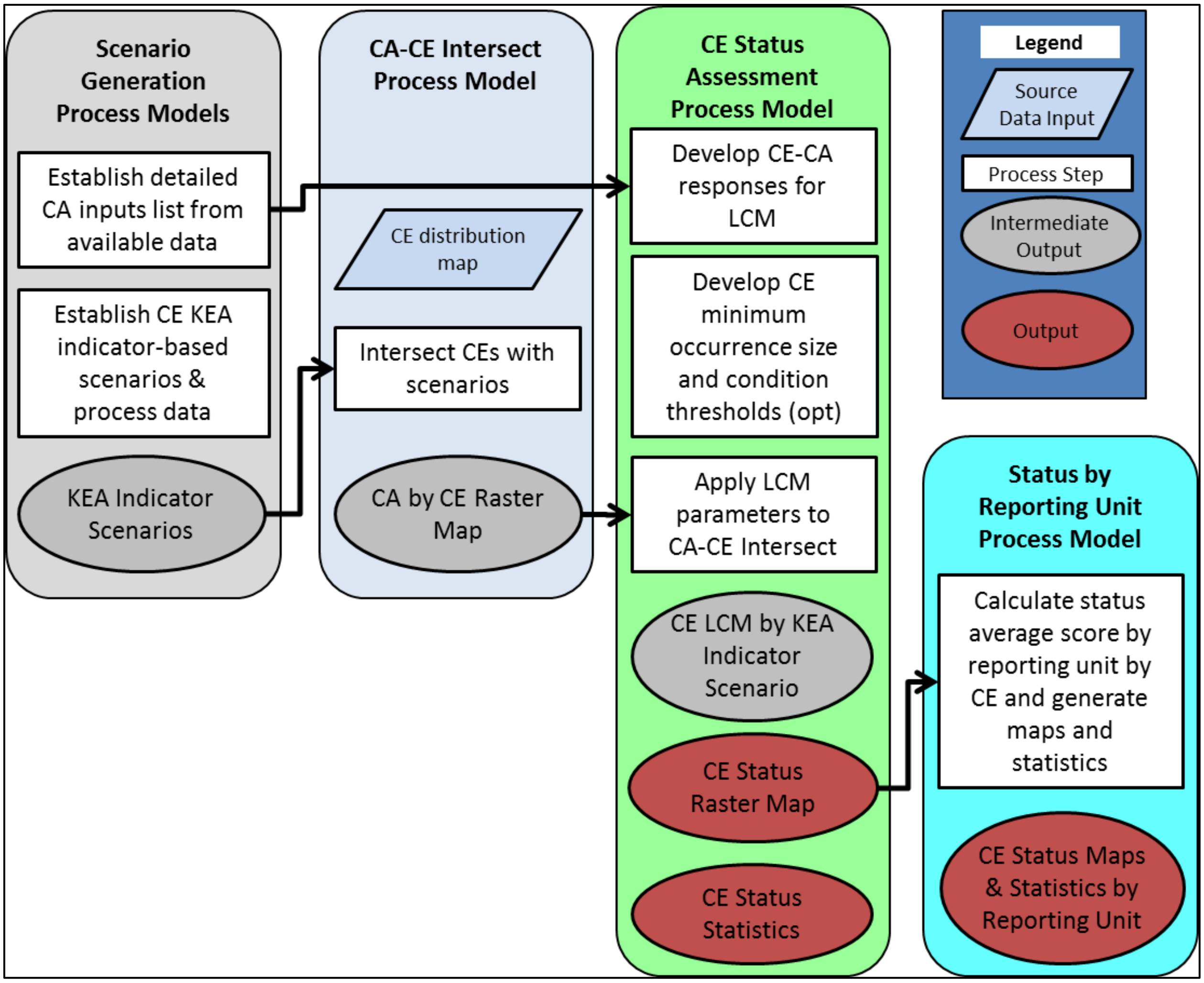

Figure 2-1. CE Ecological Status Assessment Summary Process Model. This model provides an overview of the ecological status assessment process. Round cornered boxes indicate component process models illustrated and described in greater detail later in this document

General Issues and Limitations

Geospatial modeling always introduces assumptions and abstractions of actual ecosystem processes and change agent effects. The many factors that can be observed and measured in the field cannot be fully captured with existing data and geospatial modeling. While the geospatial results can be field tested to some degree and calibrated to field observations, there will not be a one-to-one comparability between the many indicators described in the conceptual models and what can be assessed with existing data. The proposed process also does not model interactions between CAs e.g., to calculate an increase in the distribution or intensity of one CA based on the presence or effects of another CA. However, in some cases the inputs proposed for the MAR (e.g., fire condition) are based on more complex models that do incorporate such interactions. Vista scenario outputs are in raster form which is very sensitive to the resolution of the input data. For example, road maps that include very narrow features such as 25 foot wide roads may experience breaks in the output raster map at 30 meter pixel resolution. Small features may be buffered so they do not experience this effect; however, such buffering may increase the footprint of such features and over estimate their impacts.

2.1 Scenario Generation: Current and Future

The Scenario Generation Process Models describe how data inputs (either directly from source data or generated through another process) are integrated into individual KEA scenarios and a "roll up" scenario. The scenarios then are the maps of the features expected to affect CE status (including maintaining status as in areas with conservation land use). CE status is calculated in the CE Status Assessment Process Model. Because it is common to each of the scenario process models below; the following steps describe the GIS processes conducted by Vista. Any necessary pre-processing of inputs unique to each scenario process model is described in those model descriptions. In each of the three specific process models that follow (terrestrial ecosystems, species, aquatic CEs), a roll up scenario of all inputs is proposed to allow calculation of overall CE status. A proposed input to each of those is existing conservation lands represented by the USGS US PAD (Protected Area Database). This input is optional because it will not affect CE status (expected to maintain perfect condition unless CAs are present). It is proposed for inclusion only in the "All CAs" scenario because it will differentiate the conservation land use supporting condition versus areas of no data in the scenarios.

The Vista Scenario Generation function conducts the following steps:

1. The user names the scenario, provides a description, and specifies a pixel size for the output raster(s).
2. The user identifies an input map layer from the project geospatial database.
3. The user must specify what attribute to use from the input layer to represent the scenario feature of interest (e.g., a road class) and then develop a crosswalk (Vista translator) between the attribute(s) of that layer and a standard classification of CAs to be used in the MAR. Vista saves this translator to allow automatic application to any updated input layer provided.
4. The user adds the layer to the scenario by specifying whether the layer should be combined with other layers or if it should override any overlapping layers. The position in the graphic layer stack of inputs can be changed to provide the proper arrangement of layers for processing.
5. These settings in Vista then provide the software the instructions to generate the scenario. If the input is a vector layer it is rasterized according to the pixel cell size specified. Raster inputs that differ from that pixel size are resampled using a Snap Raster established in the project settings to maintain alignment of data layers. The output will be a stack of rasters when >1 input layers overlap and the "combine" setting is used. This allows Vista to recognize that >1 scenario features are present in the same location and Vista will be able to perform cumulative effects

assessment in its Scenario Evaluation function (described in the CE Status Assessment Process Model).

2.1.1 Terrestrial Ecosystems Current Scenario Generation Process Model

Scenarios for assessing upland ecosystem CE status include 3 major components: development in the ecoregion, alterations to natural disturbance regimes (primarily fire), and the presence of invasives. Other possible key indicators of status include native floristic or faunal composition, current structural stages, and actual, current fire regimes but data are not sufficient in the ecoregion to include these direct, region-wide indicators. As a result, the assessment must rely on indirect, stressor-based indicators to measure the condition of the key ecological attributes (KEAs), such as invasives or the fire regime departure summed into condition classes by Landfire.

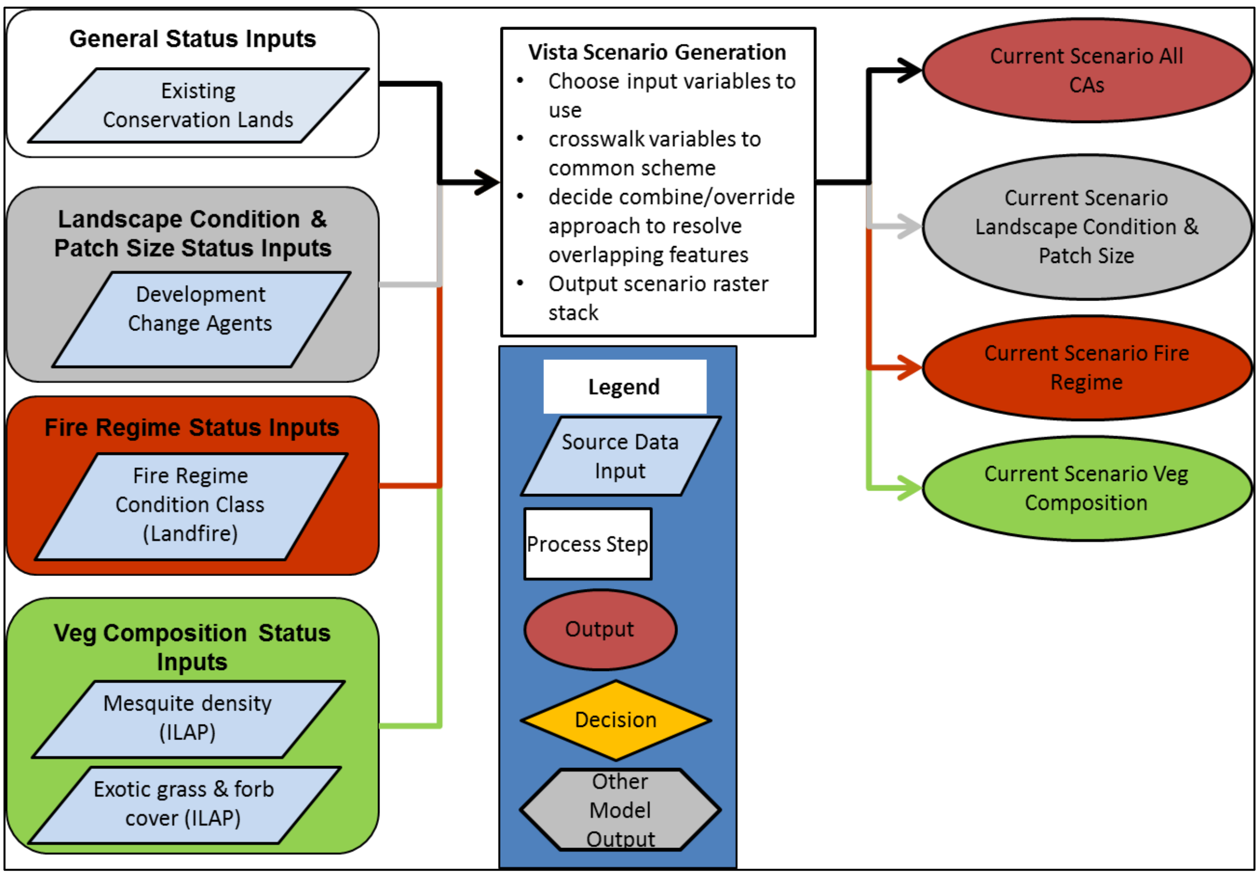

Figure 2-2. Terrestrial Ecosystems Current Scenario Generation Process Model. Inputs are in the left column of boxes; specific CAs and their forms are documented in the LCM response models for each CE. This model indicates that separate scenarios will be generated for each Key Ecological Attribute. The Vista scenario generation function is described in the process model description. The inputs on the left side are grouped according to which scenario output they form on the right. All of the outputs are intermediate products.

Table 2-1 provides a cross walk between the KEAs identified in the conceptual models for the CEs and the process model KEA scenarios discussed below. It also indicates which KEA scenarios will be used for each CE.

Table 2-1. Crosswalk of key ecological attributes identified for CEs in the conceptual models with the ecological status process model KEA scenarios that will be assessed for each CE. Notes are provided to help clarify the particular indicators being assessed within the scenario.

***Conceptual Model KEA Class:* Name →**	***Landscape Context:* Landscape Condition**	***Size/Extent: Patch Size Distribution***	***Biotic Condition: Vegetation Composition***	***Abiotic Condition: Fire Regime***
Process Model KEA Scenario →	***Landscape Condition & Patch Size***	***Landscape Condition & Patch Size***	***Veg Composition***	***Fire Regime***
Indicator Notes →	Stressor: Modifications to land surface for human use that effects CE directly or indirectly	Stressor: Modifications to land surface for human use that fragments the CE distribution	Stressor: Abundance of invasive species (mesquite and exotic grasses & forbs)	Stressor: Altered fire regimes as reflected in successional classes & their proportions
CE				
Chihuahuan Creosotebush Desert Scrub	***x***	***x***	***x***	***x***
Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	***x***	***x***	***x***	***x***
Madrean Encinal	***x***	***x***	***x***	***x***
Madrean Pinyon-Juniper Woodland	***x***	***x***	***x***	***x***
Madrean Montane Conifer-Oak Forest and Woodland	***x***			***x***
Mogollon Chaparral	***x***		***x***	***x***

Inputs

Inputs are described per the scenario types identified in Figure 2-2 and Table 2-1:

Landscape Condition & Patch Size Scenario. This scenario is proposed to represent the landscape context, and the effects of land use and development on the upland ecosystem CEs (e.g. fragmentation, noise/air/light pollution, etc). Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance from their source (Comer and Hak 2009, Comer and Faber-Langendoen 2013). In addition, land use and development cause ecosystem fragmentation which interferes with landscape scale ecological processes.

Scenario Inputs

- All development change agents. This is an extensive list, please see Appendix A.

Fire Regime Scenario. This scenario is proposed to represent the effects of fire and altered fire regimes on the upland ecosystems. Fire, a natural agent of disturbance in upland vegetation communities in the MAR, maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling. Altered (uncharacteristic) fire regime greatly influences ecosystem processes. Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuels that ultimately produce high severity fire. A fire regime introduced into non fire-adapted desert scrub ecosystems by the presence of invasive exotic grasses results in more frequent fires. This then may eliminate desert shrub and succulent species which are killed by fires.

Scenario Inputs

- Fire Regime: LandFire Fire Regime Condition Classes of moderate & high severity departure will be used.

Vegetation Composition Scenario. This scenario is proposed to represent the status of biotic condition. The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire regime, anthropomorphic disturbance). Available data allow the assessment of status affected by invasive native woody increasers (mesquite) in the uplands and invasive exotic species on the composition of the natural ecosystems. Invasive non-native grasses may out-compete and replace native desert plants. These grasses burn easily, and so fire frequency and severity increase (USDA-USFS 2009). Mesquite has greatly increased in density throughout the MAR, especially in the grasslands and encinal. Its effects on ecological condition will also be assessed through this scenario.

Scenario Inputs

- Integrated Landscape Assessment Project (ILAP) vegetation data; specifically mesquite density: ILAP developed modeled data at 30m resolution representing the percent cover of mesquite; thresholds will be applied to break this continuous cover variable into categories.
- Integrated Landscape Assessment Project (ILAP) vegetation data; specifically cover of exotic herbaceous species: ILAP developed modeled data at 30m resolution representing the percent cover of exotic invasive grass and forb species; thresholds will be applied to break this continuous cover variable into categories.

Analytical Process Description

See general description earlier for scenarios. Inputs for this scenario are expected to be used in their source form with only minor processing; no generation of inputs is anticipated.

Outputs

Outputs are multiple scenarios that correspond to Key Ecological Attributes (KEAs) of Landscape Condition, Fire Regime, and Vegetation Composition. Each scenario is a stack of raster layers (when there are overlapping CAs) that are attributed with the specific CA present in each pixel to accommodate cumulative effects of multiple CAs in the same location. Additionally, Vista generates an HTML format report for each scenario that lists the area of each CA in the region.

Issues or Limitations

Although ILAP does have modeled data for percent cover of exotic invasive herbs, the ILAP team notes that it is a model with moderate uncertainty due to the lack of field-based input data for known locations (and cover) of invasive plants. The ILAP team used plot data with species abundance, Landsat imagery, soils attributes, topographic variables, and climate variables derived from PRISM to develop their current vegetation datasets. These datasets are a series of attributes of vegetation structure & summarized composition per pixel, not a "vegetation type". Outside of the ILAP data, there is a lack of comprehensive (MAR-wide) current distribution or risk of occurrence data for exotic invasive plants. The ILAP model for mesquite density/cover is a better model than that for invasive exotic herbs, as there are more field-based locations for known occurrences of mesquite; and the input data are vegetation sampling plots, which include percent cover estimates and not just presence/absence. Hence, ILAP was able to model percent cover of mesquite in a more robust fashion than the model for the exotics.

The Landfire Fire Regime Condition Class (FRCC) and Vegetation Condition Class (VCC) datasets are produced by Landfire, and developed to compare historic reference conditions with current conditions for an individual ecological system type. They each provide a categorized measure of the difference between current vegetation type and structure, and estimated vegetation type (Biophysical Settings, BpS) and structure from the time just prior to European settlement. Landfire FRCC and VCC are not direct measures of fire risk; they are calculated based on changes to species composition, structural stage, and canopy closure, and derived by comparing expected (historic) *proportions* of structural stages with current proportions (see Rollins et al. 2007 for documentation of methods). This comparison of proportions must be done across large enough summary landscape units to adequately represent the historic conditions versus current conditions. Landfire FRCC uses Ecomap Subsections within which to calculate the FRCC. The VCC calculations are done within variable size watersheds (4th, 5th or 6th level watersheds), depending upon the fire regime group to which each vegetation type (BpS) is assigned. Each 30m grid cell for each ecological system is then assigned a “condition class” indicating its degree of departure from the expected distribution. Thus, the FRCC and VCC data take into account current successional and structural conditions in the landscape. The Landfire website states they consider the FRCC and VCC datasets to be the same, but VCC uses a more recent methodology for its development. The VCC data will be adequate for the intended REA assessment of current fire regime and successional conditions.

Another possible addition to the fire regime scenario is the use of recent burn perimeters. However, recent burns, in-and-of-themselves do not necessarily have a negative or positive effect on the upland ecosystems. One possible exception is the desert scrub types, such as the Chihuahuan Creosotebush Desert Scrub CE, which historically did not support fire. Most of the other upland ecosystems in the MAR are fire adapted, so the occurrence of recent burns may have a positive effect on those CEs. An additional issue is the burn perimeters, if used, will be relevant only to actual CE distributions; in other words calculating an index of burns for an entire watershed is too generalized to provide results specific to an individual CE. Therefore, use of fire perimeters in the terrestrial ecosystem status assessment is not recommended.

2.1.2 Species Current Scenario Generation Process Model

Species status is assessed in this REA primarily in regard to effects on species’ habitats rather than effects on individuals or populations (e.g., the effect of a road on habitat fragmentation rather than direct mortality of individuals attempting to cross a road). Because habitats are being assessed, the scenarios are largely the same as the terrestrial ecosystem scenarios with a few exceptions as noted in the process model description.

Table 2-2 provides a cross walk between the KEAs identified in the conceptual models for each CE and the process model KEA scenarios discussed below (Figure 2-3). It also indicates which KEA scenarios will be developed and assessed for each CE.

Table 2-2. Crosswalk of key ecological attributes identified for CEs in the conceptual models with the ecological status process model KEA scenarios that will be assessed for each CE. Notes are provided to help clarify the particular indicators being assessed within the scenario.

***Conceptual Model KEA Class:* Name →**	***Landscape Context: Habitat Condition***	***Landscape Context: Habitat Availability (includes human disruption considerations for bats)***	***Landscape Context: Connectivity (between populations and habitat patches)***	***Biotic Condition: Forage Quality/Vegetation Composition***	***Abiotic Condition: Fire Regime***
Process Model KEA Scenario →	***Current Scenario Landscape Condition & Patch Size***	***Current Scenario Landscape Condition & Patch Size***	***Current Scenario Connectivity***	***Current Scenario Veg Composition***	***Current Scenario Fire Regime***
Indicator Notes →	Stressor: Modifications to land surface for human use that effects CE habitat directly or indirectly	Stressor: Modifications to land surface for human use that modifies or destroys the CE habitat	Stressor: Modifications of land surface for human use that decrease permeability to CE movement within or between habitat patches	Stressor: Abundance of invasive species (mesquite and exotic grasses & forbs)	Stressor: Altered fire regimes as reflected in successional classes & their proportions
CE					
Bighorn Sheep	x	x	x	x	x
Coues White-tailed Deer	x	x	x	x	x
Pronghorn	x	x		x	
Black-tailed Prairie Dog	x	x	x	x	x
Desert Box Turtle	x	x	x		x
Chiricahua Leopard Frog	x				x
Grassland Bird Assemblage	x	x	x	x	x
Nectivorous Bat Assemblage	x	x		x	x

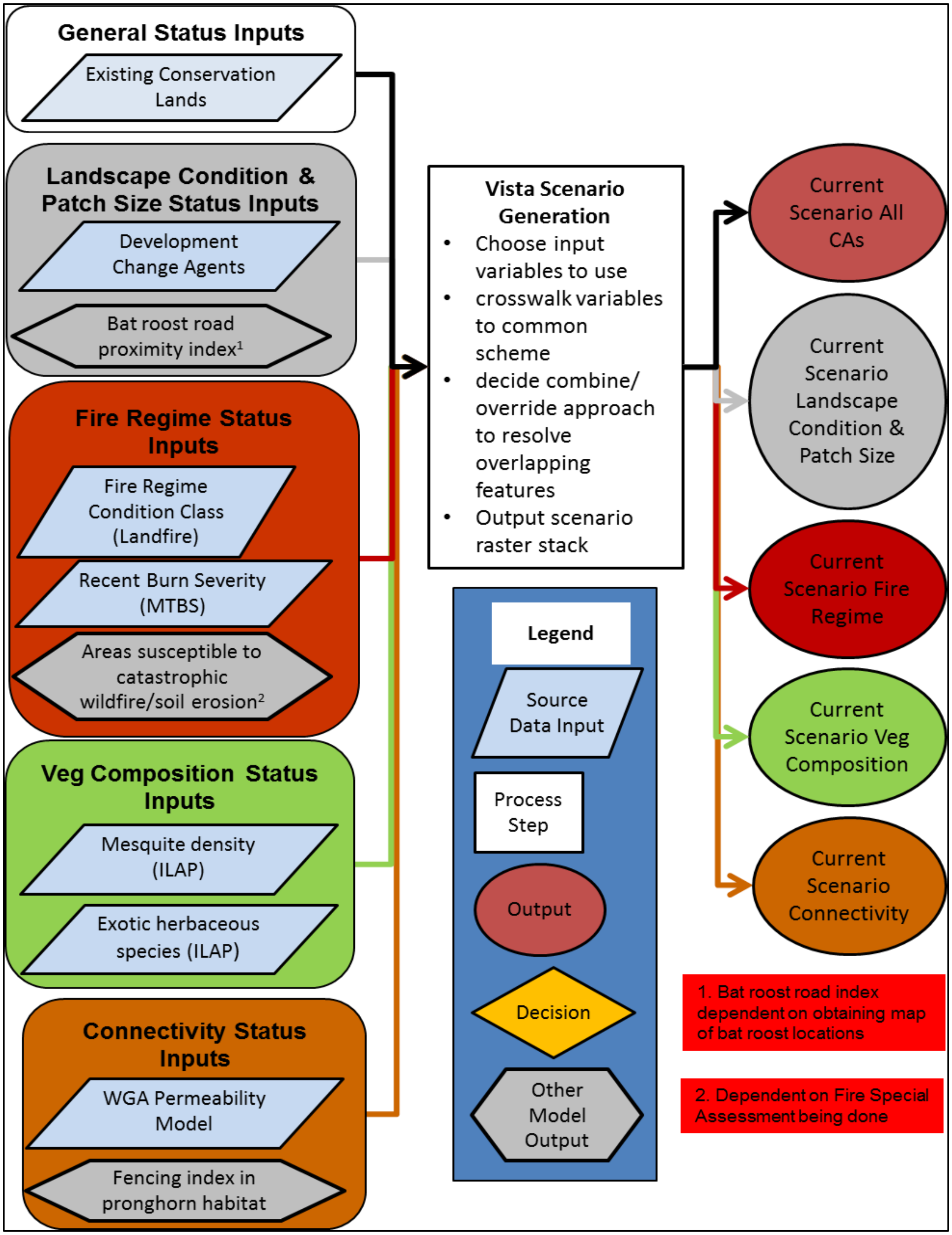

Figure 2-3. Species Current Scenario Generation Process Model. The inputs on the left side are grouped according to which scenario output they form on the right. All of the outputs are intermediate products.

Inputs

Inputs are described per the scenario types described in

Table 2-2 and Figure 2-3:

Landscape Condition & Patch Size Scenario. This scenario is proposed to represent the landscape context and the effects of land use and development on the species habitat. Development is a key change agent for all species being assessed in the MAR causing direct or indirect effects of habitat loss or degradation e.g. habitat removal, fragmentation, and pollution. Ecological conditions and landscape dynamics that support species habitat are affected by development but impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009, Comer and Faber-Langendoen 2013).

Bats are very sensitive to human disturbance at roosting sites. They may have a difficult time finding alternative roosts that meet their requirements. Loss of roosting sites is one of the key factors cited in the population decline of nectar feeding bats (AZGFD 2006; 20011, NMGF 2006, USFWS 2007; 1994). Both daytime and nighttime roost sites from which bats can reach foraging habitat are key to species success in the Madrean ecoregion. The proximity of known bat roost sites to roads is an indirect way to measure potential human disturbance of roosts.

Scenario Inputs

- All development change agents (see Appendix A for list)
- Bat roost sites (used with roads to create a roost accessibility index)

Fire Regime Scenario. This scenario is proposed to represent the effects of fire and altered fire regimes on the ecosystems providing habitat for the species CEs. Fire, a natural agent of disturbance in upland vegetation communities in the MAR, maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling. Altered (uncharacteristic) fire regime greatly influences ecosystem processes. Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel loads that ultimately produce high-severity fire. This is important for species like grassland-associated birds that generally are negatively affected by increased woody species.

Recent burns can dramatically alter habitat in a short period of time, potentially making it uninhabitable either through direct effects or indirect downstream effects due to sedimentation from post-fire erosion. For example standing pools of water in channels may be filled in by sediment and lost as suitable Chiricahua leopard frog habitat.

Scenario Inputs

- Landfire Fire Regime Condition Class (equivalent to the Vegetation Condition Class): The moderate and high severity departure classes will be used.

- Recent burn severity (Monitoring Trends in Burn Severity, MTBS data)
- For Chiricahua leopard frog, the output of the special assessment on fire effects on watershed sedimentation will be used if that special assessment is selected for implementation. However, recent information from ILAP indicates that the 'erosion potential" soil variable intended for use in this special assessment is not available outside of National Forest boundaries, and may only be completed for the Coronado NF in AZ and not in NM.

Vegetation Composition Scenario. This scenario is proposed to represent one aspect of biotic condition, that of the effect of invasive native woody increasers and invasive exotic species on the composition of the habitat for the species. For example pronghorn are dependent on good condition native grasslands -- invasion by mesquite or exotic grasses degrades pronghorn habitat and decreases good quality forage. The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem and an important aspect of quality and quantity of forage for species; many ecological processes and environmental variables affect it (drought, fire regime, anthropomorphic disturbance). Invasive non-native grasses may out-compete and replace native desert plants. Mesquite has greatly increased in density throughout the MAR, especially in the grasslands and encinal. Its effects on ecological condition will also be assessed through this scenario.

Scenario Inputs

- ILAP mesquite density
- ILAP exotic grass and forb cover [data still under investigation for suitability]

Connectivity Scenario. This scenario is proposed to represent the permeability of the landscape to wildlife movement. At the local scale, permeability is critical for species to avoid predators and access food and water. Bighorn sheep, Coues white-tail deer, pronghorn and Chiricahua leopard frog rely on available surface water for survival or completion of their lifecycle, therefore ability to move between this resource and forage resources are critical. For terrestrial mammals such as Bighorn sheep, Coues white-tail deer and pronghorn, seasonal and even daily movements between areas of foraging and breeding are also important (NatureServe 2013; USFWS 2008).

At the larger landscape scale, connectivity is critical for species population health through gene flow, dispersal, and seasonal migration. Daily and seasonal migratory movement between habitat patches is essential for adaptability to changing forage and water availability, predator avoidance, and gene flow (AZGFD 2011; NatureServe 2013; USFWS 2008). Ability to move across the landscape in response to fire, drought, and shifts in resource availability is important for climate change adaptation.

Pronghorn are particularly sensitive to features such as fencing that may not affect other wide-ranging species, due to their aversion to jumping over these features. To address this issue for pronghorn, the best available information on linear fence features within the MAR will be incorporated into the Connectivity Status.

Landscape-level permeability is based on the absence of barriers such as fences, roads and other developments, as well as natural land cover.

Scenario Inputs

- Western Governors Association (WGA) Landscape Permeability Index (this will be used for general connectivity status for relevant species)
- Existing fencing (to be applied to a fence density index for pronghorn assessment)

Analytical Process Description

The analytical process is the same as the Terrestrial Ecosystems Current Scenario Generation Process Model. The following additional modeling steps are necessary to convert the source data for inputs to the Scenario Generation process (described below per scenario type where applicable):

<u>Landscape Condition & Patch Size Scenario</u>

- Bat roost sites: road proximity will be calculated as a distance (e.g., feet or miles) to the nearest road with a single value per roost site. This will represent human accessibility to each roost site. Note that data acquisition and evaluation are not complete: BLM is working with the AZ and NM F&G agencies to evaluate whether the acquired bat roost site data are sufficient for use.

<u>Fire Regime Scenario</u>

- Landfire Fire Regime Condition Class/Vegetation Condition Class: The Landfire Fire Regime Condition Class (FRCC) or Vegetation Condition Class (VCC) dataset takes into account current successional and structural conditions in the landscape. It will be used to assess current vegetation conditions for *habitat* of the species CEs. However, some pre-processing of the 30m resolution data may be required, since each grid cell directly corresponds to an ecological system which is not necessarily directly related to species habitat. The FRCC or VCC can be summarized prior to use in the scenario, into average departure scores for some larger unit, such as fine-scale watersheds (i.e. 12-digit) or 4km grid cells, as relevant to individual species CEs.
- Recent burn severity: the MTBS dataset for fire severity is a 30m raster, available for each year from 1984 through 2011. For this assessment, only the most recent 10 years (2002 through 2011 will be used. The data for all 10 years will be combined into one dataset; and where burns overlap, the highest severity for any one year will be selected. Four to seven classes of severity are included for any one year. The highest 2 or 3 classes of burn severity will be selected for the scenario.
- Results of the special assessment of fire effects on watershed sedimentation.

Vegetation Composition Scenario

- ILAP mesquite density: ILAP developed modeled data at 30m resolution representing the percent cover of mesquite; thresholds will be applied to break this continuous cover variable into categories.
- ILAP exotic herbaceous cover: ILAP developed modeled data at 30m resolution representing the percent cover of exotic invasive grass and forb species; thresholds will be applied to break this continuous cover variable into categories.

Connectivity Scenario

- The pronghorn fence index will calculate miles of fence per square mile and attribute the corresponding decimal ratio to each 30 m pixel in the MAR.

Outputs

Outputs are similar to the Terrestrial Ecosystems Current Scenario Generation Process Model with changes per the different types of scenarios identified in this process model.

Issues or Limitations

Most issues and limitations are the same as for Terrestrial Ecosystems Current Scenario Generation Process Model; issues specific to species scenarios are described here. The assessment will rely on generalization of connectivity, otherwise described as permeability, across the region. This will not be modeled based on specific species habitat patches or population connectivity requirements and will offer less information about species such as the Chiricahua leopard frog that are moving between microhabitats and may find smaller scale development features to be impediments to their movements. For species like grassland-associated birds, pronghorn, and Coues white-tail deer, species composition within a habitat patch is important for successful young rearing and forage quality. These species may rely on the presence of specific high-protein native shrubs or a diversity of grass species. The data available for understanding the prevalence of exotic perennial grasses will limit the understanding of this dynamic to a broad scale that may not be particularly relevant for species depending on microhabitats.

2.1.3 Aquatic Ecosystems Current Scenario Generation Process Model

Scenarios for assessing aquatic CE status are complex for several reasons. First, data are not sufficient in the ecoregion to support direct, region-wide indicators of water quality, hydrologic condition, and geomorphic condition. As a result, the assessment must rely on both indirect, stressor-based indicators and a few direct measures of physical and biotic health for each KEA to approximate KEA indicator condition. Second, aquatic CEs are affected by numerous types of CAs. Table 2-3 provides a cross walk between the KEAs identified in the conceptual models for each CE and the process model KEA scenarios discussed below (Figure 2-4). It also indicates which KEA scenarios will be developed and assessed for each CE.

Table 2-3. Crosswalk of key ecological attributes identified for aquatic ecosystem CEs in the conceptual models with the ecological status process model KEA scenarios. Notes are provided to help clarify the particular indicators being assessed within the scenario.

***Concept Model KEA Class:* Name**	**Process Model KEA Scenario**	**Indicator Notes**	**NAWD* Riparian Woodland, Shrubland, Mesquite Bosque & Stream**	**NAWD* Lower Montane Riparian Woodland, Shrubland & Stream**	**NA** Arid West Emergent Marsh, Ciénega & Pond**	**NAWD* Playa & Ephemeral Lake**
***Landscape Context:* Landscape Cover**	**Current Scenario Landscape Condition**	Stressor: Modifications to watershed surface for human use	x	x	x	x
***Biotic Condition:* Riparian and Aquatic Flora & Fauna**	**Current Scenario Invasives**	Stressor: Presence of Tamarisk and Aquatic Invasive Species	x	x	x	x
***Biotic Condition:* Aquatic Fauna**	**Current Scenario Native Biotic Integrity**	Direct: Presence of indicator species, native fish Index and macro-invertebrate index	x	x	x	
***Abiotic Condition:* Water Chemistry**	**Current Scenario Habitat Quality**	Stressor: State Fish Advisories (Mercury)	x	x		
***Abiotic Condition:* Geomorphology**	**Current Scenario Habitat Quality**	Direct: Condition and stability of floodplain soils, stream beds and stream banks	x	x		

* = North American Warm Desert; ** = North American

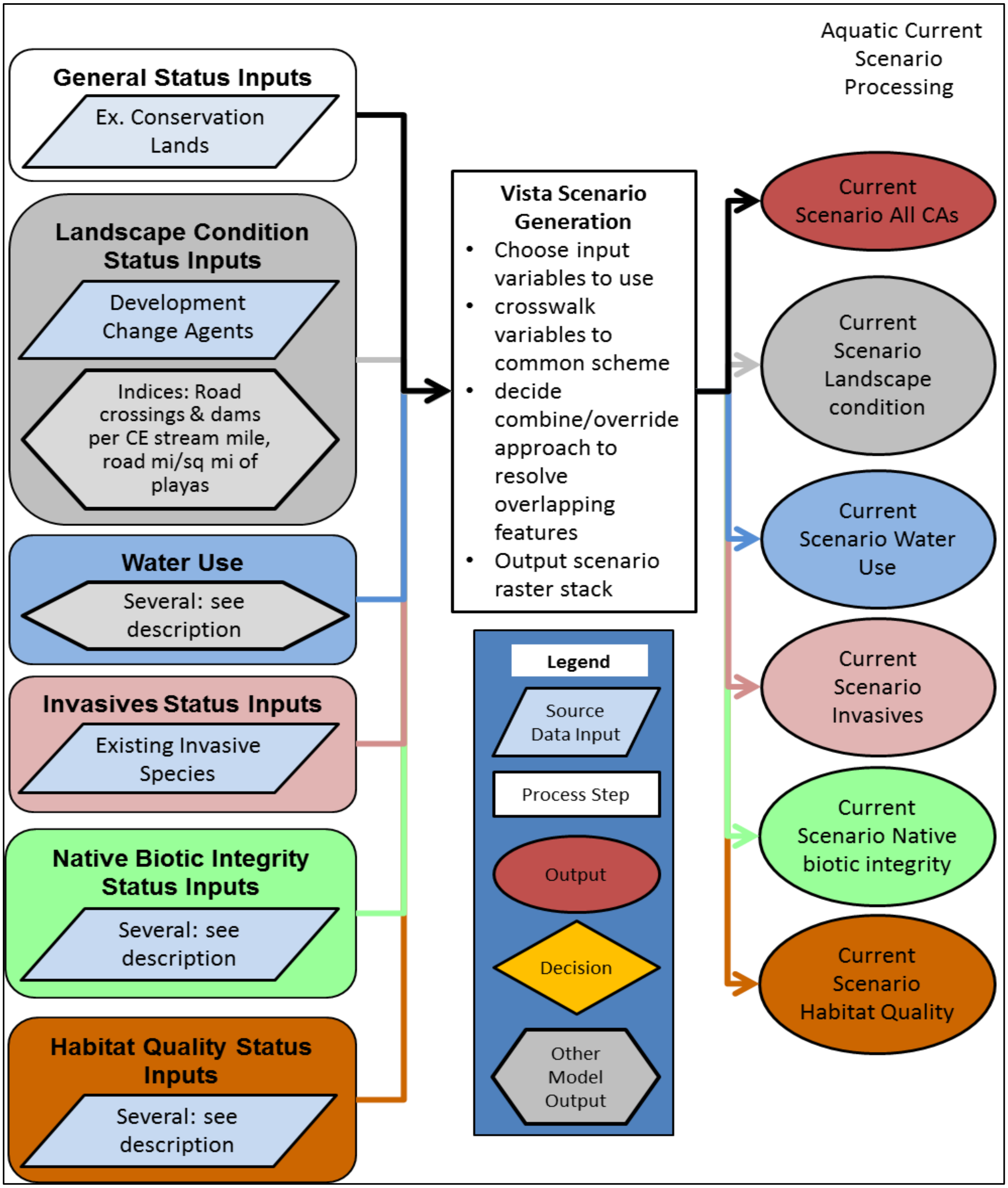

Figure 2-4. Aquatic Ecosystems Current Scenario Generation Process Model. The inputs on the left side are grouped according to which scenario output they form on the right. All of the outputs are intermediate products.

Inputs

There are a large number of inputs to aquatic CE status assessment scenarios. Following are complete descriptions of inputs by scenario type (these are source inputs, conversions to inputs are described in the following section):

Landscape Condition Status Scenario. This scenario is proposed to represent the landscape context, and the effects of land use and development on the riparian or aquatic components of the CEs.

Surrounding watershed cover in unaltered landscapes helps determine the rates of precipitation runoff versus infiltration, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the riparian/stream location from the watershed as a whole and from its immediate "near-stream" buffer zone. Surrounding watershed cover also shapes the connectivity between the riparian/stream corridor and the surrounding landscape for fauna that move between the two settings; and the longitudinal connectivity of the buffer zone alongside the corridor within which additional wildlife movement takes place (Comer and Hak 2009, Comer and Faber-Langendoen 2013).

In addition, the number of road crossings and dams interrupt the aquatic flow and aquatic connectivity, so in addition to the surrounding landscape condition, the number of road crossings and dams will be used within the extent of the CE, per 5th level HUC. Unfragmented aquatic corridors support up- and downstream movement and gene flow for aquatic animal species, natural downstream transport of larvae and seeds, and natural downstream transport of sediment and both dissolved and suspended nutrient matter -- all processes crucial to sustaining the aquatic food web, aquatic and riparian species populations, and succession and recovery from disturbances. More extensive and highly connected aquatic corridors are ecologically more resistant and resilient, for example by providing refugia and movement routes that support recovery following disturbance.

Scenario Inputs

- All development change agents (see Appendix A)
- Roads
- Dams

Water Use Status Scenario. This scenario is proposed to represent the effects of human uses of water (both ground and surface water) on the CEs.

The surface flow regime determines which aquatic species can persist in a stream system through their requirements for, or tolerances of, different flow conditions at different times of the year; shapes sediment transport and geomorphology and, therefore, aquatic habitat distributions and quality; and determines the pattern of flood disturbance. In turn, interactions between the surface flow regime and underlying aquifer conditions shape the pattern of baseflow in the former and the pattern of water table variation along the riparian corridor. The surface flow regime and surface-groundwater interactions thereby together strongly influences both aquatic and riparian habitat and biological diversity (e.g., Poff et al. 1997; Collins et al. 2006; Poff et al. 2007). However, data are not sufficient in the ecoregion to support direct, region-wide indicators of hydrologic condition. As a result, the assessment must rely on indirect, stressor-based indicators of hydrologic condition focusing on indicators of water use, as follows:

Scenario Inputs

- Surface & groundwater use: water use volume (acre/ft) by groundwater basin per capita by major use (residential, industrial, agricultural, etc) for Arizona, data as of 2010 (AZDWR 2011); and for New Mexico by county, data as of 2005 (Longworth et al. 2008).
- Dam locations (points)

Invasives Status Scenario. This scenario is proposed to represent one aspect of biotic condition, that of the effect of invasive exotic species on native species composition. The taxonomic composition of the riparian & aquatic floral assemblage is an important aspect of the ecological integrity of a riparian/aquatic ecosystem. Numerous native species of woody and non-woody plants occur preferentially or exclusively in riparian habitats, from floodplain terraces to stream banks and perennial pools; and occur in different successional settings following disturbance. These species vary in their sensitivity to different stresses such as alterations to riparian corridor hydrology (e.g., water table and flood dynamics), aquatic and riparian corridor connectivity (affecting availability of seed for recolonization following disturbance), and altered water quality. Alterations in the taxonomic composition of the riparian floral assemblage beyond its natural range of variation therefore strongly indicates the types and severities of stresses imposed on the riparian ecosystem.

Scenario Inputs

- Presence of tamarisk (any of the *Tamarix* species)
- Presence of aquatic non-native species (catfish, bull frogs, western mosquito fish, and others)

Native Biotic Response Scenario. This scenario is proposed to represent a second aspect of biotic condition, that of the species composition of native fish, plants, and macroinvertebrates. The taxonomic and functional composition of the aquatic and terrestrial faunal and flora assemblage are important aspects of the ecological integrity of a stream ecosystem. Aquatic species - as especially well studied for fishes and macroinvertebrates - vary in their roles in the aquatic food web and in their sensitivity to different stresses such as alterations to stream hydrology, habitat quality, water quality, and nutrient inputs. Alterations in the taxonomic and functional composition of the aquatic faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the aquatic ecosystem. Indices at the high end of the range will be treated as supporting ecological status whereas lower values will reduce status. The Nature Conservancy conducted a comprehensive freshwater assessment for the entire state of Arizona (Turner and List 2007). This data includes a native fish index and other direct measures of biotic health. This data set is extensive for perennial streams in Arizona and has a good representation of reaches within the MAR. In addition the Arizona Department of Environmental Quality has a Stream Ecosystem Monitoring protocol (AZDEQ 2012) and database (AZDEQ 2013) with field data and calculated indices from 2005-2012. The AZDEQ protocol and database includes macroinvertebrate indices. New Mexico does not have any data like this, so perennial reaches in New Mexico will be a data gap for this type of data. Ephemeral reaches that are included in the distribution of CEs for this assessment will not have this type of data, and will be a data gap in the CE status assessment. For areas with a data gap, the lack of data will be noted but it will not affect the status results overall (i.e., lack of data will not lower the calculated status).

Scenario Inputs

- Presence of indicator fish species (by name; Turner and List 2007)
- Native fish index (count of species by reach; Turner and List 2007)
- Endangered species index (count of number of listed of all types: birds, plants etc.)
- Macroinvertebrate index (ratio of native invertebrates observed vs. expected; AZDEQ 2012, 2013)

Habitat Quality Status Scenario. This scenario is proposed to represent several aspects of abiotic condition as measured by indicators of water quality, channel stream bed and bank stability, and degree of vegetation coverage. The chemistry of the water flowing into and through riparian and stream habitat strongly determines which plant and animal species can persist in these habitats through their requirements for, or tolerances of, different soil and stream water chemistries. Stream fauna, for example, vary in their requirements for, or tolerances of, variation in salinity, dissolved oxygen, temperature, turbidity, and the presence/absence of different dissolved and suspended matter including anthropogenic pollutants. State fish consumption advisories reflect the amount of mercury found in fish and are a measure of water chemistry. The Stream Ecosystem Monitoring protocol and database (AZDEQ 2012, 2013) includes several measures of aquatic habitat condition, including channel stability evaluations, Proper Functioning Condition (PFC) assessment (USDI BLM 1994) which measures the amount of vegetative cover along the channel, and an aquatic habitat assessment. Channel and floodplain geomorphology, shaped by watershed runoff (sediment and water) and surface flows in the stream, create the habitat conditions for both riparian and stream flora and fauna. Altered channel substrate and geomorphology strongly affect aquatic faunal assemblage composition and complexity and both stream-floodplain and surface-groundwater interactions along riparian corridors. Proper Functioning Condition Assessment (USDI BLM 1994) is an estimate of resiliency that will allow a riparian-wetland area to resist alteration of vegetation and streambank stability during high-flow events with a high degree of reliability. Data for indirect measures of water quality and direct measures of channel and riparian health are as follows:

Scenario Inputs

- State fish consumption advisories (mercury)
- Modified Pfankuch Channel Stability evaluation (AZDEQ 2012)

- Proper Functioning Condition (PFC) assessment (AZDEQ 2012)
- Aquatic Habitat Assessment (AZDEQ 2012)

Analytical Process Description

The Vista Scenario Generation function was described in section 2.1. This set of scenario process models also contains several embedded processes needed to convert source data inputs to forms suitable for input to the Vista scenarios. Following are descriptions of those processes (process model diagrams provided where needed) organized by scenario type:

<u>Development Status Scenario Indices</u>

- Road crossings per CE stream mile will be calculated and attributed to the CE buffer polygon
- Road miles per square mile of playa will be calculated and attributed to playa CE polygons
- Dams per CE stream mile will be calculated and attributed to the CE buffer polygon

<u>Water Use Status Scenario Indices</u>

- Surface & groundwater use: water use volume by groundwater basin will be normalized as volume of water use per capita. Groundwater basin refers to the groundwater basins defined by the Arizona Department of Water Resources (AZDWR 2011). The data are water use volume by use type (agricultural, urban, etc.). For New Mexico the data are by county (Longworth et al. 2008).
- Dams point locations will be intersected with HUCs and converted to count per groundwater basin for AZ and by county for NM.

<u>Habitat Quality Status Scenario Indices</u>

Scoring of the below indices will be normalized to 0-1, where 0 indicates the highest departure from undisturbed, highly functioning CE and 1 indicates best quality.

- State fish consumption advisories (mercury)
- Modified Pfankuch Channel Stability evaluation for perennial reach sample points (AZDEQ 2012)
- Proper Functioning Condition (PFC) evaluation for perennial reach sample points (AZDEQ 2012)
- Aquatic Habitat Assessment evaluation for perennial reach sample points (AZDEQ 2012)

Outputs

Outputs are multiple scenarios oriented to the aquatic CEs' KEAs. Each scenario is a stack of raster layers (when there are overlapping CAs) that are attributed with the specific CA present in each pixel to accommodate cumulative effects of multiple CAs in the same location. Additionally, Vista generates a report for each scenario with the area of each CA in the region.

Issues or Limitations

The assessment will rely on data on water use to assess hydrologic condition, and data on fish advisories to assess water quality, and direct measurements of channel stability and riparian evaluations for habitat quality. The reliance on indirect indicators, as noted earlier, arises because direct data on hydrologic condition and water quality are not comprehensively available for the aquatic CEs across the entire ecoregion. Examples of direct data not comprehensively available include stream gage records, measurements of depth to alluvial and underlying basin-fill groundwater, and measurements of a range of water quality parameters across a range of flow conditions (e.g., during baseflow, summer storm runoff, winter storm runoff). Such data are available for only a small number of CE occurrences, sampling sites, and sampling dates in the ecoregion. Relying on indirect indicators, while necessary, carries its own limitations. Specifically, data on water use provide information bearing on the overall depletion of water availability within a watershed – both surface and groundwater – but not on the details of how water use has altered the “hydrologic regime.” The hydrologic regime of a water body consists of the annual and inter-annual pattern of variation in how much water is present in or flowing through a CE, at what times of the year and for what duration – the variables to which aquatic biological dynamics directly respond. Further, other factors also affect the hydrologic regime, including unique geologic conditions at, and upstream from, a CE occurrence, as well as active in-stream water rights. Finally, data on water use integrated at the scale of HUCs may over- or under-estimate the impact of water use on the hydrologic regime of a CE, depending on where the CE occurrence is located within the watershed. These issues notwithstanding, however, data on water use provide a well-established method for assessing the likelihood of hydrologic alteration at a landscape scale, especially when supplemented with data on landscape surface condition itself, as represented here by the Landscape Condition Scenario. A similar reasoning applies to the assessment of water quality. The habitat quality data are direct field based measures, so these are high quality, high accuracy data, but limited in scope relative to the scale of the ecoregional assessment.

2.1.4 Future Scenario Generation Process Model (all CEs)

The REA also calls for assessing status for the future time period of 2025. Note that the 2060 scenario will only address climate change which is described under the climate change assessments later in this document (section 4). Following is a generic diagram and description of the process model that is used to generate the 2025 scenario by updating the current scenarios with data that maps changes (typically expansions or intensification) of CAs. The results of data assessment indicated that insufficient data exists to create a complete analog of the current scenarios for the 2025 timeframe. During Phase II Task 3, web meeting discussion will be conducted to determine if any 2025 status assessments should be conducted or the acquired 2025 CA maps will be provided as “risk maps.” See the Limitations section below for specific data gaps.

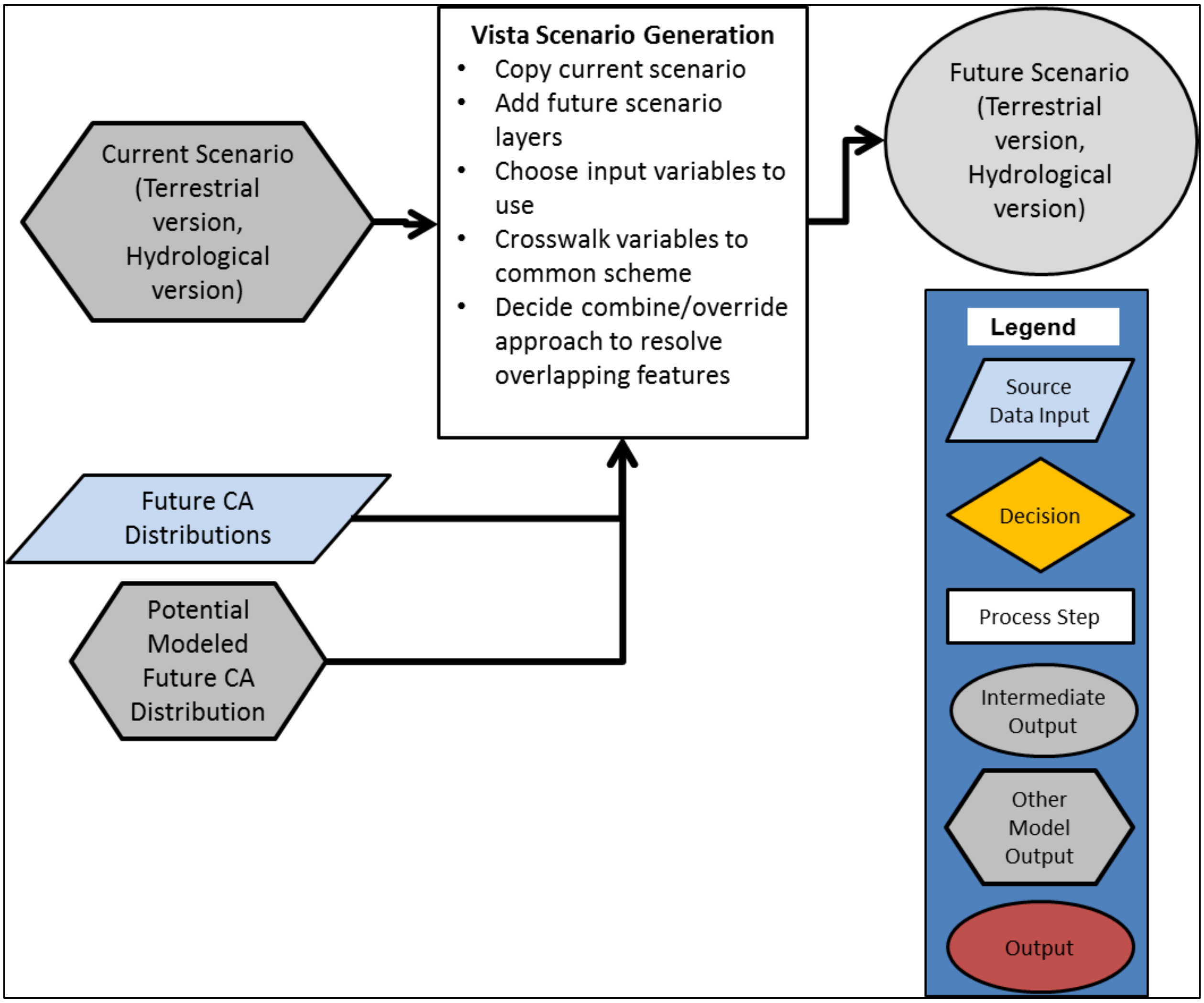

Figure 2-5. Future Scenario Generation Process Model. Current scenario inputs and the Vista Scenario Generation analytical process are described in the Current Scenario Generation Process Model. The output is an intermediate product.

Inputs

Because the future scenarios are cumulative with current features, the features in the current scenarios are carried forward into the 2025 scenarios. See the Current Scenario Generation Process Models (terrestrial ecosystem CEs, species CEs, and aquatic CEs) for the current features that will be included in the future scenarios. Few data sets were found to provide analogs to the features in the current scenario representing distribution by 2025. Following are available inputs, key gaps are noted under limitations.

- General:

- All status assessments depend on use of development CAs. Future development can be represented by urban expansion models and planned new transmission corridors; however, it is impossible to know or predict all of the potential development that may occur in the ecoregion. Future development is driven primarily by economic demand and is limited by policies and regulations and these are highly dynamic.

- Terrestrial Ecosystems Scenario
  - Future risk of invasive exotic herbaceous plants.
  - Future risk of expansion of mesquite for 2040 to 2069 time frame (see issues below).
- Species Scenario
  - See above list for the Terrestrial Ecosystems Scenarios.
- Aquatic Ecosystems Scenario
  - Input—assuming the data can be obtained, the Water Resources Development Commission (WRDC) assessed Arizona demand for water and supply available to meet those demands for the next 25, 50 and 100 years (AZDWR 2011). This would be a narrative, not a spatial assessment and would describe effects on the Arizona portion of the ecoregion, not individual CEs or watersheds.
  - Arizona Department of Water Resources (AZDWR). 2011. Water Resources Development Commission Final Report, Volume I. Arizona Department of Water Resources, Phoenix, Arizona, October 1, 2011. Online: http://www.azwater.gov/AzDWR/WaterManagement/WRDC_HB2661/Meetings_Schedule.htm.

Analytical Process Description

See the Current Scenario Generation Process Model for the processes used to generate the current scenario that will form the base for the future scenario. To update the current scenarios to 2025 generally requires the following operations:

- Replace current scenario feature with an input representing the future distribution. This is applicable to features that may have a different distribution from current such as a future expected fire regime or data inputs that are inclusive of the current CA distribution with expansion such as invasive species distribution models.
- Adding area to current features, such as with development features where all current features are expected to remain but new development is proposed or expected to be added.
- Overriding current features with new features where they overlap.

See the Current Scenario Generation Process Model for any generation required for current features that will be included in this scenario. In addition the following inputs require some level of modeling/data generation to be included:

- Terrestrial Ecosystems Scenario

    - Uncertain, until actual data inputs are found; at present only some future development features are known to be available; future exotics (poor quality dataset), and future mesquite expansion (see description of this input above, and limitations below) is for a different time frame, and a future fire risk dataset has not been found.
- Species Scenario
    - See the above list for the Terrestrial Ecosystems Scenarios
- Aquatic Ecosystems Scenario
    - Input—none, the future scenarios for water demand will be a narrative process. Not a spatial analysis.

Outputs

Outputs are per the Current Scenario Generation Process Model but areas of change in the CAs by 2025 override the current scenario.

Issues or Limitations

See the Current Scenario Generation Process Model for general limitations. Specific to the 2025 scenario the following issues and limitations have been identified:

- The inputs to a future scenario will vary in their certainty of occurring, some inputs represent fairly high confidence plans for new development while others represent modeled projections (e.g., potential urban growth).
- The following data gaps were identified that will prevent fully representing the same current scenario features in the 2025 scenario:
    - Terrestrial Ecosystems Scenario
        - Although ILAP does have modeled data for percent cover of exotic invasive herbs, they note it is a model with high uncertainty due to the lack of field-based input data for known locations of invasive plants. The ILAP effort then used this model to project expansion of exotic herbaceous species by decades out to 2060. Review of the dataset shows only one 5th level watershed in the entire MAR with ILAP projected expansion of these exotics. It is not a particularly useful model because of its very limited extent within the ecoregion, and that it is based on a model built upon very limited current locations of exotic plants. No other datasets for future risk of upland exotic invasives have been found.
        - For future fire risk there do not appear to be any datasets. The RMRS Fire Potential dataset is for potential fire risk based on the current conditions, not future; it is only appropriate for use in a very short-term time frame (~2 years from current). ILAP created one projection of risk of crown fires by decades to 2060, but only for the forests (equivalent to only one CE for the MAR).

        - Expansion of mesquite in the future could be represented by the bioclimate envelope model developed by the USGS. This bioclimate model is for the time interval of 2040-2069, a different time frame from the desired 2025 status scenario. It's not recommended to combine a 2040-2069 model with the 2025 scenario; the mesquite data could be provided as a "risk" layer for the 2060 timeframe but without any analysis.
    - Species Scenario
        - See the above list for the Terrestrial Ecosystems Scenarios
    - Aquatic Ecosystems Scenario
        - Input—No source data could be identified for 2025 representation of the current scenario features.

2.2 CA-CE Intersection

This process model describes an internal function within the Vista Scenario Evaluation (status assessment) that intersects the CAs in a scenario with the CE to attribute each pixel of the CE distribution with the CA that is present. This is the step that precedes calculating the CA effect on the CE. Unless a special assessment requires the results of this intersection, this only produces intermediate outputs used in the CE Status Assessment Process Model described later. Because this is the first model in which CE distributions are used, any geospatial processing of CE distribution inputs is described here.

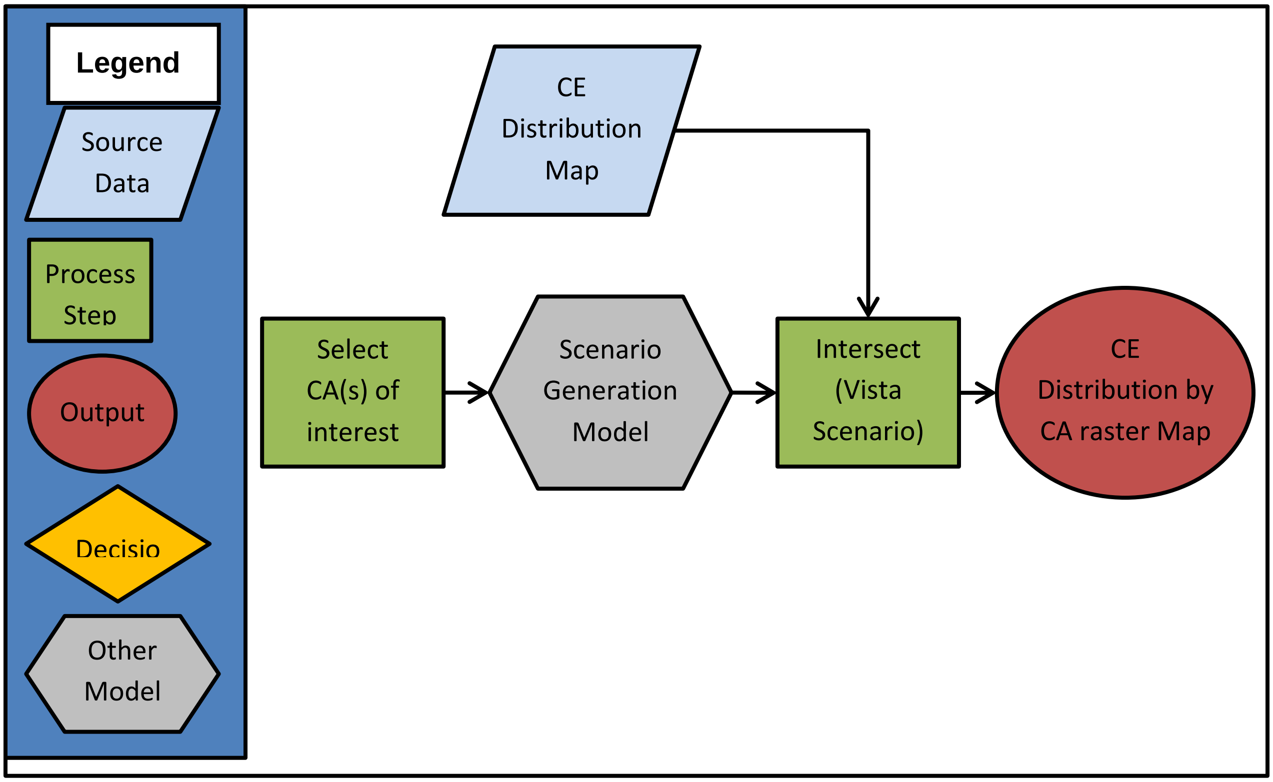

Figure 2-6. CA-CE Intersect Process Model.

This model describes how CEs are intersected with CAs which is accomplished by the Vista Scenario Evaluation function that utilizes outputs of the Scenario Generation Process Models and the CE Distribution Maps. The output is an intermediate product unless used as the primary product to answer an assessment question.

Inputs

- CE distribution maps (see below for any requiring modeling to generate a suitable input)
- Scenarios (see all Scenario Generation Process Models)

Analytical Process Description

The Vista Scenario Evaluation function conducts a GIS intersection between the selected scenario and the CE(s). Not every scenario described under the previous Scenario Generation Process Models will be analyzed for every CE. For example, Vegetation Composition scenario may not be as relevant for the Madrean Montane Conifer-Oak Woodlands, because neither mesquite nor the exotic grasses typically extend into these higher elevations.

CEs requiring modeling from source data to represent the CE in the status assessment (and special assessments) are described as follows:

Ecosystem CEs

Several of the ecosystem CEs will require some modifications to the existing source data. The primary source dataset for the ecosystems CEs (see exceptions below), will be the NatureServe terrestrial ecological systems map (NatureServe 2013), a 30m raster dataset based on SWReGap land cover mapping, and refined and modified by NatureServe ecologists over the past several years.

A. Riparian and Stream CEs

North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream CE: this CE is a combination of two ecological systems in the NatureServe Terrestrial Ecological Systems map, the North American Warm Desert Riparian Woodland and Shrubland (CES302.753) and the North American Warm Desert Riparian Mesquite Bosque (CES302.752). The raster distributions of these two ecological systems will be combined to create one distribution representing this CE.

A second step will require applying an elevation break to the distribution of this CE and to the North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream CE. The source data has these 2 ecological systems "leap-frogging" each other as elevation increases; in other words, the Lower Montane system is mapped as occurring in low elevation stream & river reaches immediately adjacent to the North American Warm Desert Riparian Woodland and Shrubland; and the latter ecological system is mapped as occurring in lower montane reaches. The elevation break that will be applied is 1200 m. All pixels of each CE incorrectly occurring above or below this break will be selected and recoded to the opposite CE.

A third step will require adding the "aquatic" component to each of these two riparian CEs. Because the associated rivers and streams are part of the concept for each CE, the NHD dataset will be used to add streams and rivers to the distribution, then buffered by 100 m on each side.

B. Playa and Cienega CEs

Playas: The source data for the distribution of the MAR playas is being extracted from a digital copy of a paper map from the Brown (1982) and Brown et al. (1980) reports. This is a polygon dataset, and the individual playa polygons will be selected from the shape file, and then be converted by Vista to 30m raster data. An additional step will require adding the playa distributions to the NatureServe terrestrial ecological systems dataset, which has no areas of playas mapped. This will eliminate incorrect ecosystem types from the playa footprints.

Cienegas and marshes: The source data for the CE was compiled by The Nature Conservancy of Arizona (but the data also include New Mexico). It contains points from a variety of sources including: known, extant cienegas located via GPS; known, extant cienegas located via heads-up digitizing by local experts; possible cienega locations digitized from paper maps by searching for place names with the word "cienega"; and historic locations of cienegas digitized from the figures in Hendrickson and Minckley (1984). Some filtering of the records in this dataset will be required, since some have high probability of error for the georeferencing, and others are historic, no longer occurring cienegas. An additional step will require buffering the points to a circle of approximately 30m diameter so that the locations will be retained once rasterized by the Vista tool.

C. Upland ecosystem CEs

Madrean Montane Conifer-Oak Forest and Woodland: This CE is a combination of several ecological systems in the NatureServe Terrestrial Ecological Systems map; it primarily includes the Madrean Lower Montane Pine-Oak Forest and Woodland (CES305.796) and the Madrean Upper Montane Conifer-Oak Forest and Woodland (CES305.798). Other ecological systems conceptually included but with very minor aerial extent are the Southern Rocky Mountain Ponderosa Pine Woodland (CES306.648), the Southern Rocky Mountain Ponderosa Pine Savanna (CES306.649), and the Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland (CES306.828). Pixels for each of these ecological systems will be selected and combined into one 30m raster distribution for the Madrean Montane Conifer-Oak Forest and Woodland CE.

Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE: source datasets are still being evaluated. If the NatureServe terrestrial ecological systems data is used, then the only processing step required will be to extract those pixels to create one 30m raster distribution for this CE. However, if the TNC grassland assessment dataset is used (Gori et al. 2012; a polygon dataset), then polygons will need to be selected from that dataset to represent this CE; then converted (by Vista) to 30m raster data. An additional step will require adding the new grassland CE distribution into the NatureServe terrestrial ecological systems dataset.

All other upland CEs will use the NatureServe terrestrial ecological systems dataset for distributions. Pixels for each will be selected and exported into a single 30m raster dataset for each CE. The data will need to be reprojected and then clipped to the MAR assessment boundary.

Species

Pronghorn: AZDGF and NMGFD will edge-match the AZ Habimap Pronghorn raster distribution data with the NMDGF CHAT Pronghorn polygon distribution data. The updated AZ Habimap Pronghorn raster distribution will be converted to a polygon dataset, re-projected to Albers/NAD83 and clipped to the final MAR study area boundary. The updated NMDGF CHAT Pronghorn polygon distribution dataset will be re-projected to Albers/NAD83 and clipped to the final MAR study area boundary. The resultant AZ and NM MAR Pronghorn polygon distribution datasets will be unioned together to merge the datasets.

Desert Bighorn Sheep: AZDGF will review their Bighorn Sheep Occupied Habitat polygon distribution dataset and attribute each polygon to a sub-species (e.g. Desert or Mountain). The updated AZDGF BigHorn Sheep Occupied Habitat polygon distribution dataset will be subset to include only Desert Bighorn Sheep polygons, re-projected to Albers/NAD83, and clipped to the final MAR study area boundary. The NMDGF CHAT Desert Bighorn Sheep polygon distribution dataset will be re-projected to

Albers/NAD83 and clipped to the final MAR study area boundary. The resultant AZ and NM MAR Desert Bighorn Sheep polygon distribution datasets will be unioned together to merge the datasets.

Coues White Tailed Deer: AZDGF and NMGFD will edge-match the AZ Habimap Coues White Tailed Deer raster distribution with the NMDGF Coues White Tail Deer polygon distribution. The updated AZ Habimap Coues White Tailed Deer raster distribution will be converted to a polygon dataset, re-projected to Albers/NAD83 and clipped to the final MAR study area boundary. The updated NMDGF Coues Whitetail Deer polygon distribution dataset will be re-projected to Albers/NAD83 and clipped to the final MAR study area boundary. The resultant AZ and NM MAR Coues White Tailed Deer polygon distribution datasets will be unioned to merge the datasets.

Black-Tailed Prairie Dog: If source data is available, AZDGF will expand their AZ Habimap Black-Tailed Prairie Dog raster distribution into NM within the MAR study area. The updated AZ/NM Habimap Black-Tailed Prairie Dog raster distribution will be converted to a polygon dataset, re-projected to Albers/NAD83, clipped to the MAR study area boundary, and unioned by itself.

Ornate Box Turtle: If source data is available, AZDGF will expand their AZ Habimap Ornate Box Turtle raster distribution into NM within the MAR study area. The updated AZ/NM Habimap Ornate Box Turtle raster distribution will be converted to a polygon dataset, re-projected to Albers/NAD83 and clipped to the MAR study area boundary, and unioned by itself.

Chiricahua Leopard Frog, Grassland Bird Assemblage and Nectar Feeding Bat Assemblage: distribution data require further review and the modeling work will be finalized, pending BLM review.

Outputs

Outputs are a raster map attributed with which CAs occur in each pixel of the CE. Note that this is an intermediate product that is not retained or delivered unless a specific assessment calls for this as a final deliverable product.

Issues or Limitations

Limitations are those described in the Scenario Generation Process Models

2.3 Status Calculation & Reporting

The status assessment process is depicted by the following two process models. Descriptions follow the diagrams for both process models as they are closely integrated.

2.3.1 CE Status Assessment & Reporting Process Models

This set of models includes the primary analytical model for calculating status and a model for summarizing results by reporting unit. The CE Status Assessment Process Model utilizes the outputs of the Scenario Generation Process Model and the CA-CE Intersect Process Models to apply the CE response models to the results of the CA-CE intersect, resulting in the status scores for each pixel of a CE. The Status by Reporting Unit Process Model calculates the CE average status by reporting unit and outputs a map of CE average status by reporting unit as well as generating frequency statistics of average status by reporting unit.

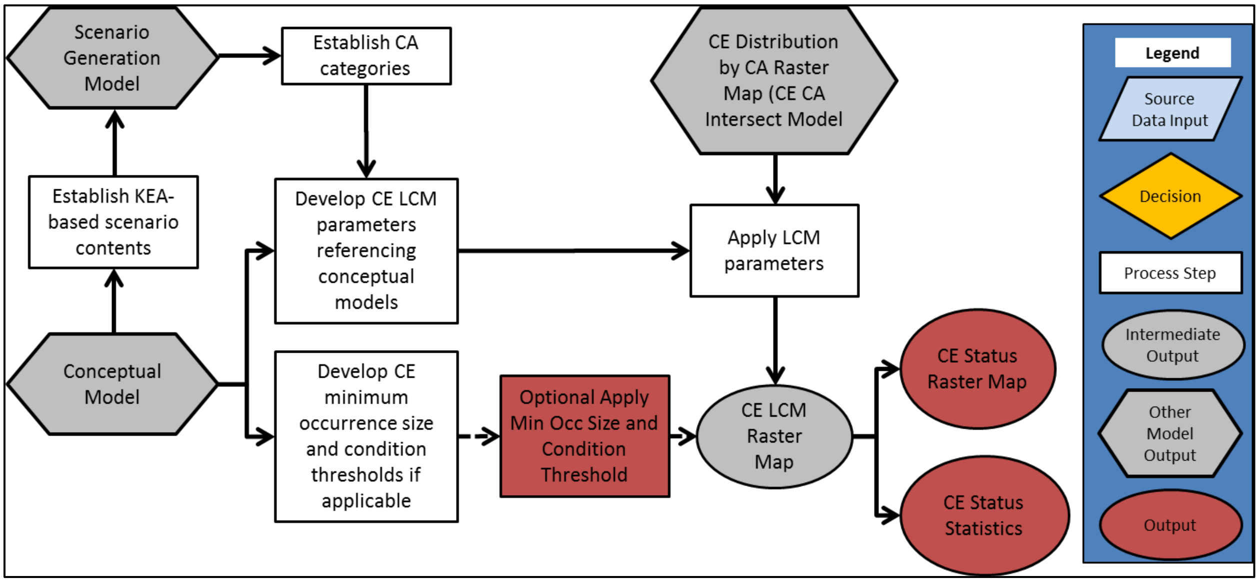

Figure 2-7. CE Status Assessment Process Model. This model integrates multiple other process models as indicated and is focused on the application of the Landscape Condition Model (LCM) to map and generate statistics on resulting CE status based on CA effects.

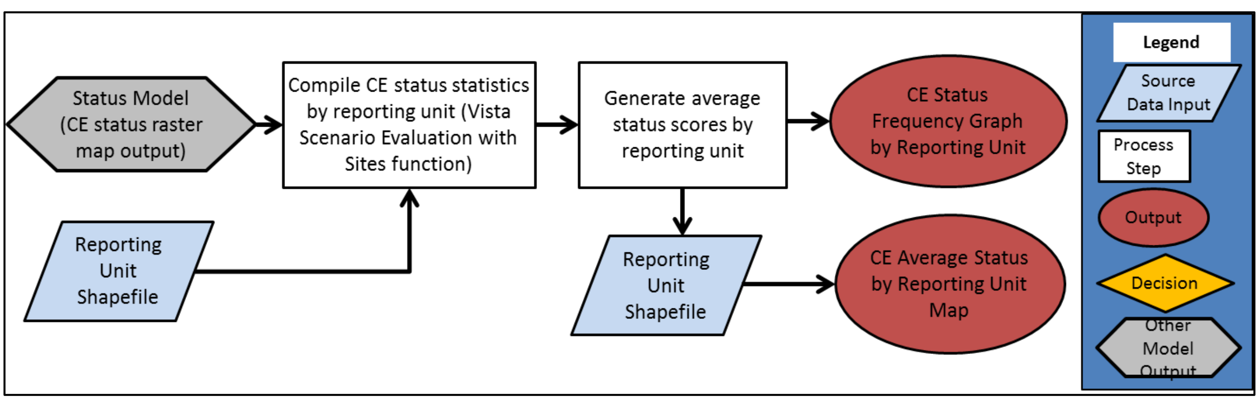

Figure 2-8. Status by Reporting Unit Process Model.

This model utilizes results from the CE Status Assessment Process Model to calculate status values frequency and average by reporting unit.

Inputs

- CE distribution maps
- CE responses to scenario features (0.0-1.0 impact weightings and, when appropriate, distances of effects in feet derived from CE conceptual models as feasible). These weightings are assigned by the project team CE specialists, drawing from the conceptual models.
- Scenarios (see Scenario Generation Process Models)
- A reporting unit polygon map (second process model)

Analytical Process Description

The CE conceptual model is used to establish the response of each CE to the individual CAs (Figure 2-9) as expressed in a particular scenario (see Scenario Generation Process Models). The CE responses are input to the Landscape Condition Model (LCM) in the form of an onsite impact weighting (0.0-1.0 scale) and, optionally, a distance over which the effect will extend (but gradually decline) beyond the CA's footprint (in feet or meters) (see output examples,

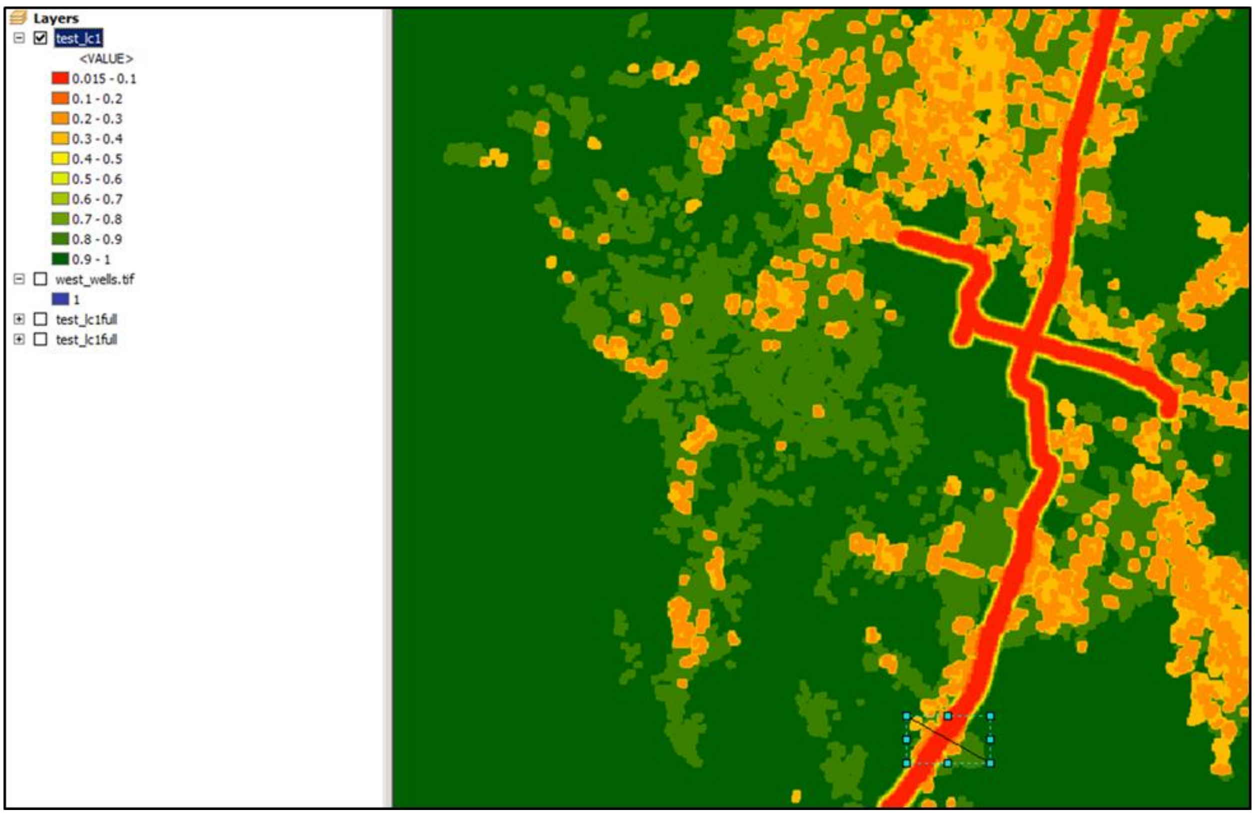

Figure 2-10 and Figure 2-11). Optionally, the CE Conceptual Model is also used (when relevant) to establish a minimum occurrence size for patches of the CE distribution that must be maintained in a viable condition (by setting a condition threshold, below which, any pixel will be considered non-viable). Such a condition threshold will be tested for the first CEs, then reviewed and discussed with the Tech Team during the thematic webinars. The LCM is applied in Vista through its Scenario Evaluation Function which incorporates the CE-CA Intersect Process Model. Details are provided in the Vista documentation but essentially the geospatial process entails:

- Utilizing the output of the CA-CE Intersect Process Model, apply the site impact weight to each pixel containing a CA according to the LCM weights specified for each CA.
- Applying a distance effect out from each pixel of each CA for the distance (in feet) specified. The distance effect is modeled according to a sigmoid curve (Figure 2-12) whereby the effect drops quickly at first and then more gradually until reaching zero effect at the specified distance according to the following formula:

$$1 / (1 + EXP(-2 * ((x(d/2))/(d * 0.25))))$$

*where x=distance from disturbance, d=decay distance threshold

- When multiple, overlapping CAs are included in a scenario, the scores for the corresponding pixels in each layer are then multiplied together to obtain the cumulative status score for each pixel (e.g., CA #1 causes a pixel score of 0.8 and CA #2 causes a pixel score of 0.6, the resulting cumulative status score for the pixel is 0.8 * 0.6 = 0.48 (Figure 2-11).
- The resulting ecoregion-wide raster status map is then clipped to the distribution patches of the CE of interest and, if applicable, the condition threshold is applied. Any pixels not meeting or exceeding the threshold are marked as non-viable. Non-viable pixels are subtracted from the patch and then the patch area is calculated. If a minimum occurrence size has been specified, any patches not meeting that size with the remaining viable pixels are marked as non-viable occurrences.
- For roll up to reporting units, the spatial results are then summarized to the reporting unit (e.g., 4km grid) by taking the average condition score from all the pixels of the CE within the reporting unit. This step is actually integrated in the processes above, but the reporting unit is specified at the start of the process. If a condition threshold is used to indicate non-viable pixels, this metric is reported by number of viable occurrences of the CE by reporting unit.

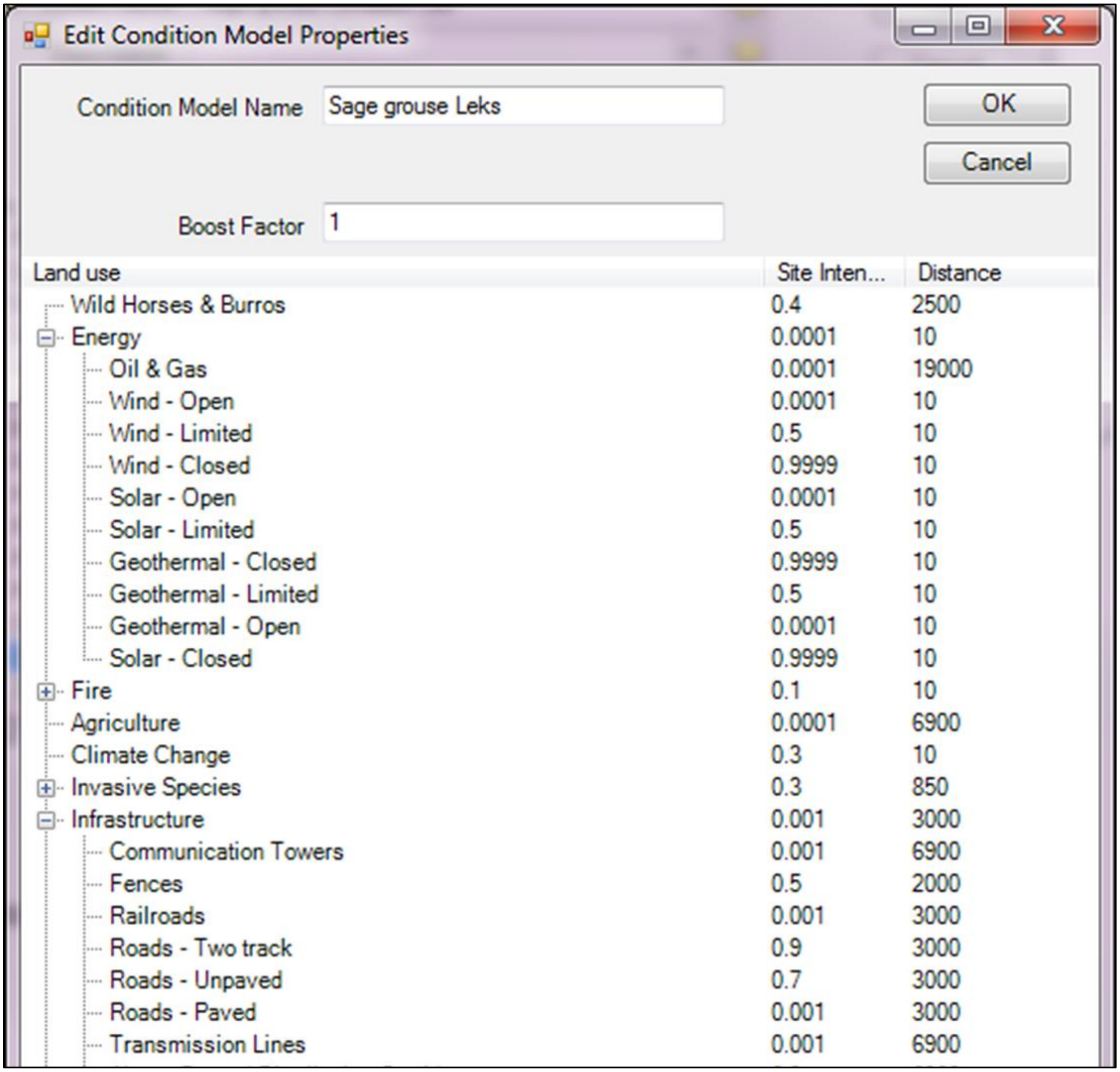

Figure 2-9. Example of partial CE response model.

For the specified CE (in this case sage grouse lek habitat) each CA is rated with a site intensity score that denotes the amount of habitat condition (on a 0.0 – 1.0 scale) that would remain and a distance (in this case feet) that the effect would extend out from the CA source. This response model is used to calculate status scores for pixels when applied to a scenario containing these CA features.

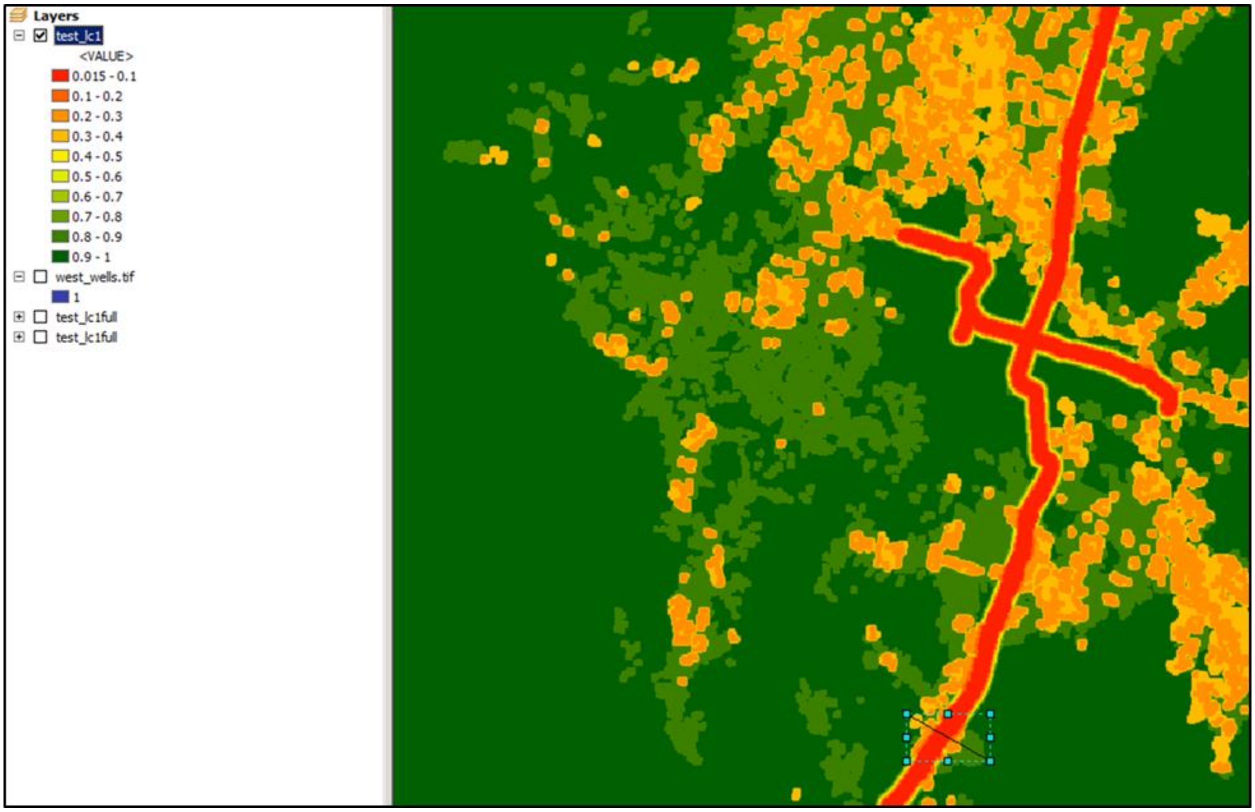

Figure 2-10. Output of a Landscape Condition Model.

Warm colors are areas of very low condition and cool colors are high condition. The transect line is illustrated in the cross section of condition values in the following figure.

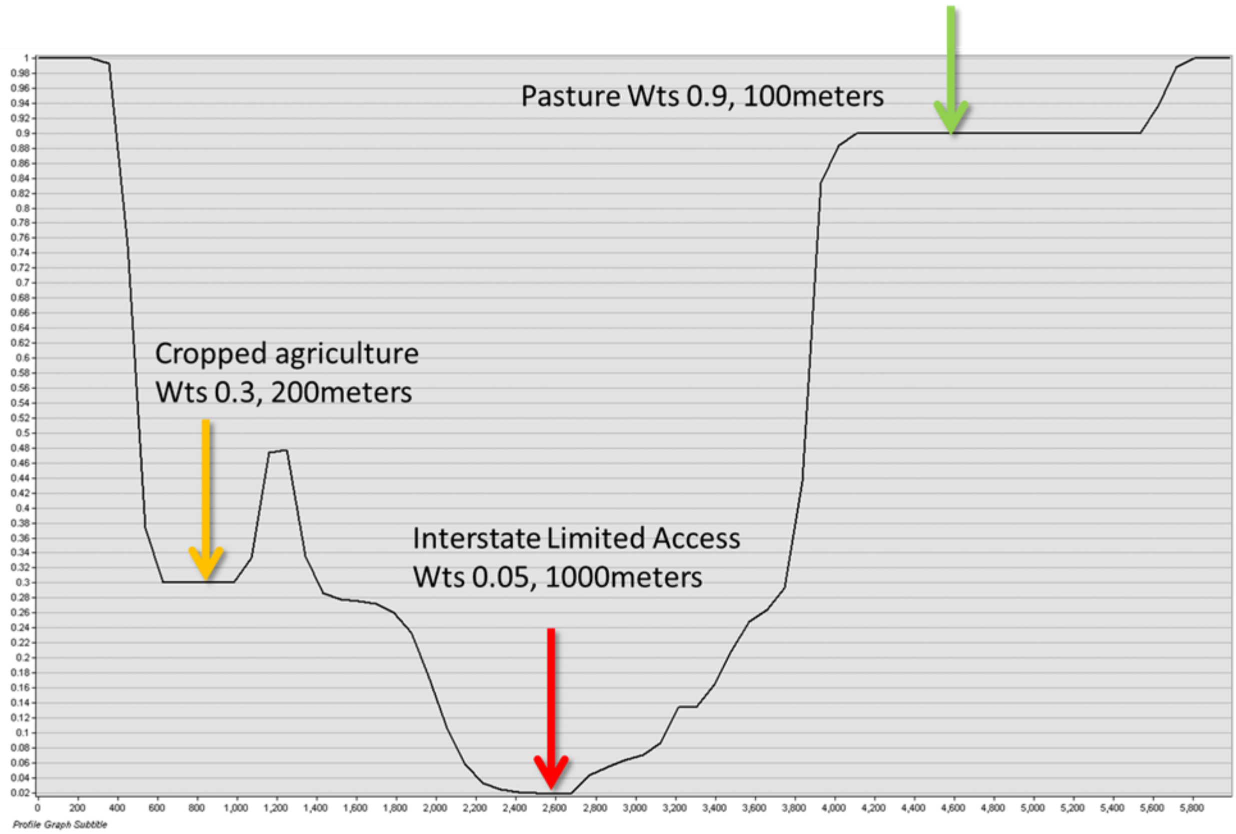

Figure 2-11. Graph of Landscape Condition Model values in cross section from previous figure. Note that the distance effects depress the condition value between the cropped agriculture and interstate.

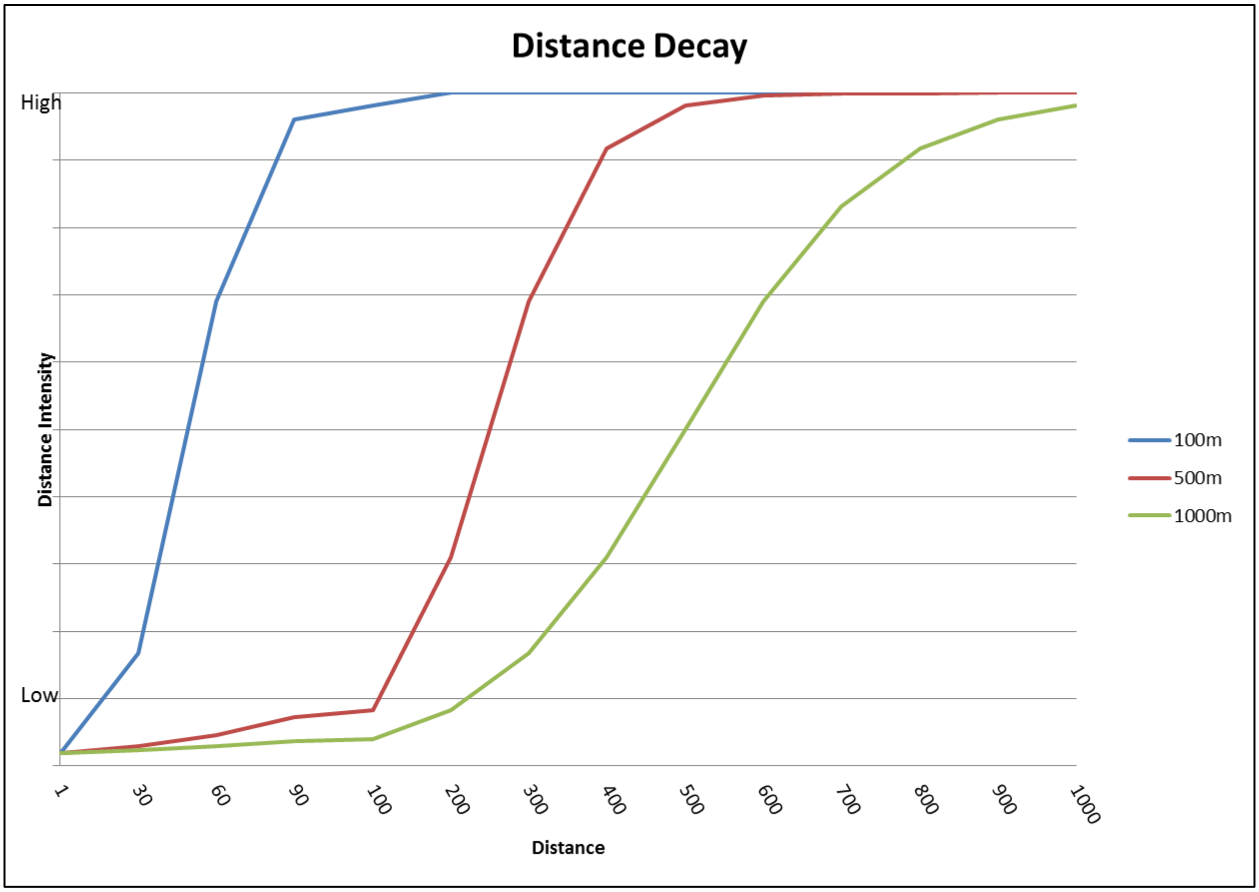

Figure 2-12. Graph of Landscape Condition Model sigmoid curves at three different distances indicating how a high intensity change agent (e.g., paved road) condition impact tapers off over the specified distance.

Outputs

Several outputs are created from the status assessment process:

- An LCM raster map for the CE distribution with resulting status scores (on a scale of 0.0-1.0) by pixel
- A raster map (when applicable) of the viable and non-viable occurrences (patches) of the CE based on a condition threshold and minimum occurrence size
- A reporting unit map of the average CE status score per unit.
- A Microsoft Access database of the status statistics by CE by reporting unit (second process model). These statistics include current area of the CE in the unit, average condition of the CE in the unit, viable occurrences and area of the CE in the unit (if condition threshold and minimum occurrence size are used).

Issues or Limitations

See other process models referenced in this diagram for their limitations. The LCM limitations include:

- The assignment of site intensity scores and distances are typically subjective as very little empirical study exists to define these values. However, the Vista LCM model allows easy changes to the site intensity scores and distances allowing for sensitivity testing as well as calibration based on observed condition.
- A technical limitation in the distance effect occurs when distance effects are short (i.e. similar to the cell size). In this case, the offsite effect will be negligible due to the threshold value of the decay function being reached within 1 or 2 pixels of the disturbance. The resulting curve will be more linear in nature.

3 Ecological Integrity

A standard approach for modeling ecological integrity has not been adopted for REAs and a variety of approaches have been used to date. The REA standards define Ecological Integrity "…as the ability of an ecological system to support and maintain a community of organisms that has species composition, diversity, and functional organization comparable to those of natural habitats with a region. Integrity also requires that an ecosystem's or species' dominant ecological characteristics occur within its natural [or acceptable] ranges of variation and can withstand and recover from most perturbations…."

After preliminary discussions with BLM, the following general process is proposed but an iterative and interactive approach will be needed to explore and communicate the process to the AMT during Phase II Task 3 to arrive at the final process that will result in a useful product. This approach is intended to provide wall-to-wall assessment of ecological integrity and thus is not a simple roll up of CE status assessment outputs (because the collection of CEs do not cover the entire ecoregion). In contrast to other approaches that use a single generic development impact model, the proposed approach generalizes and integrates the CE scenarios and responses in the model so that the integrity measures are ecologically meaningful to the categories of CEs while being generalized throughout the ecoregion.

Inputs

- NatureServe ecosystems map (the complete map, not the limited set of CEs)
- Landfire biophysical settings map (BpS) to represent the historic, potential distribution of the upland ecological systems (this is a dataset that approximates the distribution of ecological systems pre-European settlement under assumptions of a natural disturbance regime)
- Scenarios generated for terrestrial and aquatic CEs current conditions per those process models

Analytical Process Description

The first component conducts the status assessment of the uplands of the ecoregion using the following steps.

1. The uplands of the MAR will be divided into 3 "pseudo CEs" for assessment of ecological integrity (EI): montane uplands, valley uplands, and desert scrub via using the NatureServe terrestrial ecological systems dataset (comprehensive across the MAR) and selecting types to be grouped into each of the above categories.
2. The scenarios described above for terrestrial ecological systems (landscape condition, fire regime and composition) will be reviewed for any necessary changes to suit the EI model but otherwise will be used as-is.
3. The LCM response models developed for the component CEs will be reviewed and generalized for each of the pseudo CEs, e.g. the site impact and distance decay weights might be changed if appropriate from what was established for individual ecosystem CEs.
4. The three pseudo-CEs will then be assessed using the scenario generation and status assessment in Vista as described in those process models. This will output KEA scenario status rasters per the status assessment process model and will provide one set of measures of ecological integrity for uplands. Per the CE status assessment process model, a roll up scenario and status assessment can also be conducted.
5. Summarize by reporting unit per the reporting unit process model.
6. The final step of this component is to compare historic upland ecosystem composition with current ecosystem composition. Using the Landfire BpS to represent historic ecosystem distribution and the NatureServe map to represent current distribution, intersect the maps and compare the loss or expansion of each type. BpS methods are documented in Rollins et al. 2007. The comparison may be communicated through a chart that indicates the proportion of historic distribution still in the same type and then proportions of the historic distribution converted to other types (including non-natural types). This comparison will need to be done for some larger spatial landscape unit than the native resolution 30m pixels because of the nature of the BpS data. One possibility would be to use the USFS Ecomap subsections or 6th level watershed units.

The second component addresses the aquatic ecosystem integrity. The general approach is similar for terrestrial ecosystems but because the actual aquatic CEs for the MAR are very small and very limited in distribution, the pseudo CEs are the level 5 HUCs themselves using the assumption that there are, in actuality, aquatic CEs in every watershed and thus all watersheds should be assessed.

1. Select and modify as needed the aquatic CE scenarios for a generic aquatic CE. These are primarily the same scenarios used for the CEs without components specific to only 1 or 2 CEs. These will likely be the landscape condition, water use, and water quality scenarios with some adaptation for watershed-wide application.
2. Adapt/generalize the LCM response tables for the CEs within each category to develop those four higher level response models.

3. Run the status models per the general status assessment process model. Evaluating an integrated status assessment against all scenarios combined is also possible.
4. An historic to current comparison is not feasible with available data.

Issues

Some of the key issues regarding this approach include:

- The ability to relate the status measures with the Fundamentals of Rangeland Health, as defined by the BLM (USDI BLM 2006). That document was vague regarding landscape-scale indicators and approaches but a crosswalk will be attempted.
- Whether it is desirable and there is a feasible way to combine the terrestrial and aquatic integrity assessments into a single map product.
- Whether the two types of assessment (status measures and comparison of historic to current terrestrial ecosystem distribution) can or should be combined.

4 Special Assessments

This section outlines the process models for the pool of special assessments under consideration for this REA. Appendix B contains a table listing the special assessments and the AMT's preliminary prioritization rankings developed during the review of the REA Work Plan in late July of 2013.

4.1 Mesquite Special Assessment

Mesquite (both *Prosopis velutina* and *P. glandulosa*) has spread into many areas of the ecoregion, and in some locations has caused a complete type conversion from the natural ecosystems (primarily grasslands and some encinal) to mesquite scrub. According to the land cover mapping completed by SWReGap, the Mesquite Upland Scrub (as an invasive native shrubland) now covers some 19% of the ecoregion. This assessment seeks to identify areas of the MAR, currently invaded by mesquite in upland settings, where land managers might be able to remove or control mesquite and restore natural grasslands. In order to not limit the assessment to areas now dominated by mesquite (i.e. to identify other places with restoration potential), and to account for possible mapping errors in the Gap land cover data, the inputs to this assessment will include the historic distributions of both grasslands and encinal, as well as the current distribution of the Mesquite Upland Scrub. Scenarios will include the same landscape condition/patch size (using development features) scenario as used for the terrestrial ecosystem CEs. Other inputs to be used as filtering datasets will include soils data (to find areas of soils with characteristics suitable for supporting native grasslands), and data for both mesquite percent cover and locations of non-native grasses that could limit successful restoration.

Assessment Question: Where is mesquite restorable to grasslands (or other natural upland ecosystems)?

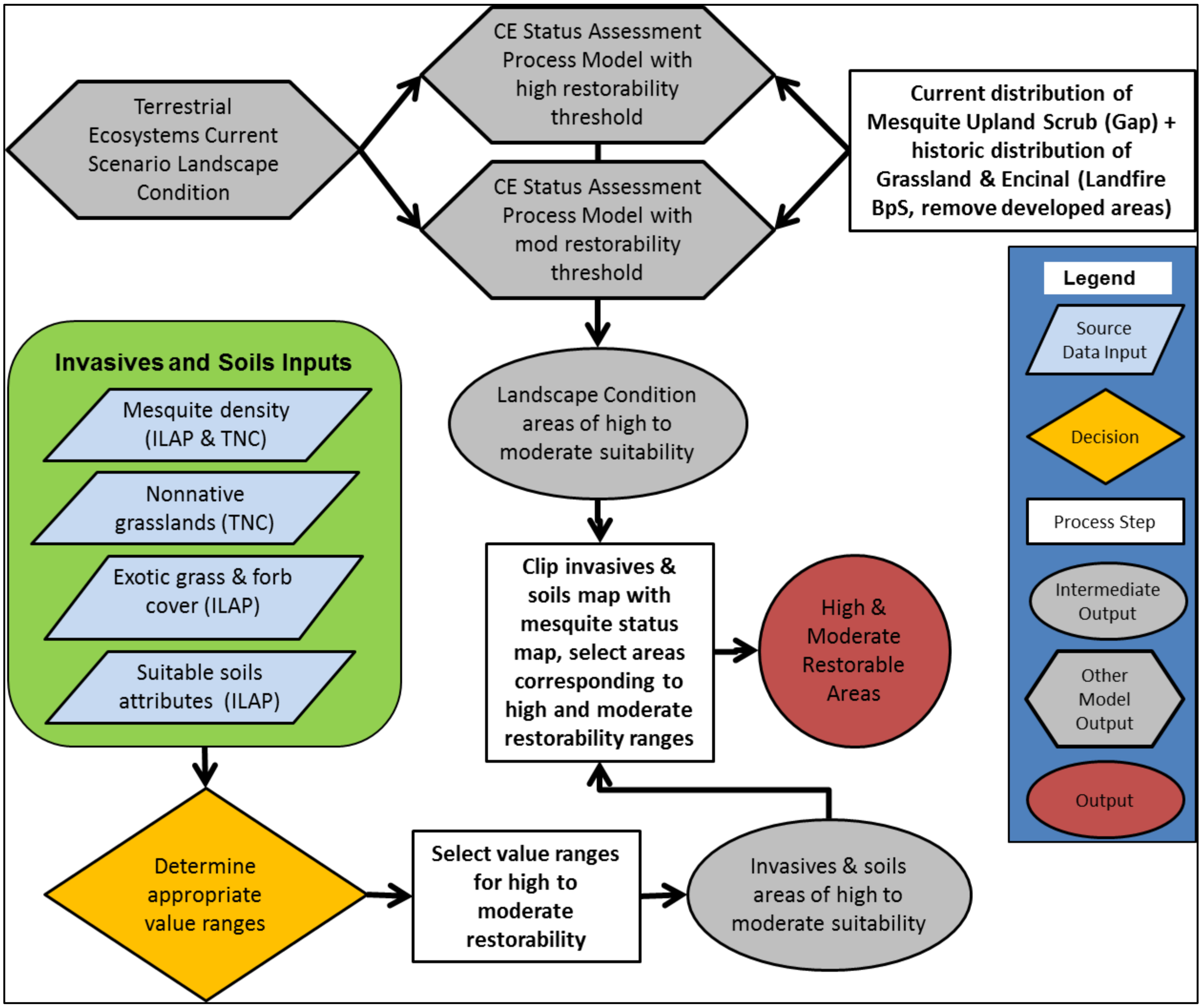

Figure 4-1. Mesquite Special Assessment Process Model. This model integrates the development of a "pseudo Mesquite CE" with the Landscape Condition scenario. These are then combined with inputs for the cover of mesquite and invasive exotic grasses, and soils with characteristics suitable for native grasslands, to identify areas with potential for restoration (reduction) of mesquite.

Inputs

- Mesquite Upland Scrub current distribution (from NatureServe ecological systems map)
- Historic distribution of grasslands and encinal woodlands (from Landfire BpS, possibly TNC grassland assessment historic grasslands)
- Percent cover of mesquite (ILAP) vegetation data: ILAP developed modeled data at 30m resolution representing the percent cover of mesquite; thresholds will be applied to break this continuous cover variable into categories.

- Percent cover of exotic herbaceous species (ILAP) vegetation data: ILAP developed modeled data at 30m resolution representing the percent cover of exotic invasive grass and forb species; thresholds will be applied to break this continuous cover variable into categories.
- The Nature Conservancy's Grassland Assessment: TNC developed expert-reviewed data that includes areas with various gradations of biotic condition, including natural native grasslands, shrub-invaded grasslands, grasslands converted to mesquite scrub with non-native understories, and converted entirely to non-native grasslands.
- ILAP soils dataset, queried for soils conducive to supporting native grasslands. SSURGO and STATSGO soils dataset compiled by ILAP. This dataset was completed for the entire MAR area; SSURGO spatial data were merged into a single coverage, and STATSGO spatial data were used to fill holes where SSURGO information was unavailable.

Landscape Condition & Patch Size Scenario. This scenario is proposed to represent the landscape context, and the effects of land use and development, which cause ecosystem fragmentation and interferes with landscape scale ecological processes. Areas of mesquite scrub in the vicinity of significant development are less likely to be restorable to other natural ecosystems.

- All development change agents. This is an extensive list; please see Appendix A.

Analytical Process Description

The distribution of Mesquite Upland Scrub and the historic distributions of the grasslands and encinal will be combined into one "CE distribution" dataset for use in this assessment. This will then be input to the landscape condition/patch size scenario, as done for all other CEs. The LCM output will be filtered to select areas meeting "suitable condition for restoration" values. Areas with high to moderate status scores, equating to good ecological condition relevant to development, will be selected. ILAP data for cover of mesquite and invasive exotic grasses will be queried to select areas with low to moderate cover of each, utilizing thresholds identified in the mesquite conceptual model. In addition the TNC grassland assessment data will provide areas with low amounts of mesquite invasion. The TNC grassland data could also be used to map areas already converted to mesquite or nonnative grasslands that might meet good LCM/soils scores.

The ILAP soils data will be filtered to meet criteria for moderate to high suitability for native grasslands, and those areas selected. The soils data were converted by ILAP from the SSURGO or STATSGO polygons to 800m resolution grids and then attributes from the original polygon data were applied to the 800m pixels. The soils attributes from which "suitable soils" will be selected include: available water capacity, bulk density ,texture (clay, sand, silt and rock), Hydrologic Soil Group, depth to bedrock, drainage index potential (based on lithology), texture (clay, sand, and rock) by layer 0-50cm, 50-150cm, >150cm, and pH.

The suitable soils and low to moderate cover of mesquite & exotics areas will then be intersected with the previously selected areas of acceptable condition mesquite distribution, to identify locations of potential for restoration, categorized into 2 classes of high or moderate restoration potential.

Outputs

Locations for the combined mesquite/grassland/encinal CE with moderate to high status for landscape condition and suitable soils and low to moderate cover of mesquite and invasive exotic grasses. These can be categorized into either moderate restoration potential or high restoration potential.

Issues or Limitations

The soils data, while down-scaled to 800m resolution, are derived from relatively coarse soils polygons with soils characteristics derived from the original polygons. Small inclusions of different soils within those larger polygons will not be discernable in the data. Areas selected as having suitable soils will require field verification, or comparison to more thematically/spatially finer data such as form ESDs. Restoration of areas heavily invaded by mesquite or nonnative grasses will require field verification and assessment. This analysis can lead to general locations with potentially acceptable conditions. Other factors will influence restoration potential including land ownership and management patterns.

4.2 Water Resources Availability

Assessment Question: What is the current and projected availability of water resources in this ecoregion?

This assessment would focus on how water availability might change across the ecoregion, and how this might affect the water-dependent Conservation Elements of the ecoregion.

An assessment of “water availability” for the ecoregion would need to have two components: (1) some way to relate present water availability to the condition of the aquatic/wetland CE types; and (2) some way to assess how water availability might change in the future, over the timeframe of the REA, and how the changes might affect the ecoregion’s aquatic/wetland CE types. The REA already includes an assessment of the current condition (status) of the ecoregion’s aquatic/wetland CE types. This assessment includes a tabulation of current rates of water use (surface, groundwater; municipal, agricultural, industrial). The challenge is looking into the future. For this assessment, the contractor proposes to use and interpret data and information from an existing report (rather than conducting new geospatial analysis to address the question).

Approximately ninety percent of the MAR ecoregion lies within the State of Arizona. An appointed Water Resources Development Commission (WRDC) for the state recently completed a comprehensive assessment of water demand relative to in-state and out-of-state supplies for the entire state. The WRDC assessment provides “low” and “high” forecasts for demand for surface and groundwater in each groundwater basin of the state for 25, 50, and 100 years into the future (2035, 2060, and 2110). For reference, the map included at the bottom of this summary shows the state groundwater basins, followed by a map showing the Madrean ecoregional boundary (green outline) and county boundaries. The WRDC assessment takes into account population change and changes in types of demand. It does **not** directly assess the potential impacts of climate change. Instead, it assumed a decrease in baseline in-state surface water supplies of 5% by 2035 and 10% by 2060, with no further decrease through 2110. The latter forecast horizon exceeds the timeframe of the REA.

The MAR REA could provide a special assessment of water availability built on the findings of the Arizona WRDC report, using the following multi-part approach:

1. For the Arizona portion of the MAR, the team would compare water supplies and demand for the years 2001-2006 (the most recent years for which Arizona state data are available on supply and demand in a form appropriate for comparison to the WRDC report findings) with the forecasted demands for 2035 and 2060. The comparison would use tables, maps, and graphs: Based on the tabular data contained in the WRDC report, the team would create maps showing the groundwater basins as used by ADWR (or else 5th-level watersheds) illustrating intensity of water demand under the WRDC "low" and "high" scenarios for water demand (color-coded on a scale representing demand rate), and a similar set of maps illustrating change in demand to 2035 and to 2060.
2. For the New Mexico portion of the ecoregion, the team would address water demand in NM by locating comparable data sources, **or** by assuming that the rates of change in demand in the groundwater basins of NM that lie within the ecoregion are comparable to the rates forecasted by the Arizona WRDC for the adjacent groundwater basins in Arizona. The analysis team would consult with the USGS and the NM Office of the State Engineer to identify the best approach.
3. The team would provide a qualitative, narrative discussion of how the forecasted changes in water use potentially would affect aquatic/wetland CE types within the MAR ecoregion, based on the ways in which cumulative water demand (to 2006-2010) has affected these resources to date.

Caveats

- The spatial reporting units of the assessment would necessarily be those of the Arizona state groundwater basins and their NM equivalents. These could be converted to 5th-level watersheds (HUCs), if desired, by a VISTA scenario based on a HUC-groundwater basin overlay.

4.3 Climate Change and Watershed Hydrology

Assessment Question: How might forecast climate changes affect watershed hydrology?

This assessment would focus on the ways in which climate change could affect surface runoff, soil moisture, and groundwater recharge across the ecoregion, and how such changes might affect the water-dependent Conservation Elements of the ecoregion.

An assessment of "climate and hydrology" for the ecoregion would need to have three components:

- A way to assess forecasts of change in climate over the timeframe of the REA, focusing on climate variables that affect the hydrologic regimes of the water-dependent CE types;
- A way to assess how the changes in these climate variables might actually affect watershed hydrology; and
- A way to assess how these changes in watershed hydrology might affect the ecoregion's aquatic/wetland CE types.

The conceptual ecological model for each of the water-dependent Conservation Elements of the ecoregion – lower-elevation riparian/stream, montane riparian/stream, cienega, and playa/lake systems – provides the framework for addressing the last of these three components. The present document describes the proposed approach for addressing the first two components. This approach builds on the assessments of climate change already included in the REA: the assessments of climate-space trends and bioclimate envelopes.

Inputs

The following approach is proposed that combines information from three sources:

- The published literature on the potential impacts of climate change on water availability across the U.S. Southwest and/or the Colorado River Basin.
- The 4x4 km forecasts of climate change developed by Healy Hamilton and her team for the MAR, from the Climate Western North American (CWNA) climate assessment. These data would cover the entire MAR ecoregion, and will be summarized for two future time horizons: 2025 and 2060.
- The $1/8^{th}$-degree (~12x12 km) forecasts of climate change *and* hydrologic response developed by the "West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface Water Projections" project, also known as "BCSD3" (USBR 2011; http://www.usbr.gov/WaterSMART/docs/west-wide-climate-risk-assessments.pdf). These forecasts cover all of the MAR ecoregion (except possibly the small watersheds that drain southward into Mexico from extreme SE AZ and SW NM). Published reports summarize the forecasts for 2025, 2055, and 2080. Appendix C summarizes the data, methods, and types of outputs of the BCSD3.

The reasons for combining three sources of information are threefold:

- The published literature provides a strong foundation for interpreting forecasts, but not specific to the MAR ecoregion.
- The CWNA 4x4 km dataset will provide forecasts for six climate variables: average annual temperature; summer maximum temperature; winter minimum temperature; average annual precipitation; summer precipitation; and winter precipitation. The 4x4 km resolution allows the

ability to distinguish changes that take place at higher versus lower elevations. In the MAR, mountain-front recharge zones and higher-elevation zones receive the greater winter precipitation. Distinguishing these hydrologic zones is crucial, because the higher elevations are the source of the water that recharges the basin-fill aquifers and much of the water that recharges the alluvial aquifers as well; and these are key drivers of spring and riparian/stream baseflow hydrology. Runoff from winter and summer precipitation of course also drives the non-baseflow surface flow regimes of the riparian/stream and playa systems. It is proposed to summarize montane versus valley climate conditions within 5th level HUC, after first distinguishing the 4x4 km grid cells by montane versus valley location. However, the CWNA forecasts for the six available variables do not include either quantitative or qualitative estimates of watershed hydrologic response; and also do not include forecasts of evapotranspiration, snowpack/snowmelt, or soil moisture dynamics which may be crucial to watershed function in this ecoregion.

- The BCSD3 forecasts, used in the U.S. Bureau of Reclamation's Colorado River Basin Study (CRBS) includes the same six climate variables, plus estimates of runoff, evapotranspiration, snowpack/snowmelt, and soil moisture dynamics. The CRBS reports also provide a substantial, peer-reviewed discussion of the implications of its modeling results for the basin that includes almost all of the MAR ecoregion. Both the CWNA and BCSD3 outputs derive from the World Climate Research Programme's Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report. However, the BCSD3 forecasts have a coarser spatial resolution than the CWNA forecasts (and it is not yet known whether they cover the small southward-flowing watersheds along the US-Mexico border). The CWNA and CRBS datasets thus complement each other.

Analytical Process Description

The proposed approach would involve (roughly) the following steps:

1. Obtain data from the BCSD3 modeling study (see Appendix C), consisting of climate and watershed response data on a 12x12 km grid for the same emissions scenarios and projections used for the CWNA study; clip the BCSD3 data to the MAR assessment boundary; and tabulate change for the desired reporting periods (e.g., 2025 and 2060, to match the CWNA reporting).
2. Classify the CWNA 4x4 km grid cells as falling into one of two categories in each HUC: mountain-front recharge zones and the mountainous areas they surround versus lower elevations.
3. Tabulate the CWNA results for the six climate variables available, for the two zones in each HUC, for the two reporting periods: 2025 and 2060.
4. Compare the BCSD3 and CWNA results for 2025 and 2060.
5. Provide narrative interpretation and summary of these results, using the BCSD3 and CWNA forecasts together.

The BCSD3 data are available at:

http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#Welcome.

Outputs

See above process summary for preliminary description of outputs.

Issues or Limitations

4.4 Fire Regime Departure and Effect on CEs

Assessment Question: What watersheds harboring important aquatic ecosystems are threatened by un-natural, stand-replacing fire?

This assessment is a subset of possible assessments to understand the relationship between fire regime and other change agents. It focuses on the relationship of fire to erodible soils such that stand-replacing fire could lead to additional erosion and sedimentation that would affect aquatic CEs. Throughout much of the arid west, fire suppression has resulted in the accumulation of fuels which, in turn, has changed both the severity and intensity of wildfires that do occur. Terrestrial ecosystems that are highly departed from historical or natural fire regimes and occur on highly erodible soils, for example, will more likely result in massive post-fire erosion and associated sediment deposition within the watershed's riparian and other aquatic systems.

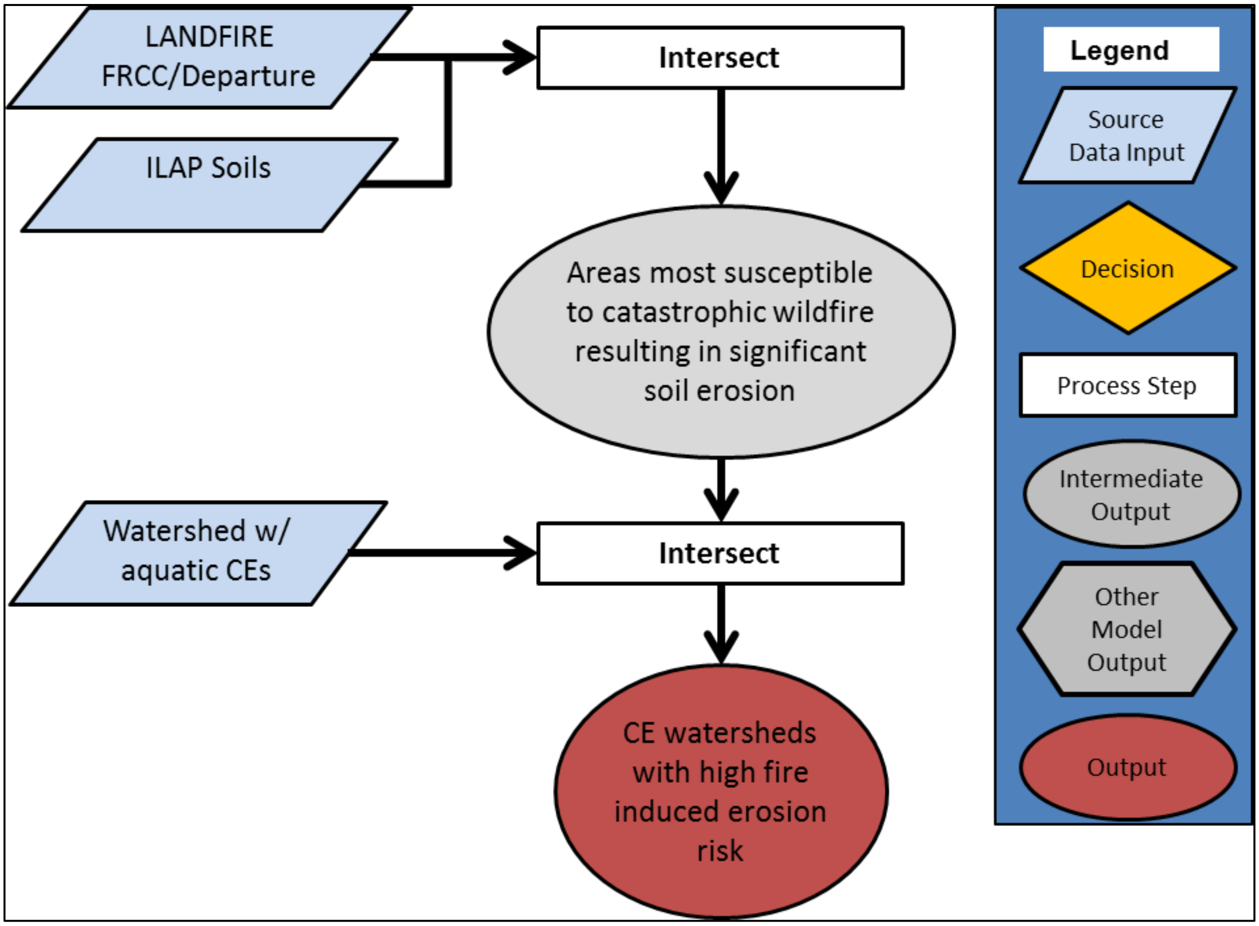

Figure 4-2. Fire Frequency and Intensity Effects Process Model.

Inputs

- LANDFIRE fire regime departure data and/or FRCC data
- MTBS data to look at fire regime over the past 40 years.
- Soils data: select/identify highly erodible soils at finest possible resolution (either ILAP compiled soils data, or SSURGO/STATSGO data).

Analytical Process Description

Fire regime departure data, as listed above, is proposed to be intersected with areas of highly erodible soils as shown in ILAP soils data (compiled or derived from STATSGO and SSURGO data) to identify those areas within the Madrean ecoregion likely to have the interactive effects of highly erodible soils and severe fire vulnerability. Next, watersheds will be selected that contain the aquatic CEs. The selected watersheds will be intersected with the fire/erosion risk map to depict those important watersheds threatened by un-natural high severity fires.

Outputs

1. Areas most susceptible to catastrophic wildfire resulting in significant soil erosion
2. Susceptible areas that have burned since 1980

Issues or Limitations

It is not clear whether the ILAP soils data on soil erodibility is at a fine enough resolution to be used at the sub-watershed level. It is assumed appropriate for analyses at the HUC-6 resolution. However, recent information from ILAP indicates that the “erosion potential” soil variable intended for use in this special assessment is not available outside of National Forest boundaries, and may only be completed for the Coronado NF in AZ and not in NM. Using the other ILAP compiled soils data is not feasible, as it only includes the standard attributes from SSURGO and STATSGO (e.g. depth, percent of the different texture classes). This would require complex modeling to derive some variable for “erosion potential” to use in this assessment; this is out of scope.

4.5 Fire and Invasive Grasses Impacts on CE Distribution

Assessment Question: Where are areas with potential for, or risk of, invasion of pyrogenic exotic invasive grasses and where have these grasses replaced native vegetation?

The introduction of pyrogenic grasses into the ecoregion has already resulted in significant changes to the distribution of many terrestrial CEs. Several of the terrestrial CEs have no history of fire because they never produced fuel loads sufficient to carry fire. Some of these systems are susceptible to invasion by exotic pyrogenic grasses that create a homogeneous layer of fine fuels. The resulting fires convert these non-fire-adapted communities into a monoculture of exotic grasses.

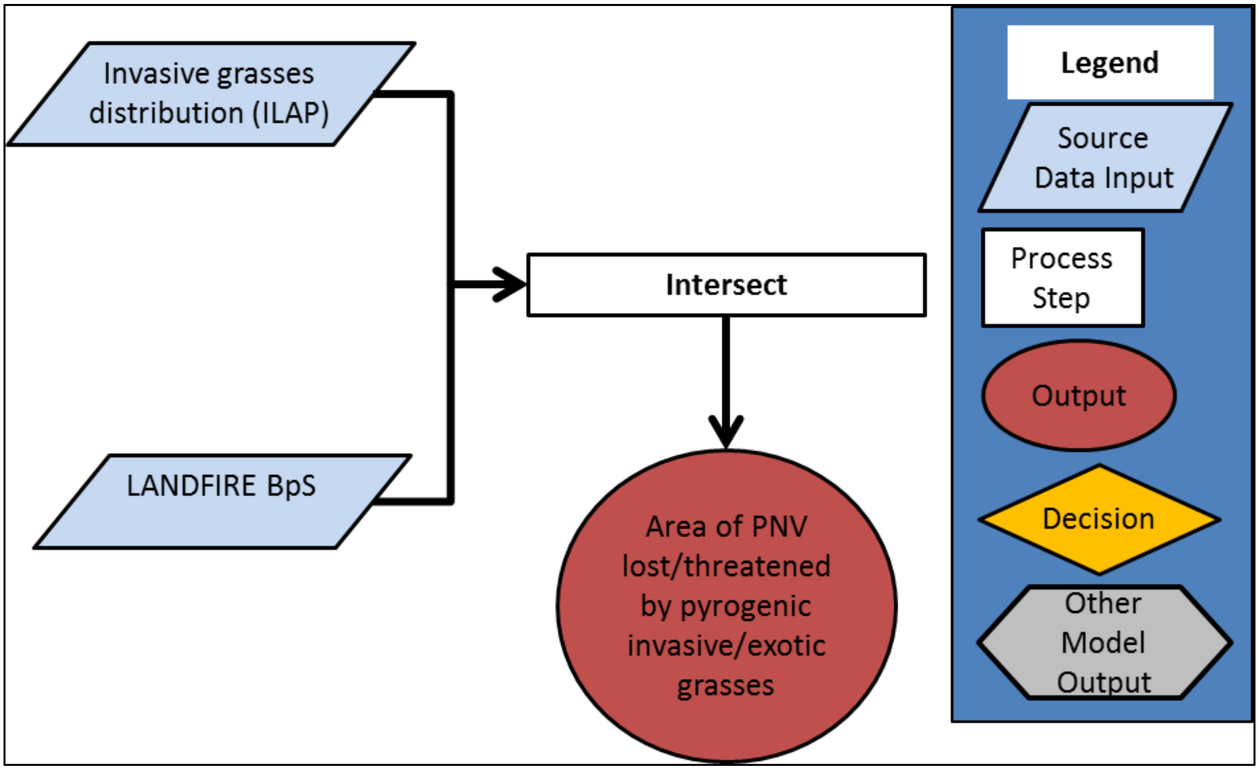

Figure 4-3. Fire and Invasive Grasses Process Model.

Inputs

- Invasive grasses distribution [ILAP still under investigation for suitability]: ILAP developed modeled data at 30m resolution representing the percent cover of exotic invasive grass and forb species; thresholds will be applied to break this continuous cover variable into categories.
- Nonnative grasslands (TNC grassland assessment); TNC identified area completely type converted to non-native grasslands.
- Potential Natural Vegetation (PNV) using the LANDFIRE BpS dataset

Analytical Process Description

First, the current distribution of the exotic grasslands will be intersected with Potential Natural Vegetation (using LANDFIRE Potential Natural Vegetation) to identify where and quantify how much of the native vegetation has been lost to these exotics.

Outputs

Map and areal statistics of native vegetation lost/threatened by invasive/exotic grasses and changes in fire regime

Issues or Limitations

Availability of existing data on distribution of invasive grasses is uncertain regarding the quality and applicability.

Source for PNV is still undecided.

4.6 *Climate Space Trends: Recent, 800-meter*

Assessment Question: What is the distribution and magnitude of climate change that has recently occurred in the Madrean Archipelago ecoregion?

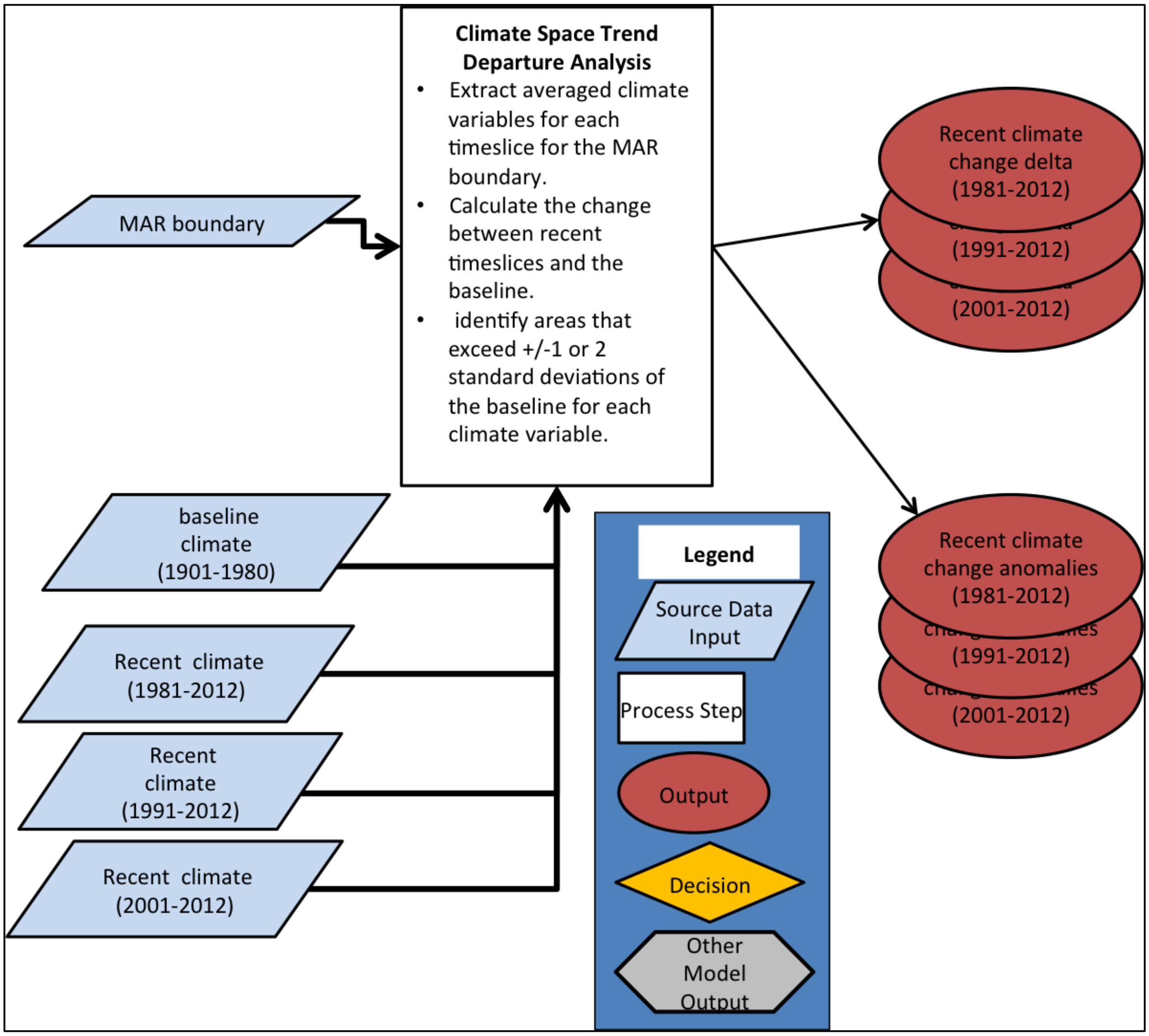

Figure 4-4. Recent Climate Space Trend Process Model. Analysis begins by clipping the extent of a suite of averaged climate variables to the Madrean Archipelago boundary and then calculating the difference and anomalies between recent and baseline time slices.

Inputs

1) PRISM 800m gridded climate surfaces of seasonal minimum temperature, seasonal maximum temperature, and monthly precipitation for average baseline time slice 1900-1980.
2) PRISM 800m gridded climate surfaces of seasonal minimum temperature, seasonal maximum temperature, and monthly precipitation for recent time slices: 1981-2012, 1991-2012, 2001-2012.
3) Madrean Archipelago geographic boundary.

Analytical Process Description

Conduct an analysis of current trends in climate space using the PRISM 800-meter spatial climate dataset.

1) Create a value representing the 20th century baseline and its standard deviation for each 800-meter pixel for each variable using the years 1901-1980.
2) Create averaged values for each variable based on 3 time slices representing recent trends: 1981-2011, 1991-2011, and 2001-2011.
3) Calculate the deltas (changes) between the recent time slices and the baseline climate per-pixel for each variable.
4) For each 30 yr, 20 yr, and 10 yr recent time slices, "anomalies," will be identified, defined here as pixels that exceed plus or minus one or two standard deviations of the baseline for a given variable.

Outputs

1) Rasters of the geographic distribution of deltas between recent and baseline for each variable for each time slice across the Madrean Archipelago ecoregion.
2) Binary rasters of the geographic distribution of anomalies (pixels that are +/- 1 or 2 standard deviations beyond the mean of the 80 year baseline) between recent and baseline for each variable for each time slice across the Madrean Archipelago ecoregion.

These comparisons between time slices representing current trends in values versus the 20th century baseline can help identify the magnitude, nature, and spatial distribution of change that has already occurred over this timeframe.

Issues or Limitations

PRISM is regarded as a highly sophisticated climate dataset and has been officially adopted by the U.S. Department of Agriculture, but it carries some degree of error and bias inherent to interpolation. PRISM's interpolated surface is based on historical weather station observations, which are biased toward areas of human settlement, low elevation, and easily accessible locations. Also interpolation of a climate surface can cause artifacts in the data because weather station data is not consistent through time. PRISM's algorithm also incorporates effects of topography on climate and while temperature reacts with topography in a more predictable manner, precipitation is much more unpredictable and an inherent weakness in all gridded climate datasets. Therefore results for trends in precipitation are less certain than those for temperature.

4.7 Climate Space Trends: Future, Added Variables, 4-km

Assessment Question: What is the projected distribution and magnitude of future climate change impacts for the Madrean Archipelago ecoregion?

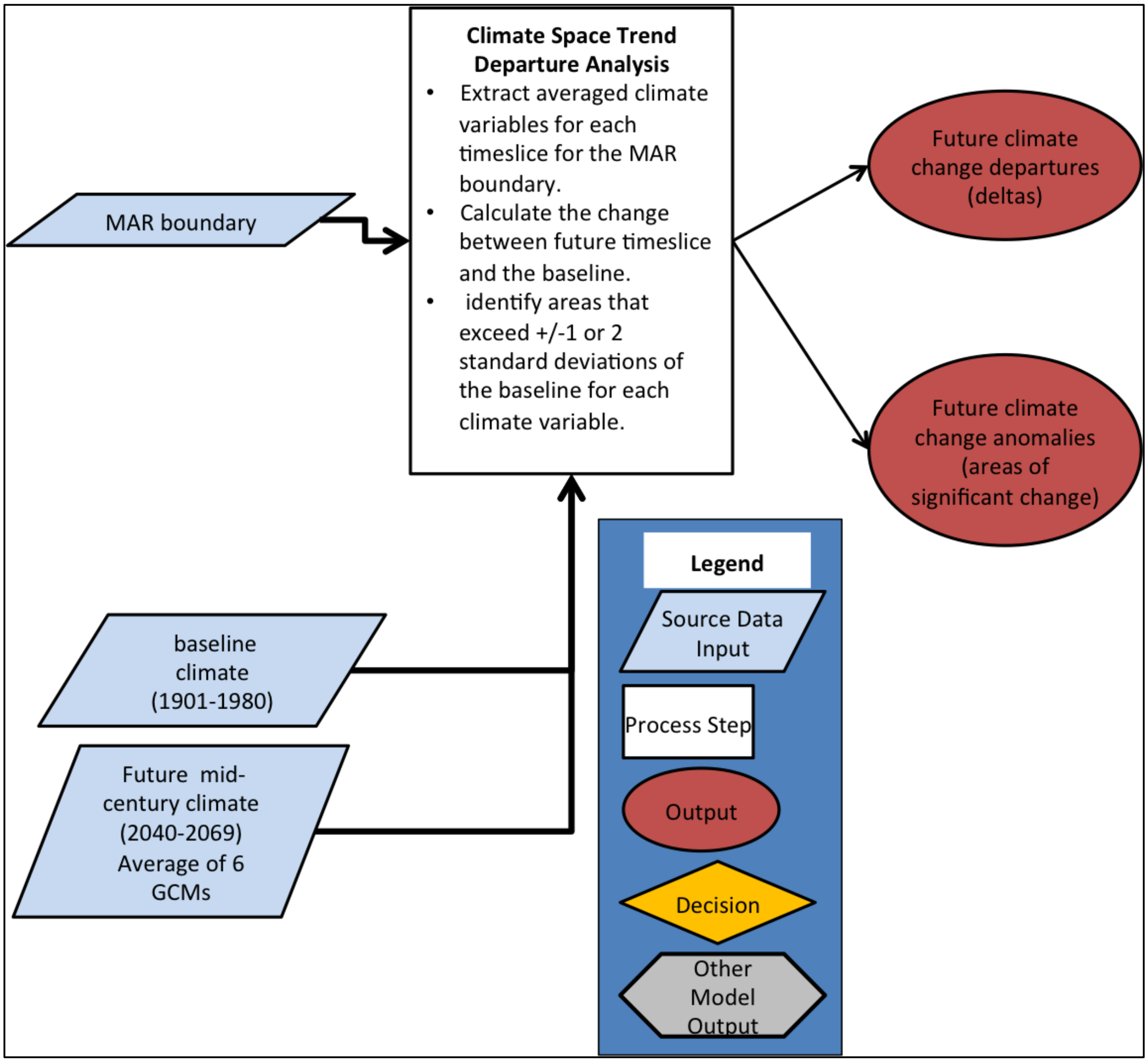

Figure 4-5. Future Climate Space Trends Process Model. This process begins by clipping the extent of a suite of averaged climate variables to the Madrean Archipelago boundary and then calculating the difference and anomalies between a projected mid-century future and a baseline.

Inputs

1) Current climate rasters for every year for each variable from 1900-1980 from the Climate Western North America dataset (Wang et al. 2012).
2) Mid Century projections from CWNA dataset (2040-2069).

Analytical Process Description

A series of per pixel analyses of trends in these basic variables will be conducted between a twentieth-century baseline and projected mid-century future conditions from an ensemble of future projections. A baseline value will be created for every 4-kilometer pixel in the REA assessment area for each of the five climate variables by averaging the years 1901-1980. In addition, the per-pixel standard deviation will be quantified across the 80-year baseline as a metric of natural climatic variability for each variable. Per-pixel value for the same variables will be created for the mid-21st century future (2040-2069). These values will be derived from averaging the six available future projections from the Climate Western North America dataset that have been run under the A2 emissions scenario.

Changes (deltas) between baseline and future climate will be calculated and the climate anomalies between the future and the baseline will be identified. The deltas represent the per pixel difference in the value of each variable between the mid-21st century future and the 20th century baseline. This analysis will identify the location of the pixels that are changing the most and those that are changing the least for each variable. The climate anomaly analysis compares the future value of each variable per pixel to the standard deviation of the baseline, to identify where future values are forecasted to exceed levels of natural climatic variability. For each variable, pixels will be identified where the future value exceeds plus or minus one or two standard deviations beyond the 20th century baseline. This analysis is intended to identify the nature, spatial distribution, and magnitude of projected climate changes that are exceeding the range of natural climatic variability to which native biodiversity is adapted.

Outputs

This assessment will produce the following datasets for the climate variables: seasonal minimum temperature, seasonal maximum temperature, monthly precipitation, and any additional variables provided by the Climate Western North America dataset requested by the AMT.

1) Rasters containing the per-pixel departure values (deltas) between the baseline and one future mid-century time slice (2040-2069, 6 projections averaged) for each variable.
2) Binary rasters of per-pixel climate anomalies (if a pixel is +/- 1 or 2 standard deviations from the mean of the baseline) for one future mid-century time slice (2040-2069, 6 projections averaged) for each variable

Issues or Limitations

Any effort to understand the impacts of future climate change on biodiversity requires outputs from global or regional climate models. Within each future emission scenario there are a wide range of models to choose from, which is why the ensemble method is applied that uses a suite of models outputs in the analysis. The ensemble method is an effective approach for some variables where models generally agree on the direction of change and only differ in magnitude. This method is more complicated for variables like precipitation where all models don't agree in the direction of change. The uncertainty and errors associated with this issue should be considered when creating and interpreting ensembles outputs for these variables.

For the future data the Climate Western North America dataset will be employed that has errors that were carried through previous source data. For some GCMs, some files were created using average temperature as a proxy for minimum and maximum temperatures. For GCMs with this error the following variables will contain incorrect results and should not be used: Monthly and seasonal min and max temperature (TMX*, TMN*, TMIN*, TMAX*); Number of frost-free days (NFFD); Extreme minimum temperature (EMT); Hargreaves reference evaporation, Hargreaves climatic moisture deficit (Eref, CMD). For these variables a subset of the GCMs must be chosen that uses actual maximum and minimum temperatures. For emission scenario A2 there are a total of 6 GCMs and a subset of 4 have correct minimum and maximum temperature values.

4.8 Bioclimate Envelope Modeling

Assessment Question: What are potential future climate impacts to species and vegetation assemblages of the Madrean Archipelago ecoregion?

The standard climate change CE assessment above provides a basic assessment of what climate change the CEs are forecast to experience within their current ranges. This assessment goes further by modeling the future distribution of the climatic conditions that occur across the current known range of a select set of CEs. While this assessment does not incorporate all relevant aspects of a CE niche, it does identify the spatial distribution of the regions of stability, contraction, and expansion in the climate envelope defined by the current distribution of a given CE.

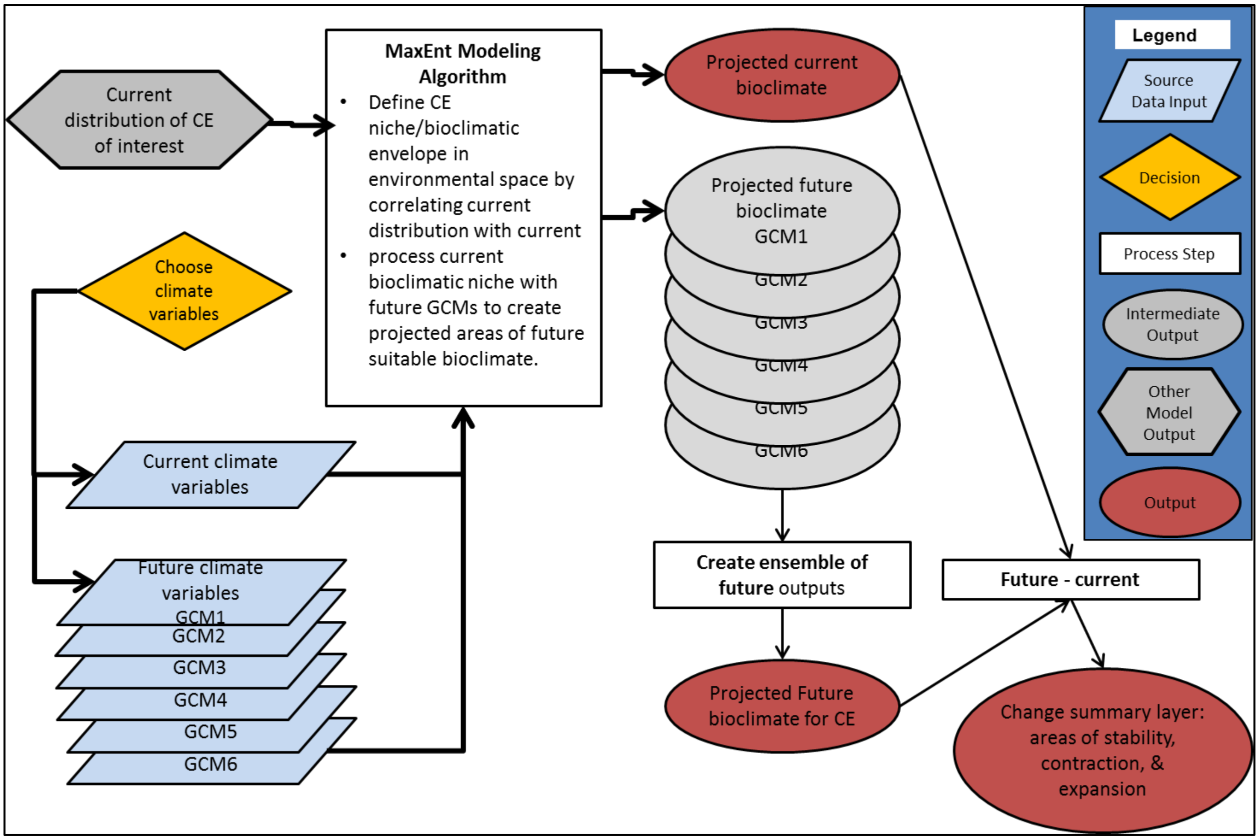

Figure 4-6. Bioclimate Envelope Process Model. This shows the MaxEnt modeling process of correlating climate variables with a distribution of a CE to define a bioclimate envelope for the current and future. This is done with multiple versions of the future for each GCM. Multiple future model outputs are then added to produce a map of model agreement for future distribution of suitable bioclimate for a CE. Finally, a summary layer is produced using the modeled current and future bioclimates to show areas of stability, contraction, and expansion.

Inputs

1) Current distribution of selected CEs
2) Baseline climate for CE of interest (ex: 1901-1980) averaged from the Climate Western North America dataset.
3) Future climate variables from the CWNA dataset: A2 scenario, 6 GCMs.

Analytical Process Description

1) Using digital distribution data for the CE of interest, spatial climate data from the current and from downscaled GCMs, and a species distribution modeling algorithm MaxEnt ((http://www.cs.princeton.edu/~schapire/maxent/), the current and future bioclimatic envelope for a given CE are modeled. All spatial climate data inputs will be from the CWNA dataset. The

defined current distribution for each CE will be used to create an appropriate temporal baseline of spatial climate data for input into the modeling effort.

2) Model the mid-century future distribution (2040-2069) of the current bioclimatic envelope for each CE based on each of the six available future projections in the CWNA dataset run under the A2 emission scenario. Thus each CE will have a current and six future modeled Bioclimate envelopes.
3) Aggregate the results across the six future bioclimatic envelope models per pixel, to identify which pixels have the highest and lowest degree of model agreement in the future distribution of suitable bioclimatic for that CE.
4) Create a binary presence-absence map from the ensemble of future modeled outputs and take the difference between projected future distribution and current distribution to create a change summary layer. This will show predicted areas of stability (current and future envelopes overlap), contraction (current envelope falling outside of future) and expansion (future envelope falling outside of current).

Outputs

1) Maps of modeled current bioclimatic envelope for each CE of interest.
2) Maps of modeled future projected bioclimatic envelope with degree of model agreement.
3) Summary maps representing the areas of stability, contraction, and expansion for each CE's bioclimatic envelope based on a threshold of model agreement.

Issues or Limitations

As with any model, the results of bioclimatic envelope modeling are only as good as the source inputs. The distribution of any given species or vegetation assemblage can rarely be assessed with complete confidence. When correlating environmental variables with CE distributions the accuracy of the output modeled niche depends on the accuracy of the input distribution. Issues like sample selection bias or data being falsely cut off by political boundaries (such as the Mexican border for the Madrean ecoregion) will affect the accuracy of the output bioclimatic envelope.

There are many additional factors that can affect the performance of niche models, including the quality and choice of inputs for climate and/or environmental variables, and the degree to which the chosen variables actually influence the distribution of the target CE. Niche models make several simplifying assumptions and appropriate climate variables must be carefully chosen that are relevant. It is also important to emphasize that niche models only produce a climatic niche. They do not account for the varying dispersal ability of different taxa, genetic or evolutionary adaptive potential across individuals or populations, and the influence of biotic or abiotic interactions.

Preliminary Prioritization of CEs Proposed for Bioclimate Envelope Modeling

A preliminary review of the full list of CEs for this REA with core BLM technical staff suggested an initial prioritization of CEs that should receive bioclimate envelope models (Table 4-1). Due to the nature of aquatic ecosystems and species that rely on them, aquatic CEs are not proposed for this type of bioclimate modeling. (Climate change effects on hydrology are included in a separate special assessment directed solely at that issue.) Up to four bioclimate envelopes can be completed by the contractor for the MAR REA. USGS completed bioclimate envelope models for 166 native plants; they are being explored for use to represent mesquite expansion. *Agave* spp. were not modeled by USGS, so if a bioclimate model for the bats is desired it will need to be done as one of the 4 CEs. A possible option for the bats would be for the NatureServe team to model agave spp., since they are they major food source for these bats. One consideration is that USGS modeling may have used a different set of GCMs than those that will be used by the NatureServe team.

Table 4-1. List of conservation elements recommended for bioclimate envelope modeling based on initial review with core BLM technical staff.

Conservation Element	Priority	New Bioclimate Model	USGS Bioclimate Model	Comments
Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	1	x	n/a	Will also represent the Grassland Bird assemblage and MAR distribution of pronghorn
Madrean Encinal	2	x	n/a	
Nectivorous Bats	3	x	n/a	USGS did not model species of agave, so a new bioclimate model for the bats would be required if this CE is one of the 4 selected. NatureServe could model agave spp. to represent the food source of the bats.
Chihuahuan Creosotebush Desert Scrub	4	x	n/a	USGS model for creosote bush as a species covers a much larger distribution than the concept of this MAR CE, so would not be recommended to use it to represent this one CE
Desert Bighorn	5	x	n/a	
Madrean Pinyon-Juniper Woodland	6	x	n/a	

Conservation Element	Priority	New Bioclimate Model	USGS Bioclimate Model	Comments
Mesquite upland scrub			Mesquite spp.	Will explore USGS model for mesquite as an answer to the "future expansion of native invasives" MQ

4.9 Climate Change Impacts on Grasslands and Grazing

Assessment Question: Where might climate change significantly affect grassland productivity, health? Where might grasslands not be restorable due to unfavorable climate? Where would climate changes affect grassland distribution?

This assessment is proposed to be addressed through bioclimate modeling of the grassland ecosystem CE (see the Bioclimate Envelope Modeling Process Model). The original management question was posed as "Where might climate change impacts on grassland ecosystems affect the ability to continue grazing?" The bioclimate envelope will indicate where future climate will no longer be within the known range of climate tolerance for the current grassland ecosystem and turnover to another ecosystem type might be anticipated.

Issues or Limitations

See the issues or limitations under the Bioclimate Envelope Modeling Process Model.

4.10 Connectivity: U.S. Only

Assessment Question: Where are areas of relative connectivity importance between the Sky Islands and what are current and expected (2025) impediments to connectivity? Note that this model is a preliminary draft pending further AMT discussion of desirable connectivity analyses.

The results of connectivity assessment are most useful when they address the movement needs of specific taxa as opposed to modeling of general connectivity/landscape permeability but the results will also be less generalizable. This assessment is proposed to address the potential movement needs of multiple species with a focus on meso and large carnivores that are sensitive to development. Some species, such as bear and cougar, will readily move through developed areas and while these may represent areas of increased mortality, modeling their connectivity will not be very information for landscape management. Modeling connectivity for species that tend to avoid developments will help identify existing or future "pinch points" that can suggest needs for avoiding additional connectivity impediments or removing existing impediments. A complete process model is pending further discussion of the desired outputs of such modeling as different approaches and models provide very different outputs that emphasize different aspects of connectivity. In lieu of providing a single process model in this draft, options are provided under Analytical Process Description for discussion and selection of the desired approach and outputs.

Inputs

Inputs depend on whether these assessments are being conducted for specific CEs or for general landscape indices of fragmentation and connectivity. Assuming both are required, the following inputs are needed:

- Footprints of each Sky Island as the connectivity targets
- A general land cover map containing natural and semi-natural land cover to represent the potential movement matrix
- Development CAs that can cause impedance to movement
- Additional inputs may be needed depending on the specific connectivity method and software employed

Analytical Process Description

Both options will model connectivity based on the current scenario and the 2025 scenario and compare the results to understand how changes by 2025 (primarily new development) may affect connectivity. Both options will use the same general inputs above and will generate a friction or impedance surface to movement that is parameterized with expected response of sensitive meso or large carnivores to movement relative to the development and land cover inputs. From there, the two options use very different concepts for modeling connectivity and have very different outputs.

<u>Option 1: Model relative connectivity importance</u>

This approach will utilize CAT or Circuitscape software to model the relative connectivity importance of each pixel between the Sky Islands. Areas calculated to have both a high degree of “flow” between the Sky Islands and are also constricted (pinch point) have very high values. Other areas that are not impeded can be important but because they are in areas with lots of optional connections, individual pixels tend not to have high relative scores. This approach does not produce recognizable corridors but is useful for understanding the relative importance of all areas for connectivity. Also, when alternative scenarios are assessed, changes in relative importance can be readily compared (e.g., are pinch points increased, reduced, shifted, etc.).

<u>Option 2: Model possible corridors between the Sky Islands</u>

This approach will utilize Corridor Designer or Linkage Mapper (or similar tool) to generate “least cost paths” or corridors among the Sky Islands. This approach produces visually satisfying and easily interpreted results but has a number of limitations explained below. When assessing the future scenario, changes in corridors can occur because of new impediments to connectivity. Most modeling tools will generate connections no matter how much impedance in the landscape but as corridors become increasingly circuitous, they become less biologically viable.

Option 3: Combined approach

Using the same inputs, it is technically feasible to use both approaches and produce both sets of outputs. This obviously increases the workload to prepare inputs in the tool-specific formats; run, review, and calibrate the models; and process deliverables so from an assessment trade-off standpoint it may not be feasible or desirable. Arizona has produced multiple linkages assessments, so for that part of the ecoregion (the majority) it may be sufficient to use existing products to represent specific corridors and only conduct Option 1 for the REA.

Outputs

Outputs will be specified after selection of the proposed approach and modeling software.

Issues or Limitations

The applicability of this assessment is limited to the taxa/landscape features used as targets for connectivity. There are a large number of issues and limitations in connectivity assessment. The more refined the desired result (e.g., specific connectivity corridors for a species) the less confidence there will be in the result owing to very limited understanding, data, and ability to model a species' connectivity requirements. The result is also not generalizable to other taxa and, therefore, other areas of connectivity importance may exist. Likewise, methods and models that produce very specific connection pathways will also have greater uncertainty that species will use that exact pathway whereas more general results (e.g., Circuitscape conductance surfaces) will provide less indication of specific areas or corridors.

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6 Glossary

Areas of Critical Environmental Concern (ACEC): Areas within the public lands where special management attention is required to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish and wildlife resources or other natural systems or processes, or to protect life and safety from natural hazards (FLPMA 1976).

Assessment Management Team (AMT): BLM's team of BLM staff and partners that provides overall guidance to the REA regarding ecoregional goals, resources of concern, conservation elements, change agents, management questions, tools, methodologies, models, and output work products. The team generally consists of BLM State Resources Branch Managers from the ecoregion, a POC, and a variety of agency partners depending on the ecoregion.

Attribute: A defined characteristic of a geographic feature or entity.

Change Agent (CA): An environmental phenomenon or human activity that can alter/influence the future status of resource condition. Some change agents (e.g., roads) are the result of direct human actions or influence. Others (e.g., climate change, wildland fire, or invasive species) may involve natural phenomena or be partially or indirectly related to human activities.

Coarse Filter: A focus of ecoregional analysis that is based upon conserving resource elements that occur at coarse scales, such as ecosystems, rather than upon finer scale elements, such as specific species. The concept behind a coarse filter approach is that preserving coarse-scale conservation elements will preserve elements occurring at finer spatial scales.

Community: Interacting assemblage of species that co-occur with some degree of predictability and consistency.

Conceptual Model: a diagram and written description that depicts conservation element status and the interactions between a conservation element, other renewable resources, and factors (change agents) that cause or restrict change in the conservation element. The ecoregion as a whole also has a conceptual model that describes the major ecosystems and drivers of ecological integrity.

Conservation Element (CE): A renewable resource object of high conservation interest often called a conservation target by others. For purposes of this TO, conservation elements will likely be types or categories of areas and/or resources including ecological communities or larger ecological assemblages.

Development: A type of change (change agent) resulting from urbanization, industrialization, transportation, mineral extraction, water development, or other non-agricultural/silvicultural human activities that occupy or fragment the landscape or that develops renewable or non-renewable resources.

Ecological Integrity / condition: The ability of an ecological system to support and maintain a community of organisms that have the species composition, diversity, and functional organization comparable to those of natural habitats within the ecoregion.

Ecological Status: The condition of a criterion (biological or socio-economic resource values or conditions) within a geographic area (e.g., watershed, grid). A rating (e.g., low, medium, or high) or ranking (numeric) is assigned to specific criteria to describe status. The rating or ranking will be relative, either to the historical range of variability for that criterion (e.g., a wildland fire regime criterion) or relative to a time period when the criterion did not exist (e.g., an external partnerships/collaboration criterion). (also see *Status)*

Ecoregion: An ecological region or ecoregion is defined as an area with relative homogeneity in ecosystems. Ecoregions depict areas within which the mosaic of ecosystem components (biotic and abiotic as well as terrestrial and aquatic) differs from those of adjacent regions (Omernik and Bailey 1997).

Ecosystem: The interactions of communities of native fish, wildlife, and plants with the abiotic or physical environment.

Element Occurrence: A term used by Natural Heritage Programs. An element occurrence generally delineates the location and extent of a species population or ecological community stand, and represents the geo-referenced biological feature that is of conservation or management interest. Element occurrences are documented by voucher specimens (where appropriate) or other forms of observations. A single element occurrence may be documented by multiple specimens or observations taken from different parts of the same population, or from the same population over multiple years.

Extent: The total area under consideration for an ecoregional assessment. For the BLM, this is a CEC Level III ecoregion or combination of several such ecoregions plus the buffer area surrounding the ecoregion. See *grain*.

Fine Filter: A focus of ecoregional analyses that is based upon conserving resource elements that occur at fine scale, such as specific species. A fine-filter approach is often used in conjunction with a coarse-filter approach (i.e., a coarse-filter/fine-filter framework) because coarse filters do not always capture some concerns, such as when a T&E species is a conservation element.

Fire Regime: Description of the patterns of fire occurrences, frequency, size, severity, and sometimes vegetation and fire effects as well, in a given area or ecosystem. A fire regime is a generalization based on fire histories at individual sites. Fire regimes can often be described as cycles because some parts of the histories usually get repeated, and the repetitions can be counted and measured, such as fire return interval (NWCG 2006).

Fragmentation: The process of dividing habitats into smaller and smaller units until their utility as habitat is lost.

Geographic Information System (GIS): A computer system designed to collect, manage, manipulate, analyze, and display spatially referenced data and associated attributes.

Grain: Grain is the native resolution of spatial datasets; for most source datasets used in REAs, such as species or ecosystem distributions, it will be a 30-meter raster. In some cases the grain or resolution may be 90-meter, or some other value divisible by 30 meters.

Grid Cell: When used in reference to raster data, a grid cell is equivalent to a pixel (also see *pixel*). When a raster data layer is converted to a vector format, the pixels may instead be referred to as grid cells.

Habitat: A place where an animal or plant normally lives for a substantial part of its life, often characterized by dominant plant forms and/or physical characteristics (BLM 1990).

Heritage: See *Natural Heritage Program.*

Heritage Program: See *Natural Heritage Program.*

Hydrologic Unit: An identified area of surface drainage within the U.S. system for cataloging drainage areas, which was developed in the mid-1970s under the sponsorship of the Water Resources Council and includes drainage-basin boundaries, codes, and names. The drainage areas are delineated to nest in a multilevel, hierarchical arrangement. The hydrologic unit hierarchical system has four levels and is the theoretical basis for further subdivisions that form the *watershed boundary dataset* 5th and 6th levels. (USGS 2009).

Indicator: Components of a system whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute (e.g., land health) that are too difficult, inconvenient, or expensive to measure (USDA et al. 2005).

Inductive Model: Geo-referenced observations (e.g., known observations of a given species) are combined with maps of potential explanatory variables (climate, elevation, landform, soil variables, etc.). Statistical relationships between dependent variables (observations) and independent explanatory variables are used to derive a new spatial model.

Invasive Species: Species that are not part of (if exotic non-natives), or are a minor component of (if native), an original community that have the potential to become a dominant or co-dominant species if their future establishment and growth are not actively controlled by management interventions, or that are classified as exotic or noxious under state or federal law. Species that become dominant for only one to several years (e.g. short-term response to drought or wildfire) are not invasives (Modified from BLM Handbook 1740-2, Integrated Vegetation Handbook).

Key Ecological Attribute (KEA): An attribute, feature, or process that defines and characterizes an ecological community or system or entity; in conjunction with other key ecological attributes, the condition or function of this attribute or process is considered critical to the integrity of the ecological community or system in question. In the BLM REAs, various analyses will be conducted to calculate scores or indexes indicating the status of key ecological attributes for various Conservation Elements (CEs).

Landscape Species: Biological species that use large, ecologically diverse areas and often have significant impacts on the structure and function of natural ecosystems (Redford et al. 2000).

Management Questions: Questions from decision-makers that usually identify problems and request how to fix or solve those problems.

Metadata: The description and documentation of the content, quality, condition, and other characteristics of geospatial data.

Model: Any representation, whether verbal, diagrammatic, or mathematical, of an object or phenomenon. Natural resource models typically characterize resource systems in terms of their status and change through time. Models imbed hypotheses about resource structures and functions, and they generate predictions about the effects of management actions. (Adaptive Management: DOI Technical Guide).

Native Plant and Animal Populations and Communities: Populations and communities of all species of plants and animals naturally occurring, other than as a result of an introduction, either presently or historically in an ecosystem (BLM Manual H-4180-1).

Native Species: Species that historically occurred or currently occur in a particular ecosystem and were not introduced (BLM 2007b).

Natural Community: An assemblage of organisms indigenous to an area that is characterized by distinct combinations of species occupying a common ecological zone and interacting with one another (BLM 2007b).

Natural Heritage Program: An agency or organization, usually based within a state or provincial natural resource agency, whose mission is to collect, document, and analyze data on the location and condition of biological and other natural features (such as geologic or aquatic features) of the state or province. These programs typically have particular responsibility for documenting **at-risk species and threatened ecosystems. (See natureserve.org/ for additional information on these programs.)**

NatureServe Vista: an extension to the Esri ArcGIS geospatial software available at www.natureserve.org/vista.

Observation scale: often referred to as sampling or measurement scale, is the scale at which sampling is undertaken. Note that once data are observed at a particular scale, that scale becomes the limit of analysis, not the phenomenon scale. ***Analysis*** or ***modeling scale*** refers to the resolution and extent in space and time of statistical analyses or simulation modeling. ***Policy scale*** is the scale at which policies are implemented and is influenced by social, political, and economic policies.

Occurrence: See *Element Occurrence*.

Pixel: A pixel is a cell or spatial unit comprising a raster data layer; within a single raster data layer, the pixels are consistently sized; a common pixel size is 30 x 30 meters square. Pixels are usually referenced in relation to spatial data that are in raster format. In this REA, some pixels sizes included 30 x 30 m and 2 x 2 km (also see *Grid Cell*).

Population: Individuals of the same species that live, interact, and migrate through the same niche and habitat.

Process models: are graphic depictions, using box and arrow diagrams, of the steps needed to conduct specific assessments that address identified REA analyses.

Rapid Ecoregional Assessment (REA): The methodology used by the BLM to assemble and synthesize that regional-scale resource information, which provides the fundamental knowledge base for devising regional resource goals, priorities, and focal areas, on a relatively short time frame (within 2 years).

Reporting Unit: Because an REA considers a variety of phenomena, there will be many phenomena and process (or intrinsic) grain sizes. These will necessarily be scaled to a uniform reporting unit, which has also been referred to as a *landscape unit* in BLM REA documents. This reporting or landscape unit will be the analysis scale used for reporting and displaying ecoregional analyses. (BLM specifies for the aquatic CEs, distribution and status will be reported at either 6^{th}-level/12-digit hydrologic unit, or 5^{th}-level/10-digit hydrologic unit. For the other CEs and the CAs, distribution will be provided at 30m resolution (or divisible by 30m), and status will be reported at the 4-km cells used for the climate analyses.)

Resource Value: An ecological value, as opposed to a cultural value. Examples of resource values are those species, habitats, communities, features, functions, or services associated with areas with abundant native species and few non-natives, having intact, connected habitats, and that help maintain landscape hydrologic function. Resource values of concern to the BLM can be classified into three categories: native fish, wildlife, or plants of conservation concern; regionally-important terrestrial ecological features, functions, and services; and regionally-important aquatic ecological features, functions, and services.

Response Model: a characterization of the way that a conservation element (CE) responds in the presence of a change agent (CA). Response in this case of geospatial assessment is in the form of a numeric score related to impacts on CE condition and, optionally, a distance out from a CA.

Scale: Refers to the characteristic time or length of a process, observation, model, or analysis. ***Intrinsic scale*** refers to the scale at which a pattern or process actually operates. Because nature phenomena range over at least nine orders of magnitude, the intrinsic scale has wide variation. This is significant for ecoregional assessment, where multiple resources and their phenomena are being assessed.

Scaling: The transfer of information across spatial scales. ***Upscaling*** is the process of transferring information from a smaller to a larger scale. ***Downscaling*** is the process of transferring information to a smaller scale.

Scenario: a geospatial depiction of the CAs and other relevant features that affect CA status at a given time. Scenarios are cumulative meaning that co-occurring features are represented in a stack of raster layers and, for future scenarios, current features are represented along with new, expanded, or intensified features.

Status: The condition of a criterion (biological or socio-economic resource values or conditions) within a geographic area (e.g., watershed, grid). A rating (e.g., low, medium, or high) or ranking (numeric) is assigned to specific criteria to describe status. The rating or ranking will be relative, either to the historical range of variability for that criterion (e.g., a wildland fire regime criterion) or relative to a time period when the criterion did not exist (e.g., an external partnerships/collaboration criterion).

Step-Down: A step-down is any action related to regionally-defined goals and priorities discussed in the REA that are acted upon through actions by specific State and/or Field Offices. These step-down actions can be additional inventory, a finer-grained analysis, or a specific management activity.

Stressor: A factor causing negative impacts to the biological health or ecological integrity of a Conservation Element. Factors causing such impacts may or may not have anthropogenic origins. In the context of the REAs, these factors are generally anthropogenic in origin.

Subwatershed: A subdivision of a *watershed*. A *subwatershed* is the 6th-level, 12-digit unit and smallest of the hydrologic unit hierarchy. Subwatersheds generally range in size from 10,000 to 40,000 acres. (USGS 2009).

Value: See *resource value*.

Vista: see *NatureServe Vista*

Watershed: A watershed is the 5th-level, 10-digit unit of the hydrologic unit hierarchy. Watersheds range in size from 40,000 to 250,000 acres. Also used as a generic term representing a drainage basin or combination of hydrologic units of any size. (USGS 2009).

Watershed Boundary Dataset (WBD): A national geospatial database of drainage areas consisting of the 1st through 6th hierarchical hydrologic unit levels. The WBD is an ongoing multiagency effort to create hierarchical, and integrated hydrologic units across the Nation. (USGS 2009).

Wildland Fire: Any non-structure fire that occurs in the wildland. Three distinct types of wildland fire have been defined and include wildfire, wildland fire use, and prescribed fire (NWCG 2006).

7 List of Acronyms & Abbreviations

AADT	Annual Average Daily Traffic
ACEC	Area of Critical Environmental Concern
AMT	Assessment Management Team
AR4	International Panel on Climate Change - Fourth Assessment Report
BLM	Bureau of Land Management
BPS	Biophysical Setting (from LANDFIRE data)
CA	Change Agent
CBR	Central Basin and Range ecoregion
CCVI	Climate Change Vulnerability Index
CE	Conservation Element
CM	Conceptual Model
COR	Contracting Officer Representative
CVS	Conservation Value Summary
CWNA	Climate Western North America
DDP	Data Delivery Package
DDTF	Data Delivery Tracking Form
DEM	Digital Elevation Model
DITF	Data Inventory and Tracking Form (formerly Data Inventory and Tracking Table)
DMP	Data Management Plan
DMT	BLM's National Operations Center's Data Management Team
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
EIA	Ecological Integrity Assessment
EIS	Environmental Impact Statement
EO	Element Occurrence
EPCA	Energy Policy and Conservation Act
ESA	Endangered Species Act
ESA	Ecological Status Assessment
ESD	Ecological Site Descriptions
EVT	Existing Vegetation Type (LANDFIRE)
FO	Field Office
FRI	Fire Return Interval
GA	Grazing Allotment
GCM	General Circulation Model
GIS	Geographic Information System

HMA	Herd Management Area
HRV	Historical Range of Variation
HUC	Hydrologic Unit Code
ILAP	Integrated Landscape Assessment Project
IPCC	Intergovernmental Panel on Climate Change
KEA	Key Ecological Attribute
LCM	Landscape Condition Model
LF	LANDFIRE (Landscape Fire and Resource Management Planning Tools)
MAR	**M**adrean **Ar**chipelago ecoregion
MBR	Mojave Basin and Range ecoregion
MDL	NatureServe's Master Data List
MDTF	Map Delivery Tracking Form (BLM's)
MLRA	Multiple Resource Land Area
ModDTF	Model Delivery Tracking Form (BLM's)
MQ	Management Question
MRDS	Mineral Resource Data System
NHD	National Hydrography Dataset
NHNM	Natural Heritage New Mexico
NOC	BLM's National Operations Center
NPMS	National Pipeline Mapping System
NRCS	Natural Resources Conservation Service
NREL	National Renewable Energy Laboratory
NRV	Natural Range of Variability
NSPECT	Non-point Source Pollution and Erosion Comparison Tool
NTAD	National Transportation Atlas Database
NWI	National Wetland Inventory
ORV	Off-road Vehicle
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PVT	Potential Vegetation Type
REA	Rapid Ecoregional Assessments
REAWP	Rapid Ecoregional Assessment Work Plan
RegCM	International Centre for Theoretical Physics Regional Climate Model
ROC	Receiver Operating Characteristic
SD	Standard Deviation
SDM	Species Distribution Model
SDR	Southwest Decision Resources
SIA	Sky Island Alliance
SNK	Seward Peninsula – Nulato Hills – Kotzebue Lowlands ecoregion
SOW	Statement of Work (for REA contract)

SSURGO	Soil Survey Geographic Database
STATSGO	State Soil Geographic Database
SWAP	State Wildlife Action Plan
TWI	Topographic Wetness Index
USFS	U. S. Forest Service
USGS	United States Geological Survey

Appendix A Current Development Change Agents and Data Sources

DV Category	Name	Organization	Description
Agriculture	Cropland Data Layer	USDA NASS	The USDA, NASS Cropland Data Layer (CDL) is a raster, geo-referenced, crop-specific land cover data layer. The 2012 CDL has a ground resolution of 30 meters. The CDL is produced using satellite imagery from the Landsat 5 TM sensor, Landsat 7 ETM+ sensor, and the Disaster Monitoring Constellation (DMC) DEIMOS-1 and UK2 sensors collected during the current growing season.
Agriculture; Urban	National Land Cover Dataset (NLCD)	MRLC	National Land Cover Database 2006 (NLCD2006) is a 16-class land cover classification scheme that has been applied consistently across the conterminous United States at a spatial resolution of 30 meters. NLCD2006 is based primarily on the unsupervised classification of Landsat Enhanced Thematic Mapper+ (ETM+) circa 2006 satellite data.
Energy - Oil and Gas	New Mexico Fluid Mineral Leases	BLM	New Mexico State-wide fluid mineral leases (oil and gas), 7/2/2013

DV Category	Name	Organization	Description
Energy - Oil and Gas	Oil and Gas Leases	BLM	The National Integrated Land System's (NILS) GeoCommunicator provides a Web Mapping Application and Map Services showing federal pending, authorized, and closed oil and gas leases, agreements, and lease sale parcels in the U.S on federal lands or where there are federal minerals.
Energy - Oil and Gas	Gas Pipelines	U.S. DOT	The U.S. Department of Transportation (U.S. DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA) is working with other federal and state agencies and the pipeline industry to create a National Pipeline Mapping System (NPMS).
Energy - Oil and Gas	Western States Oil and Gas Well Locations	Various Government Agencies	This is a compilation of oil and gas well data from various state government agencies that oversee the administration of this data in their respective states. Complied December 2010.
Infrastructure - Fencing	Location of fencing affecting Pronghorn in Arizona		Ground-truthed linear data for existing fencing within pronghorn habitat in southern Arizona.
Landfills	Dumps and Landfills	USGS	Locations of landfills and waste transfer stations in 11 western states. Data was obtained from state and federal agencies in GIS, tabular, and map format.

DV Category	Name	Organization	Description
Mines	Mineral resources (USGS Mineral Resources Data System, MRDS)	USGS	MRDS is a collection of reports describing metallic and nonmetallic mineral resources throughout the world. Included are deposit name, location, commodity, deposit description, geologic characteristics, production, reserves, resources, and references. It subsumes the original MRDS and MAS/MILS.
Mines	Active mines and mineral plants in the US (USGS National Minerals Information Center)	USGS	Mine plants and operations for commodities monitored by the National Minerals Information Center of the USGS. Operations included are those considered active in 2003 and surveyed by the USGS.
Recreation - OHV	Motorized Recreation in Arizona	AZGFD	This stressor includes the impacts of any motorized travel off-trail including but not limited to the use of ATV and OHV n ARizona on Wildlife
Recreation -Trails	Trails	BLM	BLM Recreation Trails

DV Category	Name	Organization	Description
Transportation - Airports	Public Use Airport Runways	Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA/BTS)	The Airport Runways database is a geographic dataset of runways in the United States and US territories containing information on the physical characteristics of the runways. The 6404 runways in the dataset are runways associated with the 19949 airports in the companion airport data set. This geospatial data is derived from the FAA's National Airspace System Resource Aeronautical Data Product (Effective 10 March 2011).
Transportation - Border Infrastructure	Border Tactical Infrastructure - SIA	Sky Island Alliance	Vehicle barriers, pedestrian wall/no wall delineations within Sky Island region
Transportation - Railroads	Railway Network (Node)	Bureau of Transportation Statistics	The Rail Network is a comprehensive database of the nation's railway system (node) at the 1:100,000 scale.
Transportation - Railroads	Railway Network (Line)	DOT, Bureau of Transportation Statistics	The Rail Network is a comprehensive database of the nation's railway system (line) at the 1:100,000 scale.
Transportation - Railroads	Railroads	USGS	The North American Atlas - Major railroads at a scale of 1:1,000,000 as of 2012.
Transportation - Roads	BLM Linear Features	BLM	Linear disturbance (Roads, Trails)
Transportation - Roads	US Roads, Major (USGS/National Atlas)	USGS	This data set portrays the major roads in the United States, Puerto Rico, and the U.S. Virgin Islands

DV Category	Name	Organization	Description
Utility - Towers	Digital Television Station Transmitter Sites	FCC Media Bureau	Extract of Digital Television StationTransmitter sites.
Utility - Towers	NTSC Television Station Transmitter Sites	FCC Media Bureau	Extract of NTSC Television StationTransmitter sites.
Utility - Towers	AM Radio Station Transmitter Sites	FCC Media Bureau	Extract of AM Radio StationTransmitter sites.
Utility - Towers	FCC Antenna Structures	FCC Wireless Telcom Bureau	Extract of FCC Antenna Structure Registration database.
Utility - Towers	Cellular Radiotelephone Sites	FCC Wireless Telcom Bureau	Extract of Cellular Radiotelephone Service sites.
Utility - Towers	FM Radio Transmitter Sites	FCC Wireless Telcom Bureau	Extract of FM Radio StationTransmitter sites.
Utility - Towers	Land Mobile Commericial Service Transmitter Sites	FCC Wireless Telcom Bureau	Extract of Land Mobile Commercial Service Transmitter sites.
Utility - Towers	Land Mobile Private Service Transmitter Sites	FCC Wireless Telcom Bureau	Extract of Land Mobile Private Service Transmitter sites.
Utility - Towers	Land Mobile Broadcase Service Trasmitter Sites	FCC Wireless Telcom Bureau	Extract of Land Mobile Broadcast Service Transmitter sites.

DV Category	Name	Organization	Description
Utility - Towers	Microwave Service Sites	FCC Wireless Telcom Bureau	Extract of Microwave Service sites.
Utility - Towers	Paging Service Transmitter Sites	FCC Wireless Telcom Bureau	Extract of Paging Service Transmitter sites.
Utility - Transmission	Energy Distribution Control Facilities	Global Energy Maps	The Energy Distribution Control Facilities layer depicts the facilities which are responsible for balancing the load within their respective control areas. The proper functioning of these facilities is integral to the stability of the North American Electric Power System. The Energy Distribution Control Facilities layer was created by geocoding street address information from the Transmission System Information Networks. Restricted data - must obtain data use agreement for MAR.
Utility - Transmission	Market significant transmission lines in North America.	Global Energy Maps	The Transmission Lines layer is a comprehensive layer consisting of market significant transmission lines in North America. Depicted lines are generally greater than 115 kV and tie major power plants to the electrical grid. Transmission lines are located using a mixture of sources from regional maps to aerial imagery. Restricted data - must obtain data use agreement for MAR.

DV Category	Name	Organization	Description
Utility - Transmission	Significant Electric Power Generation Plants	Global Energy Maps	The Electric Plants layer is a comprehensive representation of significant power plants within the North American power grid. The majority of plants shown are greater than three megawatts. Power plants are located using a mixture of sources from regional maps to aerial imagery. Restricted data - must obtain data use agreement for MAR.
Utility - Transmission	Substations and Taps in North American Power Grid	Global Energy Maps	The Substations layer is a comprehensive layer of the substations and taps that exist in the North American power grid. Substations are snapped into segments of the Transmission Lines layer and are found at every power plant. Substations are located using a mixture of sources from regional maps to aerial imagery. Restricted data - must obtain data use agreement for MAR.

Appendix B Compiled List of Special Assessments and Preliminary Prioritizations

This table contains the compilation of the special assessments that have been under consideration for this REA; see also the REA work plan. Preliminary prioritization rankings (H = High; M = Medium; L = Low) were provided by AMT members (DW, MB, RL, KT, CB) in late July as part of the review of the REA work plan. A simple color-coding is used to highlight the assessments that appear to be among the highest priority: the darker blue shows the highest priority assessments, and the lighter blue shows the moderately high priority assessments. No highlighting indicates lower priority. Six assessments are in the highest priority category and two are in the moderately high priority group.

			Preliminary Prioritization Ranks by AMT Members (from late July, approximately)					
Thematic Area	**Order in Work Plan**	**Name**	**DW**	**MB**	**RL**	**KT**	**CB**	**Preliminary Prioritization and Other Notes**
Hydro	1	Water Resources Availability	H	M	L	H	M-L	
Hydro	3	**Climate Change** and Watershed Hydrology	M	M	M	M	M-L	
Hydro	2	Historical Distribution of Aquatic Systems	M	L	L	L	M	Low priority; spatial data already compiled as point locations (not spatial extent), with varying degrees of uncertainty; parts of data are sensitive and cannot be distributed/published; briefly summarize data set??
Fire	5	Invasive Grasses and Fire Impacts on Non-Fire-Adapted CE Distributions	M	M	M	M	M	(Formerly listed as ~~Fire and Invasive Grasses Impacts on CE Distribution)~~

			Preliminary Prioritization Ranks by AMT Members (from late July, approximately)					
Thematic Area	**Order in Work Plan**	**Name**	**DW**	**MB**	**RL**	**KT**	**CB**	**Preliminary Prioritization and Other Notes**
Fire	4	Aquatic Systems At Risk From Fire and Erosion/ Sedimentation	L	M	M	H	H	(Formerly listed as ~~Ecological Status: Fire Regime Departure With **Other CAs** and Effect on CEs)~~
Grazing	9	Future Distribution of Grazing [in currently ungrazed areas]	L	M-L	M	L	M-L	**Dropped from consideration** per conversation with BLM core technical team (and earlier reviewer comments); not a priority
Grazing	10	Ecological Status: Climate Change Impacts on Grassland Productivity and Restorability	H	H		H	L w caveats	Proposing to address this through the bioclimate envelope modeling. If bioclimate envelope modeling is agreed to be the best approach, this assessment can be moved out of the main pool of special assessments that need to be prioritized and into the pool of climate assessments that are already confirmed will be conducted for this REA. (Formerly listed as ~~Ecological Status: **Climate Change** Impacts on Grasslands and Grazing)~~
Development	11	Connectivity: U.S. Only	M		M	Reconsider	M w comments	

			Preliminary Prioritization Ranks by AMT Members (from late July, approximately)					
Thematic Area	**Order in Work Plan**	**Name**	**DW**	**MB**	**RL**	**KT**	**CB**	**Preliminary Prioritization and Other Notes**
Invasives	12	Future Distribution of Invasive Non-native Species	H	H	L	H-M	H	Could reference existing models where available **and** sufficient (e.g., in ILAP model for herbaceous and grass exotics, only one 5th-level watershed is projected to show expanded exotics by year 2060, possibly due to insufficient input data for the model; this data set may not be adequate). Due to concerns around having sufficient data points to develop reasonable models (i.e., need to have sufficiently large number of point locations covering majority of current distribution in order to develop model that can adequately reflect potential for spread), not proposing to develop new models.
Invasives	13	Future Distribution of Invasive Non-natives: Effects of **Climate Change** and **Other CAs**		L-M	L	L-M	M	
Invasives	14	Future Distribution of Native Woody Increasers: Effects of **Climate Change**	L	H	H	L	M-L	This may be addressed through USGS bioclimate (or "suitable habitat") models for mesquite and creosotebush. Another possibility may be referencing ILAP's "shrub" expansion model.
Invasives	15	Impending Non-Native Invasions	M	L-M	L	H-M	L	

			Preliminary Prioritization Ranks by AMT Members (from late July, approximately)					
Thematic Area	**Order in Work Plan**	**Name**	**DW**	**MB**	**RL**	**KT**	**CB**	**Preliminary Prioritization and Other Notes**
Mesquite	NA	Mesquite and Restoration Opportunities	-	-	-	-	-	Although not included as a separate, special assessment in the original work plan, this is a high priority for REA participants.

The following assessments will be conducted regardless of any decisions around any of the other special assessments (this is because they have separate funding). Therefore, there is not a need to prioritize these; they are listed here for reference.

Thematic Area	Order in Work Plan	Name	DW	MB	RL	KT	CB
Climate	6	Climate Space Trends: Recent, 800-meter			H	H	H-M
Climate	7	Climate Space Trends: Future, Added Variables, 4-km				M	H-M
Climate	8	Bioclimate Envelope Modeling	H	H	H	L	

Appendix C Using the findings of the 2012 Colorado River Basin Water Supply and Demand Study to assess the impacts of climate change on hydrology in the MAR ecoregion

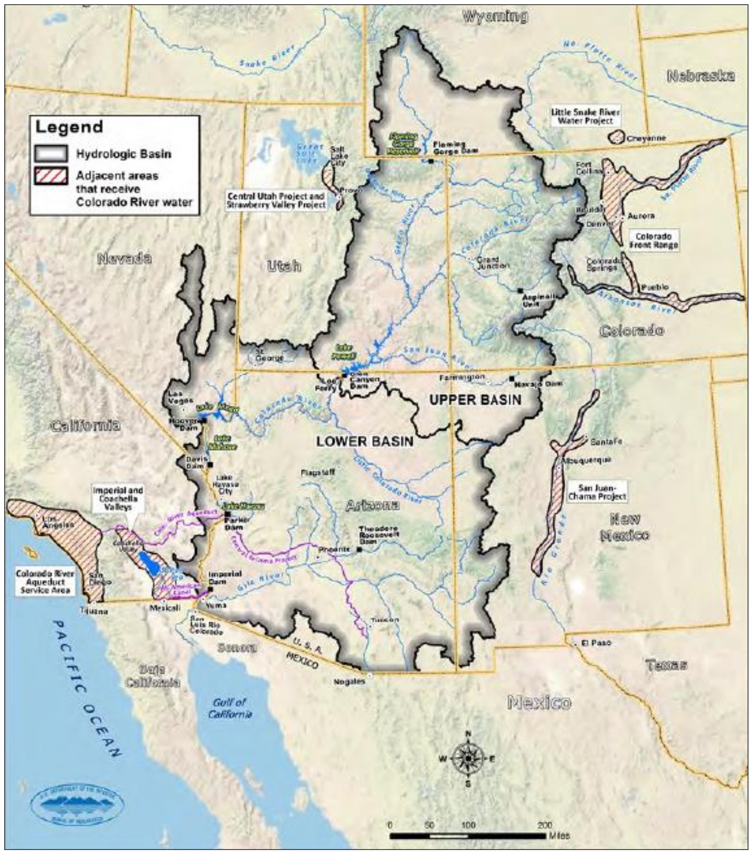
Information Sources:

USBR (U.S. Bureau of Reclamation). 2012a. Colorado River Basin Water Supply and Demand Study, Technical Report B-Water Supply Assessment, February 2012 Update. Report prepared by the Colorado River Basin Water Supply and Demand Study Team, U.S. Department of the Interior, Bureau of Reclamation, February 2012. http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/techrptB.html.

USBR (U.S. Bureau of Reclamation). 2012b. Colorado River Basin Water Supply and Demand Study, Technical Report B-Water Supply Assessment, February 2012 Update, *Appendix B2, Supplemental Water Supply Data and Methods*. Report prepared by the Colorado River Basin Water Supply and Demand Study Team, U.S. Department of the Interior, Bureau of Reclamation, February 2012. http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/techrptB.html.

Information Available:

The Colorado River Basin Water Supply and Demand Study ("CRBS Study") assessed the future availability of water across the Colorado River basin. The following figure shows the study area (from USBR 2012a). The study area includes all of the MAR ecoregion except for the watersheds that flow southward into Mexico, in extreme SE Arizona and SW New Mexico.



The Study assessed the following scenarios and associated themes:

- **Observed Record Trends and Variability (Observed Resampled):** Future hydrologic trends and variability are similar to the past approximately100 years.
- **Paleo Record Trends and Variability (Paleo Resampled):** Future hydrologic trends and variability are represented by reconstructions of streamflow for a much longer period in the past (nearly 1,250 years) that show expanded variability.
- **Observed Record Trends and Increased Variability (Paleo Conditioned):** Future hydrologic trends and variability are represented by a blend of the wet-dry states of the longer paleo reconstructed period (nearly 1,250 years), but magnitudes are more similar to the observed period (about 100 years).
- **Downscaled GCM Projected Trends and Variability (Downscaled GCM Projected):** Future climate will continue to warm with regional precipitation and temperature trends represented through an ensemble of future Downscaled GCM Projections and simulated hydrology.

The following table, copied from the technical appendix report listed above (USBR 2012b, Table B2-1), lists the data available; and the subsequent table, from the same report (USBR 2012b, Table B2-2), lists the sources of these data:

Water Supply Indicator	Relevance	Temporal Scale	Spatial Scale	Method of Analysis	Method of Display
		CLIMATE			
Temperature	Identification of trends in climate patterns	Monthly, Seasonal, Annual, Decadal	Grid cell, Select Watersheds, and Basin-wide	Statistical analysis of trends and variability	Spatial analysis and visualization
Precipitation	Identification of trends in climate patterns	Monthly, Seasonal, Annual, Decadal	Grid cell, Select Watersheds, and Basin-wide	Statistical analysis of trends and variability	Spatial analysis and visualization
		HYDROLOGIC PROCESSES			
Runoff	Identification of changes in runoff processes; identification of "productive" watersheds	Monthly, Seasonal, Annual, Decadal	Grid cell, Select Watersheds, and Basin-wide	Calculated as unit runoff; statistics to be generated	Spatial analysis and visualization
Evapotrans-piration (ET)	Identification of changes in natural losses; identification of "water stressed" watersheds	Monthly, Seasonal, Annual, Decadal	Grid cell, Select Watersheds, and Basin-wide	Calculated as unit actual ET; statistics to be generated	Spatial analysis and visualization
Snowpack Accumulation and Snowmelt	Identification of spatial changes in snowpack development and timing of melt	Monthly, Seasonal, Annual, Decadal	Grid cell, Select Watersheds, and Basin-wide	Calculated as unit snow water equivalent (SWE); peak and timing	Spatial analysis and visualization
Soil Moisture	Identification of causes of drought and severe drying conditions; identification of watersheds most impacted	Monthly, Seasonal, Annual, Decadal	Grid cell, Select Watersheds, and Basin-wide	Calculated as percentage of maximum	Spatial analysis and visualization
		CLIMATE TELECONNECTIONS			
El Niño – Southern Oscillation (ENSO)	Identify changes in teleconnections and influence on regional climate; identify relationship between long- term and shorter-term climate indices	Season, Annual, Decadal	Global/ Regional	Statistical analysis of correlation between indicator and streamflow	Correlation plots and statistics
Pacific Decadal Oscillation (PDO)	Identify changes in teleconnections and influence on regional	Annual, Decadal	Global/ Regional	Statistical analysis of correlation	Correlation plots and

Water Supply Indicator	Relevance	Temporal Scale	Spatial Scale	Method of Analysis	Method of Display
	climate; identify relationship between long- term and shorter-term climate indices			between indicator and streamflow	statistics
Atlantic Multi-decadal Oscillation (AMO)	Identify changes in teleconnections and influence on regional climate; identify relationship between long- term and shorter-term climate indices	Annual, Decadal	Global/ Regional	Qualitative discussion	Qualitative discussion
STREAMFLOW					
Intervening and Total Natural Flows at 29 Basin Locations	Identification of changes in streamflow trends and variability	Monthly; Annual; 1-, 3-, 5-, 10-year; and multi-decadal	Accumulated Flow at Point	Statistical analysis of trends and variability; drought and surplus statistics	Table and box-whisker of statistics, Basin-scale maps

Parameter	Description	Data Source
CLIMATE INDICATORS		
Historical Temperature and Precipitation	Historical gridded temperature and precipitation at 1/8th-degree resolution for the period of 1950–1999. Extension through 2005 was not documented.	Maurer et al., 2002 (http://www.engr.scu.edu/~emaurer/data.shtml)
Future Temperature and Precipitation Projections	A total of 112 future monthly temperature and precipitation projections based on Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2007) emission scenarios, subsequently bias corrected, and statistically downscaled to 1/8th-degree resolution for the period of 1950–2099.	Maurer et al., 2007 (http://gdo-dcp.ucllnl RUJ downscaled_cmip3_projections/)
HYDROLOGIC PROCESS INDICATORS		
ET, Runoff, SWE, Soil Moisture	Variable Infiltration Capacity (VIC)-simulated hydrologic fluxes and grid cell storage terms driven by observed climatology (1950–2005) and 112 future climate projections (1950–	Bureau of Reclamation (Reclamation), 2011

Parameter	Description	Data Source
	2099).	
Snowpack	Point snow water equivalent from late 1970s to present from the snow-telemetry (SNOTEL) network.	National Resources Conservation Service, 2011 (http://www.wcc.nrcs.usda.gov/snow/)
TELECONNECTION INDICATORS		
ENSO	Monthly Southern Oscillation Index (SOI) for January 1866 through March 2010.	University of East Anglia Climatic Research Unit , 2010 (http://www.cru.uea.ac.uk/cru/data/soi/)
PDO	Monthly PDO indices for January 1900 through January 2010.	Joint Institute for the Study of the Atmosphere and Ocean, 2010 (http://jisao.washington.edu/pdo/)
STREAMFLOW INDICATORS		
Observed Streamflow used in the Observed Resampled Scenario	Natural streamflow for the period of 1906– 2007 for the 29 streamflow locations commonly used for Reclamation planning.	Prairie and Callejo, 2005; Reclamation, 2010
Paleo Reconstructed Streamflow used in the Paleo Resampled Scenario	Reconstructed natural streamflows for the period 762–2005 at 29 locations derived from ecologically contrasting tree-ring sites in the southern Colorado Plateau during the past 2 millennia.	Reclamation, 2010; Meko et al., 2007
Paleo Conditioned Streamflow used in the Paleo Conditioned Scenario	Blended paleo streamflow states with observed streamflow magnitudes at 29 locations.	Prairie et al., 2008
Future Streamflow Projections used in the Downscaled General Circulation Model (GCM) Projected Scenario	VIC-simulated runoff and routed streamflow at 29 locations driven by 112 future climate projections for the period 1950–2099.	Reclamation, 2011

All data are calculated by grid cells with a 1/8th-degree (~12-kilometer) resolution. The report (USBR 2012a, 2012b) states, "…*Future climate change projections are made primarily on the basis of General Circulation Model (GCM) simulations under a range of future emission scenarios. A total of 112 future climate projections used in the IPCC Fourth Assessment Report, subsequently transformed to a local scale through bias correction and spatial downscaling (BCSD), were obtained from the Lawrence Livermore National Laboratory under the World Climate Research Program's (WCRP) Coupled Model Intercomparison Project Phase 3 (CMIP3). This archive contains climate projections generated from 16* *different GCMs developed by national climate centers and for Special Report on Emissions Scenarios emission scenarios A2, A1B, and B1. These projections have been bias corrected and spatially downscaled to 1/8th-degree (~12-kilometer) resolution over the contiguous United States through methods described in detail in Wood et al. (2002; 2004) and Maurer (2007).*" In turn, the "VIC" simulation methodology used to estimate runoff and streamflow is the "Variable Infiltration Capacity" hydrologic modeling methodology, a widely-used, well-tested methodology.

The reports themselves provide maps showing climate *change* for all climate variables by grid cell (see tables above) for three time steps: 2025 (2011-2040) versus 1985 (1971-2000), 2055 (2041-2070) versus 1985 (1971-2000), and 2080 (2066-2095) versus 1985 (1971-2000). These maps are small, making it somewhat difficult to visually assess the distribution of values within the MAR portion of the Colorado River Basin. It is expected to be able to obtain the data to generate maps focused on the MAR and interpret them accordingly.