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AREAWIDE COORDINATED CUMULATIVE EFFECTS ANALYSIS – PHASE I

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July 2008

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16. Abstract

The Areawide Coordinated Cumulative Effects Analysis (ACCEA) project evaluated whether and how a spatial accounting approach can be used to identify the cumulative impacts on the environment that result from the incremental impacts of multiple transportation and other projects, and related urbanization at a regional scale. Spatial accounting methods were employed to inventory improvement or decline in the quality of key resources over multiple time periods, jurisdictions and projects. The tools of spatial accounting include (1) data typically housed in a geographic information system (GIS); (2) models for the evaluation of environmental effects resulting from transportation projects and programs; and (3) metrics such as indicators or thresholds, which can be used to assess the importance of change in resource qualities. The ACCEA project addressed a broad spectrum of environmental resources of concern, including land use and open space, and biological, water, cultural and community resources. Fourteen distinct resource areas were addressed during seven workshops held with resource experts representing transportation, environmental, and planning agencies and interest groups. A demonstration project was conducted which focused on land use change, habitat and water quality across the Denver metropolitan region. GIS and remote sensing tools were demonstrated to provide the means for data and models integration, thus providing a technical foundation for characterizing environmental effects. ACCEA was concluded to be feasible and can provide valuable support to both project-specific assessments of cumulative impacts as well as regional accounting of environmental resources relevant to transportation planning.

Implementation:

The study results will facilitate the NEPA process by making information about cumulative effects analysis, environmental assessments, and environmental impact statements more readily available to those who are responsible for identifying and mitigating adverse environmental effects. The products of this project will be used to provide (1) general guidance and options for ACCEA transportation-related analysis in Colorado; and, (2) a review of opportunities for a coordinated approach in the Denver region.

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AREAWIDE COORDINATED CUMULATIVE EFFECTS ANALYSIS – PHASE I

by

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Workshop participants provided vital expert input. This input significantly contributed to the success of this project. The names of participants are included in the workshop notes, stored in the project's archive.

Comments and suggestions of the Agency Advisory Panel members have provided helpful guidance on components of this report. Members of the panel included Roberto de Dios, (CDOT Research) Roland Wostl, (CDOT Environmental Planning Branch) Brad Beckham (CDOT Environmental Planning Branch), Shannon Philippus (CDOT Environmental Planning Branch), Chris Paulsen (CDOT Region One), Stanley Elmquist (CDOT Region Four), Rich Griffin (CDOT Research), Steven Arnold (CDPHE), Marvin Koleis (CDOT GIS), Deborah Lebow (EPA), Larry Mugler (DRCOG), Jim Paulmeno (CDOT Region Six), Mike Vanderhoof (FHWA), Rena Brand (USACE), and Skip Spensley (S&A).

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EXECUTIVE SUMMARY

Cumulative effects analysis (CEA) is an evaluation of “the impact on the environment which results from the incremental impact of an action when added to other past, present and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions.” The Colorado Department of Transportation (CDOT) faces a complex set of challenges in managing the cumulative effects assessment process so that it provides useful and timely information to transportation decision-makers, supports consultation and collaborations with other federal, state and local agencies, and meets agency goals for administrative efficiency. The Areawide Coordinated Cumulative Effects Analysis (ACCEA) project is an effort to evaluate whether and how a spatial accounting approach can be used to address the challenges of CEA management at a regional scale. Spatial accounting methods are employed by environmental managers to inventory improvement or decline in the quality of key resources over multiple time periods, jurisdictions and projects. The tools of spatial accounting include (1) data typically housed in a Geographic Information System (GIS); (2) models for the evaluation of environmental effects resulting from activities such as transportation investment; and (3) metrics such as indicators or thresholds, which can be used to assess the importance of change in resource qualities.

Spatial environmental accounting can be used to support two tasks central to CDOT’s mission: (1) National Environmental Policy Act (NEPA) documentation of cumulative effects associated with individual projects; and (2) assessment of overall environmental consequences of transportation investments designated in regional transportation plans. In the ACCEA project, we developed and evaluated accounting methods through two primary project activities. In the first part of the project we held seven workshops with agency staff and practitioners to examine data sources, models and metrics that could be employed in areawide CEA. In the second part of the project, we designed and demonstrated accounting protocols for three selected resources. We applied these protocols to a hypothetical case study of a major highway expansion in Jefferson County (C-470 between Kipling and I-70). Based on results of the workshops, we found that

regional accounting is technically feasible and potentially of considerable value to CDOT and other organizations involved in transportation planning and NEPA assessment.

Availability of Data. We reviewed about 60 data sources for this project. Areawide data are available for almost every topic we examined. These can be obtained with modest effort as a download from public sources. Time series data are not available in every resource area; however, there are a number of time series data sources that have not yet been employed in this context. These include, for example, county assessor's files that can be used to identify past, present, and future development. The demonstration project confirms that regional accounting can be accomplished even in resource areas for which limited data are available.

Utility of Models and Methods. Project participants identified policy-relevant spatial models for almost all topics addressed through the workshops. For some environmental accounting topics, sophisticated models have been developed by researchers and applied extensively in practice (e.g., water quality and transportation/land use models). Overall, however, participants emphasized the value of simple models that are broadly understandable and easy to apply.

Relevance of Metrics. Over 100 metrics were reviewed in this project and about 35 selected by participants for the regional accounting framework. The workshops suggest that thresholds (critical levels of resource quality) for endangered species and wetlands are generally accepted across the region and are technically adaptable to regional accounting. A much larger number of local standards and practice-based metrics is also technically feasible in the context of NEPA analysis and regional transportation planning. These are credible in NEPA review and planning although not yet accepted across all agencies. However, we were unable to reach agreement about thresholds for many of the resources addressed in the workshops.

Demonstration of Regional Accounting Methods. The main products of the demonstration project are tables that describe the contribution of the transportation project under review to a change in the level and quality of key resources. These tables provide a framework for quantifying effects at varying spatial scales and over past, present and future timelines. The demonstration suggests that further development of coordinated datasets, tools, and protocols will substantially reduce costs of areawide CEA to individual NEPA projects. For example, much of the data used in CEA tabulations can be collected regionally and evaluated centrally.

Value of Regional Accounting. Project findings support the value of areawide environmental accounting for both project-specific NEPA assessment and regional planning. Some participants argued that spatial models in many cases are insufficient to document environmental significance under NEPA. Most participants agreed, however, that use of spatial models can improve CEA if they help quantify regional context and delineate the contribution of individual projects to regional environmental change.

Recommendations. The project also clarified the importance of launching a collaborative effort across agencies, local governments, and other stakeholders to obtain a common understanding of data and models; establish validation of the models; acknowledge priorities and preferences of participants who would use the models; and integrate model usage into administrative processes for decisions. Coordination across agencies, local governments and stakeholders should continue to be a focus in later phases of this project. The following recommendations were proposed to foster this partnership.

1. Make regional accounting cost-effective through construction of shared datasets, web-based data portals, and shared analytical tools.

2. Establish interagency data-sharing agreements.

3. Create an inter-governmental working group to develop protocols and priorities for regional accounting.

4. Establish procedures to guide contractors in implementing regional accounting frameworks.

5. Assess opportunities for integration of regional accounting information into the transportation planning process including initiatives such as Strategic Transportation, Environmental, and Planning Process for Urbanizing Places (STEP UP).

Implementation Statement

The products of this study will be useful in the NEPA process by making information about CEA, environmental assessments (EAs) and environmental impact statements (EISs) more readily available to those who are responsible for identifying and mitigating adverse environmental effects. By providing data from originating agencies in a standard form future CEA can be done more quickly. With the results of the resource workshops there is a better understanding of the resources and the indicators that are listed in the NEPA documentation, the metrics of indicators that allow those resources to be quantified and any thresholds of the metrics that may be used to determine when unsuitable conditions may exist. The identification of analysis protocols provides a means for quantifying effects for a selection of resources or issues. Finally, the model for a specific resource may be applied by NEPA consultants and CDOT personnel to identify potential future outcomes of alternative scenarios.

The products of this project will be used to provide (1) general guidance and options for ACCEA transportation-related analysis in Colorado; and, (2) a review of opportunities for a coordinated approach in the Denver region.

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1. INTRODUCTION

The Colorado Department of Transportation (CDOT) is charged with ensuring that state transportation projects comply with environmental regulations and protect resource qualities in the state while meeting the demands of Colorado residents for efficient transportation systems and services. In doing so, CDOT is confronted with the challenge of performing meaningful and cost-effective environmental analyses, acceptable to the resource agencies involved, so that environmental information can inform and support decision-making at appropriate points in the transportation planning and development process.

The National Environmental Policy Act of 1969 (as amended) [42 USC §4321, 4331- 4335, 4341-4347, 3724375] (NEPA) along with its accompanying regulations (40 CFR §1500-1508), provides the guidelines for developing an effective planning and decision-making process in the preparation of environmental assessments (EAs) or environmental impact statements (EISs). Within this process, analysts must document the purpose and need for a project, existing environmental and social economic conditions, direct and indirect environmental consequences, and possible alternatives.

Cumulative effects analysis (CEA) is also required by NEPA. The Council on Environmental Quality (CEQ) has defined cumulative effects as: "the impact on the environment which results from the incremental impact of an action when added to other past, present and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." Cumulative effects are the combined, incremental effects of human activity that influence the quality of resources, ecosystems, or human values. While impacts may be insignificant by themselves, they can accumulate over time, from one or more sources, and can cumulatively result in degradation of important resources. Consistent with the CEQ regulations (CEQ, 1987), effects and impacts are synonymous terms.

Analysis that spans a historical timeframe and anticipates future conditions is thus important to CEA. Under the definitions and guidelines of the CEQ, a CEA must not be delineated by artificial boundaries but must represent the natural areas defined by the extent of the effects. The resources and impacts involved are all inherently regional in character; the environmental resources transcend local jurisdictions and are most often defined by their bio-geographic extent resulting from factors such as climate, elevation and topography, soils and vegetative cover. These characteristics make it necessary to prepare cumulative effects assessments on a regional basis. The geospatial technologies of GIS and remote sensing are well-suited to the tasks required, providing both the seamless and historical data necessary for CEA.

For purposes of meeting ACCEA research goals, this project sought to develop regional spatial databases and assessment procedures that can be used to support CEA for multiple projects and programs across the metropolitan Denver region (e.g., Denver Regional Council of Governments (DRCOG) 2030 Transportation Plan). Some of these projects require environmental assessments and/or environmental impact statements. All require some assessment if only to justify the conclusion that they are 'categorical exclusions'. Development of transportation projects will impact a wide variety of natural and cultural resources across the region and cumulative effects will have to be assessed for the entire area impacted by these projects and other regional development.

The focus of the ACCEA research and development activity is the creation of "accounts" used to detail variations in quality of key resources in the context of historical, current and forecast conditions. These accounts are intended to provide a window on long-term resource trends and a basis for forecasting future conditions under alternative planning and project scenarios. Resource accounts rely on the development and collation of regional spatial databases. The ACCEA models for the various resource topics take the spatial data as inputs and generate metrics for the areawide resource accounts. Transportation projects and land use change forecasts drive the CEA models, and changes in the resource metrics over time constitute the cumulative effects. Involvement of stakeholders is necessary to assure the usability of data and models, and appropriateness of the analysis.

The project emphasizes "coordination" among CDOT staff and their federal, state, regional and local partner agencies to establish ACCEA methods that are understood and acceptable to all. With the help of a cross-agency coordinated approach, CEA can be streamlined to support decision-making at the level of regional transportation planning and programmatic or individual project assessments.

1.1. Objectives

The purpose of this project was to compile information and develop tools for ACCEA for the metropolitan Denver region. The objectives were as follows:

1. Obtain background spatial and non-spatial information from the literature, including CEA-related information from unpublished EA and EIS reports that have been completed for CDOT in the past.
2. Interview metropolitan Denver land developers to determine the factors that motivate them in selecting areas for development. Included were questions about the environmental laws and regulations that affect them and their reactions to them.
3. List and describe sources of digital data that are related to CEA or may contribute to a better CEA effort. Obtain any data that are available from originating sources. If necessary, modify the data to meet CDOT-Geographical Information System (GIS) standards.
4. Create documentation and summaries from a series of resource-specific meetings of expert panels to identify or verify resources of concern in CEA, identify criteria and an appropriate scale of measurement for them, determine if thresholds indicating an unsuitable condition exist and, if so, the values of the thresholds.
5. Identify environmental resources and issues of interest to CDOT and other government agencies based on input from advisory panels. Select protocols for CEA of the identified resources and issues from the information collected during the project or, where none exist, develop protocols using GIS or computer modeling.
6. Identify a select few resources of interest, the extent of influence of urban development on them, and GIS models of the temporal and spatial effects of transportation development on it.

Methods to accomplish these objectives are detailed in the respective sections in the following report. Section 2 describes the methods developed for ACCEA. Section 3 details workshop assessments of data, metrics and thresholds for the various resources relevant to ACCEA (e.g., land use, water, biological, cultural and community resources or domains). Section 4 presents the

ACCEA application case study addressing a single project and its integration into an areawide (regional) resource accounting scheme. Section 5 presents findings and conclusions. Section 6 summarizes the acronyms and abbreviations used in the report. Section 7 lists the literature that was cited in the report. The appendix provides the complete resource matrix.

There may be follow-on phases of the ACCEA project. Phase II of the project would extend the results of this study to other resources and formalize protocols for use of ACCEA databases and models by CDOT and its partner agencies. In Phase III there would be a full implementation of ACCEA spatial databases and models, and training of CDOT and other agency staff to use the tools.

2. AREAWIDE COORDINATED CUMULATIVE EFFECTS ANALYSIS: METHODOLOGY

2.1. Overview

A generalized schema for the ACCEA research and development activity is illustrated in Figure 1. It involves the integration of spatial databases developed for historic and current conditions, and forecasts of these. The ACCEA models for the various resources take the spatial data as inputs and generate metrics for the regional resource accounts. Planning and project assessments are derived from involvement of stakeholders in the data and models development, assuring usability of the data and models, and to help establish protocols for their use in transportation planning and implementation.

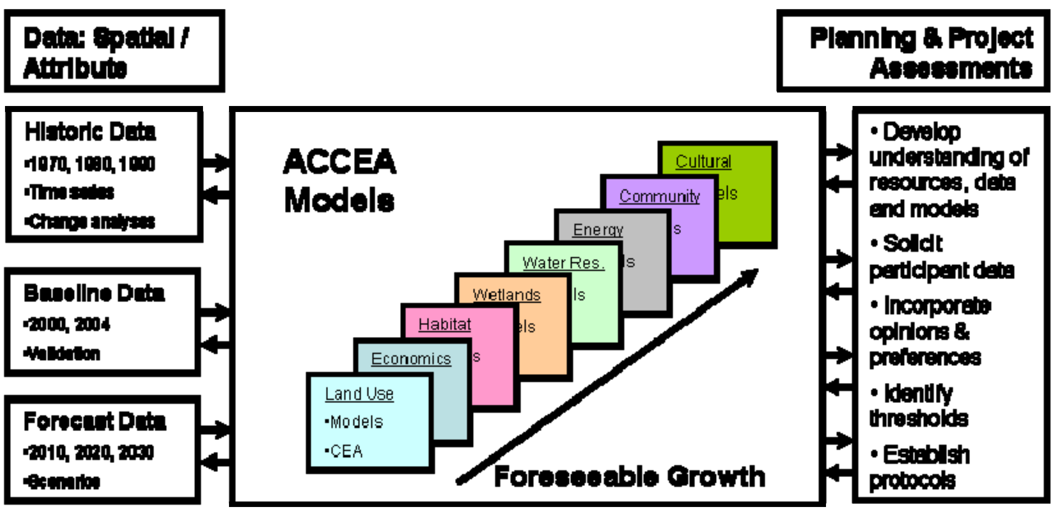

Figure 1. General schema of the areawide coordinated cumulative effects assessment process

We have adopted a general approach to the development of ACCEA that is based on the following steps (after Grimes, et al., 2004; CEQ, 1997):

- Describe the project components, environmental and land use setting;
- Identify resources or issues of concern;
- Identify metrics for measurement of impacts and thresholds of significance for each of the resources of concern;
- Conduct CEA analyses and determine level of cumulative effects and
- Interpret analysis results and establish follow-up actions.

Step 1: Describe Project Components, Environment and Land Use Setting

The components of the proposed project and the project phases in which they will occur (e.g., construction and operation) are identified. Included in this step are:

- Define the study area boundaries. These will be resource-specific, and are adjusted to account for data availability (e.g., some demographic data are summarized by block group), character of the resource (e.g., commuting range for project-induced development), and range of impacts. The project components, the environmental setting, and the land uses will be described. This is a preliminary step. Boundaries may have to be refined as part of the analysis of cumulative effects.
- Identify the study area's goals and objectives. It is important to develop an understanding of the community's vision and goals as they relate to ecological, social, economic and growth-related issues. This step involves implementation of public involvement activities. Elements of the ACCEA workshops described in Section 3 could be employed in the context of public meetings and other aspects of public engagement.
- A baseline environmental and socioeconomic inventory should be conducted to identify notable features or unique features of the environment. These may include sensitive species and habitats, community facilities, historical and archeological features, and land uses. According to the CEQ, the significance of an action must be analyzed in several contexts including society as a whole, the affected region, the affected interests, and the local area (CEQ, 1997). GIS tools provide the means to collate and archive these data.
- Identify impact-causing activities. Potential environmental impacts arising from road development projects fall into three categories: i) direct impacts; ii) indirect impacts; and iii) cumulative impacts. Direct impacts are caused by the road itself, by road building processes such as land conversion, and removal of vegetation. Indirect impacts (also known as secondary, tertiary, and chain impacts) are usually linked closely with the project. Indirect impacts are more difficult to measure and can affect larger geographical areas of the environment than may be initially anticipated. Examples include degradation of surface water quality by the erosion of land cleared for a new road, and urban growth near a new road. Cumulative impacts are the total

effect, including both direct and indirect effects, of all actions taken no matter who has taken the actions. Cumulative environmental change can arise from additive, multiplicative or synergetic effects. They can arise from multiple past, present, and future projects, as well as from secondary growth effects.

Step 2: Identify Resources and Issues of Concern

Resource issues of concern can be identified during consultations with experts and stakeholders. This step is essential to ensure that assessment resources are not spent on irrelevant issues. For the ACCEA project this step was implemented through a series of workshops with experts and stakeholders who addressed the various resources. Results of these workshops are summarized in Section 3 of this report. Agency and public scoping activities have been a primary focus of this Phase 1 research project. The UCD management and research teams have met with the Agency Advisory Panel (AAP) and the Practitioner Advisory Panel (PAT) to obtain advice on questions related to research scope and focus. In addition a series of workshops were held which addressed the various resources and themes appropriate for areawide CEA evaluation. A broad spectrum of environmental professionals, who are involved in review and approval of transportation plans and related environmental, documentation participated in the workshops. Topics for the meetings included:

1. Workshop 1. Introduction and overview of ACCEA project
2. Workshop 2. Land use including recreation and open space, agriculture, mining and energy use
3. Workshop 3. Water resources including water supply and demand, floods and drainage, and water quality
4. Workshop 4. Biological resources including wetlands
5. Workshop 5. Cultural resources including historical and archaeological resources
6. Workshop 6. Community impacts including environmental justice
7. Workshop 7. Demonstration Project

Step 3: Identify Metrics for Measurement of Impacts and Thresholds of Significance

Metrics may be based on ecological attributes (e.g., habitat availability, wildlife populations), physical-chemical attributes (e.g., air or water contaminant concentrations), land and resource use attributes (e.g., development densities, conversion of agricultural land), and social attributes (e.g., acceptable perceived change). The agenda for the workshops included: identification of data sources in the domain; review of relevant CEA methods; discussion of methods and data sources; discussion of metrics, indicators and critical thresholds; and, development of agreement on core methods and uses of data.

Also considered were the temporal and geographic scope for the assessment. Temporal scope considers past, present, and reasonably foreseeable actions. Determination of how far into the past and how far into the future to examine other actions is based upon the nature of the project and based upon the history of the corridor. The reasonably foreseeable future can be based on the planning horizon of the transportation agencies involved. Geographic scope is the spatial extent of impacts associated with the collection of projects and associated actions. Under the definitions and guidelines of the CEQ, a CEA must not be delineated by artificial boundaries but must represent the natural areas defined by the extent of the effects. The resources involved in this study are all inherently regional in character. The environmental resources transcend local jurisdictions and are most often defined by their bio-geographic extent resulting from factors such as climate, elevation and topography, soils and vegetative cover. These facts make it necessary to prepare cumulative effects assessments on a regional basis. The geospatial technologies of geographic information systems and remote sensing are well-suited to the tasks required, providing both the seamless and historical data necessary for CEAs.

For each of the resources of concern a threshold of significance should be identified. A threshold is a point at which a resource undergoes unacceptable change or reaches an unacceptable level. Establishment of significance can be based on the following approaches:

- Regulatory or policy - compare the residual effect to a regulatory guideline (e.g., air quality) or a government policy (e.g., land use).

- Scientific - compare the residual effect to a state of adverse environmental conditions, based on scientific and/or empirical information.
- Proportional – scale the range of impacts using a (say) 5-point scale based on the collective judgments of resource experts and stakeholders.

With all approaches it is necessary to state all assumptions and uncertainties, and to seek consensus on the thresholds. A “buffer” around the threshold can be used as an early-warning system for management purposes to reduce or halt the advancement of the effect toward the threshold. If quantitative thresholds cannot be identified, qualitative conclusions can be made that rely on professional judgment (e.g., magnitude, geographic extent, duration) and collaborative decision making.

Step 4: Conduct ACCEA and Determine Level of Cumulative Effects

Central to the ACCEA approach was the use of GIS database and modeling tools to conduct analyses across the region as well as for specific projects. GIS and remote sensing techniques for data management, modeling and impact assessment and visualization are well-suited to the tasks required. Given that the resources involved are predominately regional in character, it is possible to prepare cumulative effects assessments on a regional basis. Development of spatial data sets in standardized formats, scales, and projections provided a means for comparison of attributes across the study region and over time.

Several examples of ACCEA using GIS technology have been undertaken recently. The UCD research group (Johnson, et al., 2004) developed several models that were oriented toward specific critical resources within a well-defined study area bounding I-25 north of Denver. That project demonstrated the feasibility for collating spatial databases for a large region and linking analysis models which account for cumulative effects for several resources. That project demonstrated how GIS could be used to assess land use change and potential impacts on habitat using GIS overlay and distance techniques. Also demonstrated was the linkage of a spatial database with commonly used flood design procedures to measure hydrologic impacts due to land use change. Another example is the development of GISST (GIS Screening Tool) by an

EPA-sponsored group for an interstate corridor in Texas (EPA Region 6). GISST was developed using ArcInfo Workstation in the Arc Macro Language (AML).

The ACCEA Phase I analysis approach, illustrated in Figure 1, involved the collation of GIS and related attribute datasets. Emphasis was placed on datasets to establish a baseline; these were most often 2-5 year old datasets obtained from various federal and state providers. Older datasets were obtained where possible. Information developed at the ACCEA workshops provided input and guidance on metrics for measurement of cumulative effects for the various resources. GIS-based models are used to compute accounts of the resources that tabulate the extent of the resource over time, considering historical, current and forecast conditions. These accounts give details on the variations over time, thus providing perspectives on the changes that have occurred and a basis for forecasting future conditions as well as model calibrations. Growth forecasts and land use changes drive the analyses, and the calculated changes provide the predicted cumulative effects. Valuation of the cumulative effects per thresholds are derived from involvement of stakeholders in the data and models development, assuring usability of the data and models, and to help establish protocols for their use in transportation planning and implementation.

Step 5: Interpret Analysis Results and Establish Follow-Up Actions

Interpretation of cumulative effects is based on results of model predictions described in the previous step. Cumulative effects are described through tabulation over time of changes in the metrics for the various resource accounts created through the GIS analysis. The primary method for judging significance of projected impacts is to evaluate these changes in the context of the overall aim of the project, study area goals, and notable features. Consideration of these changes per the thresholds involves coordination by CDOT staff and their partner agencies to establish agreement on the significance of the changes, and to consider mitigation actions.

Mitigation should be considered if the potential impacts could worsen the condition of a notable feature, could interfere with or delay the planned improvement, could eliminate the notable feature or render the value ordinary, or are inconsistent with the law (Irwin and Rhoads, 1992). Mitigation strategies involve altering the type, alignment, and design of the project(s) as well as modifying the construction techniques and facility maintenance. For example, storm water runoff impacts on water quality may be mitigated by detention basins and treatment. A few induced growth impacts can be mitigated through forms of access and land use controls.

3. ACCEA WORKSHOPS: THE FRAMEWORK FOR A REGIONAL ACCOUNTING SYSTEM

3.1. Introduction

In this section of the report we describe the conceptual framework for a spatial accounting system in the Denver Metropolitan region. This conceptual design is constructed around metrics (thresholds and indicators) that can help transportation agencies illuminate and track the condition of key resources under their purview. With the help of this conceptual design, we address two other questions. First, is regional accounting feasible considering availability of data and other resources? Second, will regional accounting provide useful support to (1) NEPA practitioners conducting project review, and (2) transportation planners and other decision-makers participating in development of the regional transportation plan? The answer to these questions depends on several factors: the technical character of the effects of transportation investments on specific resources; the availability of temporal and spatial data in specific resource areas; and the suitability of relevant models and analytical methods. As important, the feasibility of regional environmental accounting depends on agreement among agencies about the objectives of the effort and appropriate metrics and methods.

In order to gather a variety of perspectives from agency staff and practitioners, we approached this part of the ACCEA project by organizing a series of resource-specific meetings to explore the questions above and lay the foundation for design of an accounting framework. These meetings had three objectives: identify or verify resources of concern in CEA analyses; identify models, measures and appropriate scales of measurement for key resources; determine if there is consensus on quantifiable thresholds and their values. The workshops were designed specifically to provide guidance regarding the five steps in a Regional CEA defined previously; 1) describe the project components, environmental and land use setting, 2) identify resources or issues of concern, 3) identify metrics for measurement of impacts and thresholds of significance for each of the resources of concern, 4) conduct ACCEA and determine if cumulative effects are significant, and 5) interpret analysis results and establish follow-up actions.

3.2. Methods

We employed a semi-structured focus group interview method to assess the utility of CEA-related methods and thresholds for each of 14 topic areas. We selected this approach rather than more structured interview methods for three reasons. First, we were prepared to provide substantial background materials for participants to read before each workshop; our intention was to support a free-flowing technical discussion of specific data sources, models and metrics. Second, we decided that a permissive focus group environment - without requirements that participants vote or reach consensus - would encourage conversation and allow ideas to emerge from the group. Our team was skeptical that consensus about CEA methods was possible until a formal, multi-level process of policy review would be initiated. Rather, our purpose at this early phase of involvement was to seek informal areas of agreement identified through review of notes and transcripts. Third, considering that all participants were invited because of their knowledge of NEPA, we anticipated that there would be sufficient homogeneity in attitudes and understandings so that participants could become engaged with the materials and respond to each other even in a relatively short session. One concern about the focus group approach was that some relationships among participants might be highly-charged (among agencies) or commercial in nature (between contractors and CDOT), thus inhibiting conversation; this did not turn out to be a concern for workshop participants.

Participants were selected for the workshops because of their level of activity and expertise as agency staff or consultants involved in cumulative effects-related analysis in the Denver Metropolitan area. We used three levels of screening to develop lists of workshop participants: (1) identification of relevant agency staff through contacts at federal and state agencies with NEPA consultation roles; (2) technical experts, local government representatives and others identified by CDOT staff; and (3) technical experts, local government representatives and others identified by the project advisory panel.[1] At each level of screening we also used the snowball method to identify other potential participants. The invitation lists included representatives of many of the major consulting firms, relevant federal agencies (e.g., Environmental Protection Agency), state agencies (e.g., Department of Public Health and Environment), and a number of

[1] The project advisory panel was comprised of five consultants identified by CDOT with substantial knowledge of CEA methods.

municipal and public works agencies. Because the workshops focused on agency processes and staff experience and knowledge, we invited only a small number of academics and staff from non-profit or advocacy groups. A participant list is included in the archive for this project.

Workshops were held in a neutral (university or regional government) location. Participation rates in the workshops were relatively high (Table 1). Fifty to seventy invitation letters were distributed for most of the workshops. For Workshop 6 (Community Impacts) the invitation list was extended to include about 50 local planning directors in the region. None of these planning directors participated. Excluding the invitation to planning directors, participation rates in the six substantive workshops ranged from 45-80%. Another 39 participants attended the Demonstration Project workshop, designed to generate guidelines for a demonstration of cumulative effects protocols in a limited project area (see Section 4). A total of 485 invitations were extended; 226 people participated in one or more workshops.

Each workshop was divided into three sections. (1) Overview - the first section included an overview of project purposes and structure, and a brief discussion among participants of general principles within the topical area of the workshop. (2) Small group discussion - the second section of the workshop was a one hour-and-a-half session in which smaller groups of participants reviewed technical problems in CEA. Participants were asked to discuss key issues identified by project staff and rank data sources, technical models and indicator measures (or thresholds) with respect to their utility in NEPA documentation and transportation planning processes. These sessions were organized around an instrument described below. (3) Review of

Table 1. Workshop Participants

Workshop	Participants	Number Invited
1. Introduction	31	48
2. Land Use	33	41
3. Water Resources	38	67
4. Biological Resources	21	47
5. Cultural Resources	28	57
6. Community Impacts	36	102
7. Demonstration Project	39	123
Total	226	485

small group discussions - in the third section of the workshop, the entire group re-convened for another 45-minute session focusing on further discussion of a report from each break-out session. The purpose of this part of the workshop was to revisit the small group discussions and generate additional ideas from other participants. The full group sessions were led by two moderators; the small group sessions were led by a single moderator.

The workshops focused substantively on 14 small group discussions, covering 1) recreation, 2) energy, 3) agriculture and 4) mining (land use workshop); 5) water demands and supplies, 6) flood plains and drainage, and 7) water quality (water resources workshop); 8) threatened or endangered species, 9) habitat and 10) wetlands, (biological resources workshop); 11) historical and 12) archaeological resources (cultural resources workshop); and, 13) environmental justice and 14) economic effects (community impacts workshop). We selected these topics through discussions with CDOT and the project advisory group about key problems in regional CEA and issues relevant to our case study area, the Denver metropolitan region. The 14 small group discussions were each organized around a technical paper produced and distributed to participants prior to the workshop. These technical papers presented an overview of CEA issues for each topic and a list of data sources, models and metrics in current or potential use. Each technical paper was also distilled into a survey instrument – formatted as a chart - used by moderators to guide discussion and by participants to aid in the ranking of the utility of data, models and metrics.

Workshop discussions were documented extensively. We recorded and later transcribed both small and large group sessions. The individual recorders for each session also took notes in longhand. Flipcharts used by moderators were transcribed. Finally, participants were asked to submit their own notes and rankings at the conclusion of each workshop. These materials were compiled and reviewed by project staff. We analyzed the results in three steps: 1) first-level screening of notes and other materials to identify points where discussion in the sessions converged on partial agreement about ranking of the utility of specific data sources, models and metrics; 2) second-level review of materials to identify areas of partial agreement among participants about issues in the organization of CEA on an area-wide and coordinated scale; and, 3) additional review of materials related to salient issues emerging in discussion.

We present the framework for a regional accounting system as a set of tables placed in following sections of this report. These tables are organized around metrics that were identified in workshops as the most appropriate measures of cumulative effects. Each metric is associated in the table with its composite data sources, models or analytical methods, and thresholds where agreement about these could be reached in the workshop.

3.3. Findings

Over 100 metrics were reviewed in these workshops. Workshop participants selected 35 metrics as most suitable according to three criteria: (1) technical feasibility; (2) usefulness for project-level NEPA review; and, (3) usefulness in review of the regional transportation plan. Availability of data varies among resource areas. Historical data are not available for most of the resources reviewed in this project; current data are available for almost all of the resources; projected data are only available for a few resources. Within this patchwork of data availability, however, there is sufficient areawide coverage to provide a sufficient foundation for a spatial accounting system. Recommended analytical methods include buffers around transportation routes to describe affected areas; rules of thumb and factors to indicate the magnitude of potential effects; and spatial overlays of affected areas on resource extents to describe acres of affected resources. While these methods are simple they were considered adequate for a regional accounting system. This section of the report reviews the results of discussions at the 14 small group sessions concerning the overall utility of data, methods and metrics; how and where they should be used; and their implications for applicability of regional CEA.

3.3.1. Land Use: Recreation, Agriculture, Mining and Energy

The land use workshop was held on August 26, 2005 and included 33 participants. The workshop was organized around four discussion groups: recreation and open space, agriculture, mining and energy use. This section of the report focuses on the recreation discussion group because participants argued that this is an important emphasis for an areawide CEA. Prior to the workshop, participants were provided a discussion paper with background on key issues and a proposal for key metrics.

Data: Data sources for assessing cumulative recreational effects tend to be inconsistent and fragmented. Consistent, regional data sources include DRCOG's open space GIS and state parks data. Otherwise, data sources describing local parks and open space are a patchwork, compiled separately by individual municipalities, counties and other jurisdictions. Participants pointed out that considerable work is required to collect these data and address inconsistencies. Spatial data on mining activity are available from the United States Geological Survey, the State of Colorado, and local governments.

Models: With respect to scope, participants in the recreational discussion pointed out the difficulties in defining geographical scope for recreational lands. For example, Denver-area residents travel long distances for recreation, which suggests that the scope of CEA should encompass the region if not the state. Participants also suggested that a regional CEA should encompass open space of all kinds as well as developed recreational lands, including dedicated public lands such as parks and private lands controlled by conservation easements. At the same time, participants emphasized the functional distinctions between recreational and open space lands in terms of user experience and activity. Participants noted four potentially negative direct impacts: noise, air pollution, water pollution and aesthetic experience. One potentially positive direct impact is improved access to recreational lands. A variety of indirect impacts was discussed mostly linked to the effects of increasing accessibility on property values. Workshop participants agreed that models of environmental effect in an areawide CEA could be simple buffer overlays of proposed transportation routes on recreational and open space lands.

The agriculture discussion group reviewed the Land Evaluation Site Assessment (LESA) modeling approach, which is well established for analysis of proposed farmland conversion in more rural areas of the state. However, LESA is not designed as a tool for a regional CEA analysis nor is it a tool for analyzing farmland removal from within an urban environment. No LESA-style analysis for the remaining farmlands within the Denver metro area is currently underway. Most importantly, LESA is not targeted to the kinds of specialty agricultural businesses such as floriculture, garden supply and organic farms that may be characteristic of the urban fringe. One participant pointed out that an economic input-output model may be suitable for evaluating the role of agricultural processing, supply and specialty enterprises in regional economies.

A number of sophisticated models for assessing the life cycle energy use and energy use impact of transportation systems were examined by the energy use discussion group.

Metrics: Participants discussed a range of metrics related to recreation and open space (Table 2). These include conversion of private open space or agricultural lands, loss or increase of land values, fragmentation levels, and changes in air quality levels, change in noise levels, and change in the ratio of developed land to recreational and open space lands. Participants also suggested that a rating system should be developed to assess the value and type of recreational and open space land.

Agricultural metrics for a regional analysis include SSURGO to identify the land's potential for agriculture and CVCP to determine the baseline agricultural land use (Table 3). Foreseeable agricultural land use can be estimated from information sources such as zoning maps, regional plans and the associated documents. The SSURGO and CVCP data could also be used at the local and project scales. However, particularly at the project scale, more detailed, multi-factorial information will likely be required to provide the resolution necessary for comparison of alternative transportation project proposals.

The mining discussion group reviewed metrics ranging from coal production to mineral mining. New aggregate mines and reclaimed land were considered to be the highest priority in the Denver area (Table 4). Metrics can include tons of production and acres of soil displacement, tailings or other activities. Aggregate mines provide construction materials for transportation projects. However, they also affect riparian habitat and function. In other parts of the region such as Weld County, oil and gas production may occur in urbanizing areas and cause conflicts with neighbors. Participants suggested that the urban conflict metrics should receive more discussion.

Table 2. Recreation and Open Space

Metric Name	Dataset Source	Analytical Methods	Metric Description	Thresholds
Undeveloped land per resident	CVCP, Assessor and Parcel Records	Mosaic of undeveloped land datasets; tabulation by jurisdiction or neighborhood.	Acres of undeveloped land per resident; overall description of landscape openness	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%
Sports field area	Various county and city datasets	Mosaic of local parks data; tabulation by jurisdiction or neighborhood.	Acres per resident; describes developed and organized recreational opportunities	Professional standards (e.g., American Planning Association); local planning guidelines
Neighbor-hood park area	Various county and city datasets	Mosaic of local parks data; tabulation by jurisdiction or neighborhood.	Acres per resident; describes recreational opportunities for families with children	Professional standards (e.g.,American Planning Association); local planning guidelines
Open space area	CVCP, DRCOG open space data, county and city datasets	Mosaic of open space data; tabulation by jurisdiction or neighborhood.	Acres of dedicated open space lands and conservation easements per resident; describes availability of protected open space	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%
Hiking/ biking trail length	Various county and city datasets	Trail network measurement; tabulation by jurisdiction or neighborhood.	Miles per resident; describes availability of hiking and biking recreation	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%
Noise levels	State and local noise assessments	Surveys and compilation of survey data; tabulation by jurisdiction or neighborhood	Acres affected at different decibel levels; describes noise impacts on recreational experience	Local, state and federal statutory thresholds

Table 2. Continued

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Open space accessibility	Various county and city datasets; US Population and Housing Census	Buffer or network measures; tabulation by jurisdiction, sub-region or neighborhood	Population within 15 minute drive of contiguous open space; accessibility measure	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%
Trail accessibility	Various county and city datasets; US Population and Housing Census	Buffer or network measures; tabulation by jurisdiction, sub-region or neighborhood	Population within 15 minute drive of continuous trails; accessibility measure	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%
Neighbor-hood park accessibility	Various county and city datasets; US Population and Housing Census	Buffer or network measures; tabulation by jurisdiction, sub-region or neighborhood	Population within 15 minute walk of a neighborhood park; accessibility measure	Professional standards (e.g., American Planning Association); local planning guidelines

Table 3. Agriculture

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Irrigated Agriculture Class	CVCP	Reclassification, time-series analysis	Total Acres, Maximum Size, Minimum Size, Average Size, Modal Size	Not applicable
Agriculture Class (not irrigated)	CVCP	Reclassification, time-series analysis	Total Acres, Maximum Size, Minimum Size, Average Size, Modal Size	Not applicable
Prime Farmland	SSURGO	Mosaic, reduction, reclassification, time-series analysis	Total Acres, Maximum Size, Minimum Size, Average Size, Modal Size	Not applicable
Agricultural Zoning	Zoning maps	Digitizing, scanning, mosaic, selection, time-series analysis	Total Acres, Maximum Size, Minimum Size, Average Size, Modal Size	Not applicable

Table 4. Mining

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
New aggregate mines	USGS; local data	Mosaic of aggregate mining datasets	Acres	Not identified - important for riparian areas
Reclaimed land	USGS; local data	Mosaic of reclaimed land datasets	Acres, acre/acre)	Not identified - important for riparian areas

The energy use discussion group reviewed a variety of metrics such as per capita transportation use and transportation use by mode. Participants were skeptical about the feasibility of developing metrics on energy consumption and utilization that would be practical at the NEPA project level.

Regional Accounting: Overall, participants were strongly positive about the utility of a regional accounting system related to recreation and open space. They agreed that spatial data, models and metrics could become fundamental project-level assessment tools for determining baseline conditions, tracking on-going changes, assessing regional change, and linking project-level and regional metrics. They also agreed that cumulative analysis of recreation and open space would be useful in development of the four-year transportation plan. However, participants emphasized several qualifications. First, regional accounts should be based on a functional rating system of recreation and open space uses. Second, regional accounts should be used as a vehicle to more fully incorporate community values and the outcomes of local planning processes into regional transportation planning, and vice versa. The level of commitment to these plans by local jurisdictions should also be taken into account. Some workshop participants also pointed out that there is no longer a substantial amount of cultivated agricultural land in the transportation planning area and mining is not a major NEPA topic for transportation agencies.

The discussion group focusing on transportation system energy use agreed that the environmental effects of energy use are significant. There was consensus that methods to track and reduce energy consumption should be researched further. It is unclear how regional accounting for energy use could be incorporated into the NEPA process, however. Participants in the session were considerably more optimistic about use of energy metrics at the transportation planning level.

3.3.2. Water Resources: Supplies and Demands, Floods and Drainage, Quality

The water resources workshop was held September 30, 2005 and included approximately 30 invited participants representing several state, federal and local agencies and various consultants, as well as representatives from CU Denver. The participants were divided into three breakout groups following introductions and a project overview. In the breakout sessions they discussed issues pertaining to CEA for three areas of potential impacts, 1) water supply and demand, 2) floods and drainage, and 3) water quality. Participants were earlier provided with a draft document on water resources metrics and a short questionnaire requesting feedback on the various metrics in terms of data availability, assessment methods and models, relevance of the metrics, thresholds of significance, and the prospects for regional CEA.

There was a number of water supply and demand metrics that were rated highly relevant (Table 5). However no single metric alone was considered useful for water supply and demand CEA. Rather, a comprehensive accounting of the various factors comparing water supply versus demand was considered to be required. The following sections summarize the important features as identified by the workshop participants.

Water Supplies and Demands

Data: Water supplies and demands data are generally available from the various water providers; particularly Denver Water, the Northern Colorado Water Conservancy District (NCWCD) and local water districts. The Denver Regional Council of Governments collects and summarizes supply-demand data of various kinds for the Denver metropolitan region. Also, the Colorado Division of Water Resources is currently involved with a Statewide Water Supply Initiative (SWSI, (CWCB, 2005)) directed to identifying water supply options to meet increasing demands for the various river basins of the state. Data on supplies and demands are developed with considerable effort by these agencies. However, there does not seem to be a central repository of location-specific data on supplies and demands that can be readily collated across the region. The data reside with the various providers and it was considered to be a significant task to request, obtain and collate, and maintain these data for purposes of areawide CEA.

Metrics: A number of water supply and demand metrics were rated highly relevant. In Table 5 are listed some fifteen (15) metrics for overall accounting and specific components of the water supply and demand comparison. These include an overall accounting comparison of supplies versus current and projected demands, various components of supply (e.g., surface and groundwater), and water conservation measures of various kinds. Some of the metrics could be used to portray impacts in source river basins which would extend the geographic scope of assessment (e.g., source basin diversions and flow depletions). No single metric alone was considered useful for water supply and demand CEA. Rather, a comprehensive accounting of the various factors comparing water supply versus demand was considered to be required.

Models: The water providers (esp. Denver Water) have developed and maintain complicated water supply and demand accounting models that reflect source water collections, treatments and deliveries. There are other versions of regional water supply and demand accounting models under development. However, these are major activities involving stakeholder involvement, and complex water balance accounting across multiple river basins and water user scenarios. Also, water supply versus demand accounting is complicated by variability in supply from year to year, water rights administration and changes in water rights (e.g., transfers from agricultural uses to municipal uses). It was felt that such complications make modeling of water supply and demand too difficult for transportation CEA purposes.

Thresholds: No fixed thresholds were identified for the water supplies and demands resource. We portrayed possible thresholds using proportional scaling over a range of metric values. Participants did not rate the relevance of these thresholds highly. The reason for the low ratings of relevance seemed to be that the participating agencies did not see how transportation project influences could be separated from overall population growth and associated land development. They saw limited application of the water supplies and demands metrics for transportation CEA.

Table 5. Water Resources – Supplies and Demands

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Water supplies compared to water demands – ratio (WS/WD)	USGS, Denver Water, water providers, CWCB/SWSI; difficult to collate various sources with demands.	GeoDb compilation; Time series analysis; GIS displays. Comprehensive comparison of supplies and demands quite complicated.	Amount of water withdrawn for water supply, by source – time series and % change (+/-) normalized by demands. Time series of deliveries, totals and by source; % change (+/-)	WS/WD: 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = < 90%
Total water demand (TWD)	DRCOG, Denver Water, water providers, CWCB-SWSI.	Geo database compilation, time series statistics, GIS displays	Indicates magnitude of water use over time and forecasts to 2030. % change based on time series; Map display of TWD & % change at time increments	TWD % change: 1 <= 0% 2 = 0 - 5% 3 = 5 -10% 4 = 10 - 20% 5 = >20%
Water conservation – amount conserved (WC)	DRCOG, Denver Water, water providers; forecast to 2030?	Geo database compilation, Tabulation of types and amounts; WC%= WC/TWD*100; GIS displays	Percent of total water supply which is conserved; higher conservation reduces overall demands. Map display of WC%	WC%: 1=30% 2=20to10% 3=10to5% 4=5to2% 5=<2%
Surface water supply by source (SWS):	USGS, Denver Water, water providers, CWCB/SWSI	GeoDb compilation; Time series analysis; GIS displays	Amount of water withdrawn for water supply, by source. – time series and % change (+/-).Time series of deliveries; totals and by source; % change (+/-)	SWS % change: 1=<0%, 2=0-5%, 3=5-10%, 4=10-20%, 5=>20%
Groundwater levels (GWL):	USGS, DRCOG, Denver Water, water providers, CWCB/SWSI	GeoDb compilation, Time series of water levels & statistics - % change (+/-); by source and indicator wells.	GW levels indicate the state of remaining supplies from the aquifer; decreasing levels indicate supply depletion. GIS maps of drawdown areas [ft]	GWL change: 1=<20, 2=20-50, 3=50=100, 4=100-250, 5=>250

In general, water supplies and demands were rated highly relevant to areawide CEA in recognition of their importance to sustaining economic and environmental values in Colorado. However it is not evident that transportation projects singly and throughout a region can be identified as primary factors in generating water demands, or that transportation projects' effects can be separated from the overall mix of activities leading to water demand increases.

Flood Runoff and Drainage

Data: Data on flood runoff and drainage works are generally available from the agencies responsible for flood damage mitigation. In the Denver metro region the Urban Drainage and Flood Control District (UDFCD) has responsibility for coordinating the planning, design and construction of drainage works which cross multiple jurisdictions. The UDFCD conducts watershed studies which project future land use changes and resultant flood runoff impacts; data for these studies are usually found in the watershed reports and are not readily available in a coherent manner across the region. The Federal Emergency Management Agency (FEMA) sponsors and coordinates the development of flood plain inundation maps used to regulate building in threatened areas. These maps, although variable in quality and not uniformly up to date, are readily available. Indeed, the FEMA flood inundation maps are a primary concern with transportation project designs which seek to avoid incursion into designated floodways. Watershed data of various kinds are readily available from federal GIS data repositories. For example, the U.S. Geological Survey (USGS) maintains and distributes digital elevation, land use and stream hydrography data which can be used to model watershed flood runoff. The National Weather Service (NWS) also has watershed data developed to support their flood warning operations. Other data supportive to modeling flood hydrology are readily obtainable for download. For example, soils data are obtainable from the USDA Natural Resources Conservation Service (NRCS).

Metrics: A number of metrics were proposed for characterizing flood runoff and drainage impacts (Table 6 and Appendix 1). These ranged from floodplain proximity and encroachment, flood runoff quantity, impervious surfaces associated with urbanization, and channel erosion. Floodplain encroachment is a primary concern in design of transportation facilities and is effectively mitigated. Flood runoff increases are driven by increases in impervious surfaces

Table 6. Water Resources – Floods and Drainage

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Urban and highway runoff quantity (URO):	USGS, DWR, UDFCD	GeoDb compilation, GIS-55 model has demonstrated computation of flood peaks	Flood flows – peaks and volumes for past, current and future conditions – at selected locations. Flood peaks as % increase from base line.	1=<5%, 2=5-10, 3=10-20, 4=20-30, 5=>30%
Impervious lands (IMP):	USGS, satellite imagery	GeoDb compilation, image processing, image statistics	Urbanization results in increased impervious surfaces; associated with increased flood runoff and water pollution. Impervious areas as % of total area	1=<5%, 2=5-15, 3=15-25, 4=25-40, 5=>40%

associated with urbanization. Impervious surface area (or % of area) was the highest rated metric.

Models: A wide variety of flood runoff models are available and used for transportation project planning and design. The Driscoll model (Driscoll, et. al., 1990) was developed for the FHWA and is a widely used method; it also accounts for pollutants in highway runoff. The Purdue University Long Term Hydrologic Impact Assessment (LTHIA) model (Engel, 2001) is another example of a computer simulation model which accounts for flood runoff changes with land use; it also accounts for water pollutants.

Thresholds: Flood runoff and drainage were rated highly relevant to transportation projects and regional CEA in recognition of the influence that highways have on flood runoff due to increases in impervious surfaces (Table 6). Secondary growth influences of highways leading to residential and commercial development also increase impervious surface areas and can lead to increases in flood runoff in comparison to natural conditions. Here, it is possible to separate out the influence of highways from other land uses and secondary growth in the vicinity of a project and at the local scale (e.g., watershed). The influences of impervious surface increases on flood runoff were considered relevant and can be modeled using any number of standard methods. A distinct threshold based on impervious area is described in the water quality section below.

Regional Accounting: Flood runoff is routinely accounted for in a watershed. The size of the watershed may range from a large area conveying runoff for an entire region, to a small sub-basin which is a part of the larger watershed. Therefore the scale of hydrologic analysis can vary depending on the location(s) of concern. For example, the drainage area contributing runoff to a particular transportation project comprised can be defined for just that project. Then the contribution of the project to changes in impervious area of the drainage area can be tabulated and the influence of the project on flood runoff can be determined. For regional accounting the collection of sub-basins comprising the overall area can be identified at some scale; perhaps equivalent to the scale of the project-specific watershed. Then the influence of multiple transportation projects and secondary land use changes can be determined for each sub-basin; and results for the region can be tabulated using statistical summarization of the sub-basins responses to the changed land uses. This approach is demonstrated for the water quality case study in Section 4 of this report.

Water Quality

Data: Information on the status of water quality for Colorado rivers resides primarily with the Colorado Department of Public Health and the Environment (CDPHE). The CDPHE is responsible for water quality assessments and classifications, and managing processes for maintenance and improvement. They coordinate these activities with the U.S. Environmental Protection Agency. Their information is readily available via download from internet databases and includes the stream classifications and status reports. The DRCOG coordinates with the CDPHE for water quality management in the Denver metropolitan region through the conduct of Total Mass Discharge Loading (TMDL) studies for streams in the region. Ancillary data on land use and vegetative cover, watersheds and drainage networks are available from the USGS, NRCS, EPA and other agencies, and are also generally available through Internet download from these public agencies.

Metrics: Water quality concerns were rated as the most relevant of the three water resources sub-fields. The highest rated metric for water quality was impervious surface area increases associated with transportation projects and secondary growth (Table 7). A variety of methods are applied for assessing threats to water quality, ranging from relatively simple accounting of water quality factors to complicated biochemical process simulation models. A prime example of a

Table 7. Water Resources – Water Quality

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Impervious lands (IMP)	Land use data (USGS, counties, cities), satellite imagery; current and forecast.	GeoDb compilation, image processing, image statistics; methods based on land use or population density.	Urbanization results in increased impervious surfaces; assoc. with increased flood runoff and water pollution. IMP is % of total area; apply for watersheds in vicinity of projects and entire region.	Proportional 1 = <5%, 2 = 5-15, 3 = 15-25, 4 = 25-40, 5 = >40%
Water Quality Listing (WQ303(d)) and WQ Assessments (WQ305(b))	CDPHE listing of impaired and threatened waters; DRCOG summaries. CDPHE Integrated Reports (IR) categorization of designated (beneficial) uses.	CW Act, Sect. 303(d) segments; GIS map of stream segments with classifications. 305(b) stream status categorization data are available in GIS formats keyed to river segments.	Clean Water Act Section 303(d) Segments – State Priority Data identify segments that are WQ limited, use protected and no degradation; also CDPHE monitoring and evaluation (M&E) lists.	Regulatory: Number of segments and status tabulation over time; length and % supporting designated use; complied by CDPHE/DRCOG.

simple accounting method is that for impervious services (Brabec, et. al., 2002). It is widely recognized that increased urbanization has resulted in increased amounts of impervious surfaces – roads, parking lots, roof tops, etc. – and a decrease in the amount of forested lands, wetlands and other forms of open space that absorb and clean storm water.

Models: Impervious surfaces are also readily estimated using GIS databases and remote sensing image processing (Yang, et. al.., 2003) and it is possible to separate transportation project effects from other land use changes, at least for local watersheds within which highway projects occur. GIS-based water quality models which link land use (with impervious surfaces) and estimate non-point water quality of runoff are well established as assessment and planning tools to identify general trends in water quality for a specific watershed (Engel, 2001). There are two kinds of models available for TMDL process, receiving water quality models and watershed models that can assess the impact of pollutant loadings on the water body. A specific model is selected based on the model's capabilities to simulate the site-specific physical, hydrological and water quality features of interest. An example of a receiving water quality model is the River and Stream Water Quality Model (QUAL2K) (http://www.epa.gov/athens/wwqtsc/html/qual2k.html) which simulates the conventional pollutants (nitrogen, phosphorus, dissolved oxygen, BOD, sediment oxygen demand, algae), pH, periphyton, and pathogens. Watershed models have capabilities of deriving pollutant loadings from both point and non-point sources. An example of a watershed model is the Better Assessment Science Integrating Point and Non-point Sources (BASINS) (http://www.epa.gov/waterscience/basins). BASINS is a watershed model that integrates data and assessment tools in a customized GIS environment for performing water quality analysis. The GIS provides the integrating framework for BASINS by organizing spatial information, such as land use, highways, and point source discharge locations, so that it can be displayed as maps, tables, or graphics. Existing and future land use data are used in the BASINS model to assess potential changes in annual phosphorus loading and cumulative impacts from alternatives.

Thresholds: Thresholds of impervious area as a percentage of a watershed have been identified and used as general indicators of the threat to water quality of a specific watershed. A seminal study by Schueler (1994) cited eleven studies as evidence that stream quality declines at 10 to 15 percent imperviousness. There seems an acknowledged relationship between impervious surfaces and the quality of runoff originating from those surfaces (e.g., Arnold and Gibbons, 1996; Brabec, et. al, 2002). Several factors caution against a strict adherence to imperviousness ratio but there is strong evidence in the literature and wide adoption of this relatively simple measure by planning agencies. For example, GIS-based impervious cover tabulations have been used to evaluate the performance of the Delaware Water Resources Protection Area (WRPA) ordinance (Kauffman, et al. 2006); new development has been restricted to less than 20 percent impervious cover to protect water supplies. The monitoring and evaluation listing of impaired waters of the CDPHE was developed to address regulatory requirements of the Clean Water Act and the U.S.

Environmental Protection Agency, and it provides a useful means to track the state of a region's water quality over time. However, these listings are not considered amenable to detailed ACCEA assessments for a collection of transportation projects and other urban development.

Regional Accounting: Although conceptually possible, it is not clear that impervious surface runoff quality effects on specific water segments can be tracked for an entire region given the complicating factors of stream assimilative capacity, multiple inputs changing over time, complicated water balance and biochemical reactions, and other complicating factors. Models of water quality which can be applied across a region were considered too difficult and expensive to develop and apply in a reliable manner acceptable to regulatory authorities. Water quality models are typically used as part of TMDL (Total Mass Discharge Loading) planning procedures which are on-going in ten (10) Denver metro region watersheds. However, TMDL planning activities which are coordinated by the DRCOG are significant efforts involving various stakeholders and regulatory authorities, data collections and assessments. The results of TMDL activities are relevant to regional CEA concerns but are considered too time consuming, complicated and expensive for general application. The monitoring and evaluation listing of impaired waters of the Colorado Department of Public Health and the Environment (CDPHE), which was developed to address regulatory requirements of the Clean Water Act and the U.S. Environmental Protection Agency, also provides a useful means to track the state of water quality of a region's waters over time.

3.3.3. Biological Resources: Threatened and Endangered Species, Habitat and Wetlands

The biological resources workshop was held on October 28, 2005 and included 30 invited participants representing several state and federal agencies as well as representatives from CU-Denver and Health Sciences. The participants were divided into three breakout groups following general introductions and a project overview, where they discussed issues relevant to CEA of threatened and endangered species (T&E) (species of concern that were not Federally listed were also discussed), habitat/plant communities, and wetlands. Participants were earlier provided with readings and at the workshop were provided with a questionnaire covering some of the issues discussed in the workshop. Critical to the project, were discussions that focused on data, metrics, models, thresholds, and regional accounting. The following sections relate what workshop participants felt were important features for each of these categories.

Data: One of the primary objectives of the Biological Resources Workshop was to identify relevant data that is relatively easy to obtain and incorporate into a GIS. Table 8 lists the datasets

Table 8. Biological Resources – T&E Species

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Preble's meadow jumping mouse	Input data based on model parameters	GIS analysis; temporal/spatial modeling; HSI	Acres per class; connectivity index; count by size class	Current condition (no loss)
bald eagle nest sites	CNHP; NDIS; local surveys; land use plans	GIS analysis; temporal/spatial modeling; HSI	Counts; distribution; proximity to food sources	Current condition (no loss)
black-tailed prairie dog	Input data based on model parameters	GIS analysis; temporal/spatial modeling; HSI	Acres per class connectivity index; count by size class	Carrying capacity of managed units
burrowing owl	CNHP; NDIS; local surveys; land use plans	GIS analysis; temporal/spatial modeling; HSI	Counts; distribution;	TBD
ferruginous hawk	CNHP; NDIS; local surveys; land use plans	GIS analysis; temporal/spatial modeling	Counts; feeding habitat area and distribution	TBD
plains sharp-tailed grouse	CNHP; NDIS; local surveys; land use plans	GIS analysis; temporal/spatial modeling	Counts; habitat area and distribution	Carrying capacity of managed units
northern redbelly dace	CWS	Surveys	Counts	No loss of habitat?
Colorado butterfly weed	CNHP; land use plans	GIS analysis of habitat; counts;	Counts; habitat area; habitat distribution	TBD
Ute ladies tresses	CNHP; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD
Bell's twinpod	CNHP; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD

that were initially considered as fulfilling the needs of a regional CEA. For threatened and endangered species (Federally listed) and other species of concern, the workshop participants identified data from the Colorado Natural Heritage Program (CNHP), the Natural Diversity Information Source (NDIS), and Colorado Division of Wildlife (CDOW) as important (other data is also listed in Table 8). Data on habitat/plant communities includes CNHP, the Colorado Vegetation Classification Project (CVCP), the Colorado Division of Wildlife's riparian vegetation mapping project, among others (Table 9). And finally, wetlands data, which includes U.S. Army Corps of Engineers (USACE) Section 404 permit points, the Soil Survey Geographic (SSURGO) database, National Wetlands Inventory (NWI), and the Colorado Department of Transportation (CDOT) (Table 10).

Table 9. Biological Resources – Habitat/Plant Communities

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Prairie area dynamics	CNHP; CVCP; weed surveys	GIS analysis; temporal/spatial modeling	Total area of prairie; average, modal, minimum, maximum patch size; connectivity; perimeter/area ratio	1=<=0% 2=1-5% 3=5-10% 4=10-20 5=>20%
Xeric and Mesic Tallgrass Prairie	CNHP; CVCP; Boulder County; weed surveys	GIS analysis; temporal/spatial modeling	Total area of prairie; average, modal, minimum, maximum patch size.	1=<=0% 2=1-2% 3=2-3% 4=3-4 5=>4%
Plains Cottonwood Riparian Woodland	CNHP; CVCP; riparian vegetation mapping; weed surveys	GIS analysis; temporal/spatial modeling	Total area; average, modal, minimum, maximum patch size.	1=<=0% 2=1-5% 3=5-10% 4=10-20 5=>20%
riparian shrub and herbaceous communities	CVCP; riparian vegetation mapping; weed surveys	GIS analysis; temporal/spatial modeling	Total area; average, modal, minimum, maximum patch size	1=<=0% 2=1-5% 3=5-10% 4=10-20 5=>20%

Table 10. Biological Resources – Wetlands

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Regulated wetlands	USACE Sec. 404 permit points; SURGO; Boulder Cnty GIS; Riparian vegetation, CVCP, NWI; USGS; land use plans	GIS analysis; temporal/spatial modeling; photo interpretation; remote sensing	Acres, maximum, minimum, average, modal; count, count; frequency table; temporal change	1=<=0% 2=1-2% 3=2-3% 4=3-4 5=>4%
Unregulated wetlands	SURGO; Boulder Cnty GIS; Riparian vegetation, CVCP, land use plans	GIS analysis; temporal/spatial modeling	Acres, maximum, minimum, average, modal; count, count; frequency table; temporal change CDOT Policy is no net loss	TBD
Built wetlands	USACE; CDOT; Ducks Unlimited?	GIS analysis;	Acres, maximum, minimum, average, modal; count, count; frequency table; temporal change	not applicable
Regulated wetlands connected to riverine and lacustrine systems	SURGO; Habitat maps, flood zone maps, hydrological maps	GIS analysis, temporal/spatial modeling	Acres; acres connected to riverine; acres connected to lacustrine; temporal change	1: =0% 2: >0 – 1% 3: >1 – 3% 4: >3 – 5% 5: >5%
Water quality mitigation function class	CDPHE impairment data. EPA? Effects of planned infrastructure on impairment, land use plans	GIS analysis, temporal/spatial modeling	Sediment, nutrient, toxicant retention. Removal of sediment, nutrient, toxicant from water inflow source	TBD

Table 10. Continued.

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Floodwater retention function class	Urban Drainage and Flood Control. Riparian Vegetation Classification. Floodplain mapping. Wetland mapping	GIS analysis, temporal/spatial and system models (capacity to reduce flow, floodwater retention, groundwater recharge)	Floodwater retention/attenuation Groundwater recharge. Sediment control, stabilization of banks Flood conveyance	TBD
Habitat function class	T&E species surveys, trapping data Riparian Vegetation Classification, weed surveys, land use plans		Waterfowl feeding and nesting Feeding, resting, reproductive habitat for upland and wetland species Fish habitat	TBD
Human utility class	Recreational user and use surveys, land use plans	User surveys; use monitoring; economic models; temporal/spatial models	Scenic beauty Recreation	TBD

Note: TBD = to be determined.

Metrics: A variety of metrics were discussed as being potentially useful in regional CEA. In the T & E breakout group such measures as connectivity measures, acres per class, habitat area, core habitat area, habitat perimeter, and habitat distribution were suggested as possibly being valuable. In the Habitat/Plant Communities session, total area of prairie, patch size, and connectivity were among those suggested. Wetland mitigation by wetland “banking” is a viable strategy for offsetting the impact of transportation projects. Wetland type and wetland function do not necessarily correlate, and CDOT is working on a functional assessment methodology similar to the “Montana Method.” Participants in the wetlands session discussed a number of metrics for regulated wetlands, unregulated wetlands, built wetlands, and several others. A few of the metrics discussed by the participants includes area, area connected to riverine, area connected to lacustrine, and flood water retention.

Models: Models suggested by workshop participants were largely limited to habitat suitability index models (HSI) in the T and E session. These models are used to identify where suitable habitat areas are located within the Front Range study region. Habitat suitability models should be developed using the *Model Builder* tools in the Environmental Systems Research Institutes' (ESRI) ArcGIS and can incorporate some of the datasets mentioned above. The habitat and wetlands groups supported the idea of using temporal/spatial modeling utilizing available data and GIS.

Thresholds: Thresholds for each of the resource areas covered by the workshop were discussed in the general session and also in the individual breakout groups. Follow-on conversations with individual participants, CDOT personnel, and other experts after the workshop also contributed to the thresholds listed below. The Threatened and Endangered species group looked specifically at species found within the study region including Preble's meadow jumping mouse (Preble's), black-tailed prairie dog (BTPD), and several others listed in Table 8. Because Preble's is a threatened species, current condition is the threshold (e.g., habitat). The black-tailed prairie dog is not federally listed but is a state species of concern; therefore, its status in the region is considered important. The threshold for BTPD is recommended as the carrying capacity of managed populations. Other species, as indicated in Table 8, have thresholds that are yet to be determined. Habitat thresholds have been established as a range of percentages (Table 8), while wetlands sessions discussions suggested that thresholds for most categories would have to be determined at a future date.

Regional Accounting: The establishment of models such as the HSI models may provide a mechanism for regional accounting of habitat for individual species. Habitat may be enhanced and a viable population may be transplanted or introduced into suitable and unoccupied habitat if available. Long-term survival of the BTPD is probably dependent upon the location of suitable habitat in open space within each of the counties where the populations can be properly managed.

3.3.4. Cultural Resources: Historical and Archaeological

Data: The SHPO's Cultural Resources database is not comprehensive but rather cumulative of survey results that are mainly project-specific. Some parts of the database have been generated by local programs that aim for comprehensiveness within a geographical area; others were generated by thematic studies or through advocacy efforts. There was some discussion of the desirability of a genuinely comprehensive survey effort. This may be appropriate within limited areas affected by multiple projects. But workshop participants generally acknowledged that the database does not provide systematic continuous coverage and is unlikely to do so in the future.

In addition to SHPO, there are other data sources not used widely in the historic preservation community that do provide more-or-less systematic coverage of various historical dimensions. One key example is the date of construction ("yearbuilt") attribute attached to most structures by county assessors. Other possible examples include dates of subdivisions; water resources such as ditches and reservoirs; mining claims; land withdrawals from the public domain; mapping of railroads and streetcar lines; historical land-use data; centennial farms, ranches and businesses. None of these are substitutes for Cultural Resource Surveys. To the extent that they are systematic and may be converted into GIS, they may be useful in the scoping stage of project evaluation. One workshop participant described the ease of drawing APE (Area of Potential Effects) boundaries for cultural resources by using assessors' construction dates, which showed areas of uniformly new development as well as the extent of historical nodes that appeared related to the project corridor.

There may be important opportunities for inter-agency agreements in the cultural resources area. Participants commented, for example, that a data-sharing agreement between SHPO and CDOT would be useful. Data-sharing agreements could also be forged between these state agencies and local jurisdictions. These could be used to roll-up community-level data collection efforts into a statewide database. There are significant obstacles to the implementation of the state-local data-sharing agreements, however. The standards and forms of local designations and surveys may vary from state and national standards. These divergent standards would need to be resolved into a consistent framework.

Models: Participants commented that direct impacts of highway projects on historic resources are addressed by current rules and practices. The introduction of Section 106 helped to reduce highway impacts by requiring more landscaping and routing highways around communities. A number of participants also commented, however, about the importance of indirect and cumulative effects analysis. In particular, cumulative effects of roads and associated development may have a strong negative influence on the quality of cultural resources. For example, noise impacts of multiple roads, visual changes in the character of urban settings, and increasing density all may contribute to declining quality of cultural resources. In addition, participants commented that a robust assessment of such effects would include assessments of the economic and social viability of communities. Economic impacts include a variety of measurable factors such as property value, business viability, jobs and investments. On the negative side, for example, real estate investors may be discouraged from purchase and renovation of structures in historic districts during the construction phase of road development. On the positive side, highways bring life and growth back to historical towns. While these impacts are difficult to model, some may be captured through buffers.

Metrics: Table 11 describes the cultural resource metrics that were considered to be a high priority by the workshop participants. The concept of measurable thresholds for acceptable impacts on a regional basis was controversial in the workshop because of the uniqueness of cultural resources. A district, building, or site cannot be assumed equivalent to another. However, within defined classes of resource and defined geographical areas, thresholds, indicators or other metrics may be useful in evaluating impacts. For example, within a corridor or a valley, knowing whether an affected property is the last dairy farm or early-era motel court - or only one of a hundred - could be helpful even if not necessarily conclusive. This is part of the CRM concept of historical or archaeological context.

Regional Accounting: Participants in the workshop emphasized that review of impacts on historic resources is inherently site-specific because it depends on the historic character of each property and its character-defining features. Some were reluctant to consider historical and archaeological features in terms of general values that could be quantified across regions or compared between sites. There were also comments about the general reluctance of the historic preservation community to use GIS. One participant privately noted that "historians won't use computers." On the other hand, many of the participants were interested in opportunities to improve data and data-related tools used in cumulative effects assessment.

Another important comment is that regional CEA analysis is akin to the context studies already performed as a part of cultural resource assessments. These generally involve some kind of

Table 11. Cultural Resources

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Loss of National Register-eligible districts	SHPO, CDOT and local historical society datasets	Surveys of historical integrity; tabulation by jurisdiction or region	Number of districts with diminished integrity	Proportions of loss with reference to historical context; Levels of integrity loss
Loss of other National Register-eligible resources	SHPO, CDOT and local historical society datasets	Surveys of historical integrity; tabulation by jurisdiction or region	Number of buildings, structures, sites, objects with diminished integrity	Proportions of loss with reference to historical context; Levels of integrity loss
Loss of listed resources of national importance	SHPO, CDOT and local historical society datasets	Surveys of historical integrity; tabulation by jurisdiction or region	Number of listed resources with diminished integrity	Proportions of loss with reference to historical context; Levels of integrity loss
Loss of listed resources of statewide importance	SHPO, CDOT and local historical society datasets	Surveys of historical integrity; tabulation by jurisdiction or region	Number of listed resources with diminished integrity	Proportions of loss with reference to historical context; Levels of integrity loss

Cultural resource valuation and inventory at a regional scale. There are opportunities both for efficiencies and improved outcomes by coordinating the preparation of context studies for multiple transportation projects. GIS data might become an increasingly useful part of such studies. One participant described as "magic" the experience of using a database to bring up comparable properties that would have taken weeks to locate through archival research.

3.3.5. Community Impacts: Economic Effects and Environmental Justice

Data: The discussion in the workshop about data sources focused on (1) tabular data sources that are not typically organized in a GIS; and (2) process of data collection. Participants listed tabular data that are not typically in a GIS and which should be considered in community impacts assessment. These include information about businesses or institutions such as: motels; trailer parks and schools; educational institutions; churches; major work centers; ethnic businesses; goodwill centers; information on transportation accessibility (potentially available from transit organizations); RTD travel surveys and other information about ridership on specific routes; information collected through the home mortgage deduction act; assessed values; information related to Section 8 housing; information available from the diocese; second language churches; windshield surveys (including surveys of second language billboards); information from the Department of Motor Vehicles such as year and model of vehicles; information available from the state vital statistics website; information on educational attainment; and data available from public health departments.

Models: Cumulative effects related to environmental justice may include multiple road investments in a specific area with joint direct and indirect effects on residents of the area (e.g., impacts on health or community cohesion), and indirect development effects that may influence the character of a community (e.g., loss or gain of certain types of businesses). A change in road alignment - added to previous industrial locations such as a smelter and dog food plant - may also generate cumulative effects related for example to noise or odor. Participants emphasized that cumulative effects of transportation investments may be both positive and negative. Positive cumulative effects of transportation projects may include accessibility and mobility. For example, the Georgia DOT was sued for not building roads in certain parts of the Atlanta area, thus diminishing accessibility to services for low-income populations. This lawsuit suggests a positive cumulative effect of multiple road investments in certain areas, such as a potential increase in accessibility for specific populations residing in these areas.

Participants also pointed out the importance of assessing community cohesion factors in regional CEA related to environmental justice. These may include a bridge that is considered part of the community fabric; the “old Slovenian home”, where parents or grandparents may be living; and private companies that provide important services to the community. One participant asked whether factors of this kind reasonably can be evaluated on a regional scale, or do they depend on local, idiosyncratic data. Finally, there was discussion of direct and indirect effects of individual projects. These may include noise, daycare, access to jobs, and availability of walking routes. Models of social proportionality of effects using census data are reasonably well-established; other types of methods are in the developmental stage.

Metrics: Three types of metrics were introduced as described below. These address (1) proportionality of effects on different population groups; (2) other demographic and economic factors that may influence vulnerability; and (3) interaction of social and environmental factors over time (Table 12).

Table 12. Community Impacts and Environmental Justice

Metric Name	Dataset Name	Analytical Methods	Metric Description	Thresholds
Proportionality of direct effects on low-income and minority populations	US Population and Housing Census, school data, data from community institutions such as churches, regional plans, STIP/TIP	Tabulations of census data; statistical analyses; creation of projected population surfaces	Affected low-income and minority populations as a proportion of overall population in a reference area	Disproportionate share of adverse effects in low-income or minority populations
Vulnerability levels of low-income and minority populations	Census and community data sources to identify age, gender, and other socio-demographic characteristics	Tabulations of Census data; statistical analyses	Presence of other characteristics of potentially vulnerable populations	Disproportionate percentage of non-native English speakers, older persons, and other potentially vulnerable populations
Interacting effects of previous investments	Data from various sources regarding air and water quality, noise, safety, hazardous materials, visual quality, and	Tabulations of Census data; tabulations of local environmental data; statistical analyses	Accumulating effects of previous transportation or industrial investments and other unwanted land uses on	

	community cohesion.		low-income and minority communities	

Regional Accounting: The discussion about regional accounting focused on two primary issues. On the positive side, some participants argued that regional accounts are useful for environmental justice CEA because they provide support for mitigation on a regional scale, not project-by-project. Regional mitigations can take advantage of economies of scale and have the potential to generate more substantial improvements for communities or population groups. On the negative side, other participants commented that it is difficult to account for both negative and positive impacts on a regional scale. Most important, accessibility benefits – the opportunity for different population groups to travel to jobs and services - may be difficult to assess and compare in a technical sense. If the regional accounting is incomplete, how useful is it?

3.3.6. Air Quality

At the outset of the ACCEA development process, it was thought that Transportation Conformity analysis, which assures conformance of transportation plans with State air quality plans, would suffice to address air quality and that Conformity could serve as a model for cumulative effects analysis. However, upon fuller consideration toward the end of Phase I of the ACCEA development process, it was realized that the level of analysis for air quality should be of the same depth as was being considered for the other environmental media, habitat and species. This section therefore sets forth air quality issues in need of address, suggests rather broad concepts for analysis, and should be considered a work in progress.

CDOT Environmental Ethic and Air Quality in Cumulative Effects Analysis

In accordance with CDOT's environmental ethic and commitment "to support and enhance efforts to protect the environment and quality of life for all of Colorado's citizens," the ACCEA Protocol includes discussion regarding known and anticipated air quality effects of transportation projects on a region-wide basis. CDOT's ethic "goes beyond environmental compliance (and) strives for environmental excellence, ensuring that measures are taken to avoid or minimize the environmental impacts of construction and maintenance of the transportation system and that mitigation commitments are implemented."

Regarding air quality considerations, it is acknowledged that

(1) Transportation Conformity determinations are of limited value in NEPA and cumulative effects assessments;
(2) There is evidence of environmental degradation, as well as human health impacts[2], due to air pollution at levels below the National Ambient Air Quality Standards; and
(3) NEPA environmental assessments are required to consider "any adverse environmental effects" of the proposed action (emphasis added), thus any anticipated adverse effects related to air pollution, direct and indirect, will be included in cumulative effects analyses.

Air quality assessments conducted for the purposes of NEPA are broad in scope, going well beyond the question of whether transportation projects may result in future violations of criteria pollutant standards. A broader scope still is appropriate for cumulative effects analyses, which look to past, present and future effects of transportation projects, direct and indirect.

♦ *While every attempt will be made to quantify and map likely environmental impacts for analyses, where they are not quantified, a qualitative analysis will be conducted and incorporated into cumulative effects analyses. The Air Pollution Control Division and CDPHE are committed to assist with additional data gathering and mapping.*

Air Pollutant Issues Appropriate for Cumulative Effects Analysis

All air pollutants are toxic at sufficient levels of exposure. "Criteria pollutants' are in a legal category for which there are national ambient air quality standards, hence 'criteria,' set by the EPA. The criteria pollutants are:

Carbon monoxide
Lead and lead compounds (EPA has placed lead in both the toxic and criteria categories)
Nitrogen dioxide

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[2] One such human health problem is restricted lung function and development related to exposure to traffic, as demonstrated by Gauderman, et al. The study to be published in the Lancet (February 2007) found that significant deficits in lung development in children ages 10 to 18 who lived within 500 meters of a freeway or large roadway versus those living further than 1500 meters of a freeway. Deficits demonstrated at age 18 are likely permanent, according to the authors, since lung development is nearly complete by age 18. See Gauderman, et al, "*Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study*," The Lancet Online February 2007; 368.

Ozone
PM_{10}
$PM_{2.5}$
Sulfur dioxide

A separate legal category includes "air toxics," for which there are no federal or State standards. Among these are 21 mobile source air toxics (MSAT) listed by EPA (see list below). These are emitted primarily from on-road mobile sources. Generally, on-road mobile sources and fuels contribute the greater amount of ambient (outdoor) air pollutants. Automobiles cause 50-80 percent of all combustion-related pollution, and contribute a significant amount of evaporative emissions of VOC's, many of which are toxic.[3]

Mobile sources are responsible for 44 percent of outdoor toxic emissions, almost 50 percent of the cancer risk, and 74 percent of the non-cancer disease risk, according to EPA's National Air Toxics Assessment for 1999. In addition, 70 percent of benzene emissions were attributed to mobile sources for that year. Benzene is a known carcinogen. In a mobile source air toxics (MSAT) rule finalized in March 2000, EPA listed the following 21 MSAT of greatest concern:

EPA's Listed Mobile Source Air Toxics

Acetaldehyde*	Diesel Exhaust	MTBE
Acrolein*	Ethylbenzene	Naphthalene
Arsenic cpds*	Formaldehyde*	Nickel cpds*
Benzene*	N-Hexane	POM (Sum of 7 PAH)*
1,3-Butadiene*	Lead cpds*	Styrene
Chromium cpds*	Manganese cpds*	Toluene
Dioxin/Furans*	Mercury cpds*	Xylene

Those MSAT designated with an asterisk are also on EPA's list of 33 Priority air toxics as denoted in its Integrated Air Toxics Strategy, formerly known as the Urban Air Toxics Strategy. Monitoring nationwide since 1999 indicates that air toxics levels in many 'rural' areas are similar to those found in urban areas, due to mobile sources. This is because substantial vehicular traffic in urban, suburban and even many rural areas creates a large amount of pollution. In fact, people living in less populated, non-industrial areas drive longer distances than do city dwellers, all visiting the same town centers for shopping and social activities, congesting the intersections and parking lots just as in cities. Thus, the Strategy has evolved to address the "integrated" issues of

[3] Various EPA and APCD fact sheets, regulatory background documents

urban, suburban and rural air toxics. The Integrated Air Toxics Strategy is a fluid one, and may evolve further. Per Colorado and other states' monitoring findings, the compounds crotonaldehyde, 1, 2, 4, trimethylbenzene, and 1.3, 5-trimethylbenzene may be added to EPA's MSAT list.

Traditional Risk Assessments and Limitations

Criteria Pollutant Risk and Uncertainties

Traditional human health risk assessments for criteria pollutants are conducted singly, pollutant by pollutant, as though each is the only pollutant of concern. For this reason, potential additive or synergistic effects of inhaling airborne pollutant mixtures known to be in ambient air are not considered. Further, risk to species other than human is considered secondarily, and not very extensively when EPA considers setting the standards. Because of this, non-human species may receive less adequate protection than humans.

Air Toxics Risk and Uncertainties

The CDPHE calculated risk results for air toxics have been monitored at three Denver sites and two in Grand Junction (2001-2003). Mobile source air toxics predominated and drove the risk as calculated. Excess cancer risk was well above the EPA "acceptable" (non regulatory) level of 100 per million at three of the sites, and at the acceptable level at two sites.

Table 13. Monitor Location and Cancer Risk

Monitor Location	Excess Cancer Risk	Major risk drivers (MSAT unless otherwise indicated)
CAMP station Downtown Denver, 21st & Broadway	200 per million	Crotonaldehyde Trichloroethylene (cleaning solvent for metal parts) Formaldehyde
Welby station, NE Denver industrial area	100 per million	Crotonaldehyde Formaldehyde 1.1.1.1. Benzene Arsenic (possibly from prior smelting operations)
Swansea Elementary, NE Denver	100 per million	Crotonaldehyde Formaldehyde Benzene Arsenic (possibly from prior smelting operations)

Grand Junction Traffic site (parking area)	200 per million	Crotonaldehyde Formaldehyde Acrylonitrile (chemical products industries)
Grand Junction Mesa Co. Health Dept.	200 per million	Crotonaldehyde Formaldehyde Benzene

Elevated risk levels (Hazard Index of 2) for non-cancer disease were calculated for non-cancer respiratory and neurological disease at CAMP, Swansea, and the Grand Junction traffic site. A Hazard Index of 2 for respiratory disease was calculated for the Welby site. A Hazard Index is calculated for multiple monitored chemicals that target specific organs or system, e.g., neurological. A Hazard Index of less than or equal to 1.0 is assumed to be safe.

The risk assessments for Denver and Grand Junction likely underestimated risk. Roughly 65 air toxics were monitored from 2001-2002 in Grand Junction, and from 2002-2003 in Denver. The 65 constitute a very small subset of the 188 EPA-listed air toxics, and are an even smaller subset of the many thousands of airborne compounds which are potentially toxic upon inhalation or other means of exposure. In accordance with the EPA standard risk assessment methodology, criteria pollutants were not included in the risk calculations (except for lead, which is in both categories).

The CDPHE is concerned about and is following up with additional trends monitoring, hot spot monitoring, and further assessment work in addition to exploring with EPA possibilities for more comprehensive risk assessment. Advances in this area will be shared with CDOT to improve risk assessment for the purposes of cumulative effects analyses.

♦ *The understanding that currently human and other species' exposure to air pollutants is understated should underpin cumulative effects analyses. This premise is qualitative at this writing but very important, and should be incorporated into all cumulative effects analyses. Statistical means to quantify the uncertainty should be explored by the APCD and CDOT.*

At this time, the following facts should be considered and incorporated in cumulative risk analyses:

(1) Monitoring for a suite of toxics will usually involve a small subset of EPA's listed 188 and an even smaller subset of the universe of toxic air pollutants;
(2) Certain air toxics known to be present in substantial quantities were not monitored in the 2001-2003 studies due to technological limitations. For example, mercury in its various phases and Acrolein are not easily measured. Acrolein is highly toxic and unstable, yet presumably widespread from tailpipe emissions, according to EPA National Air Toxics Assessment 1999 and draft 2002 work. Mercury from power plants, vehicle exhaust and other sources is also thought to be ubiquitous and harmful via inhalation and ingestion;
(3) Naphthalene levels appear to be increasing nationwide, yet this was discovered only in the years since the Colorado monitoring was underway; thus Naphthalene was not included in the suite of chemicals monitored from 2001-2003. Naphthalene is a component of diesel exhaust, and is also used to treat wood products such as railroad ties and telephone poles; and,
(4) Unexpectedly, the toxics 1,2,4-Trimethylbenzene and 1,3,5-Trimethylbenzene were monitored in relatively high amounts, adding to cumulative risk. These compounds are sometimes added to gasoline, thus may be of mobile source origin.

Improving Risk Characterization: New Monitoring Protocols and TRIM Model

EPA and others are working toward improved, quantified, risk characterization. Monitoring protocols for Mercury, Acrolein and Naphthalene plus some additional air toxics have recently been developed by the EPA. The APCD has monitored in Grand Junction for Acrolein for the past two years (2005 and 2006) and seen high levels of this combustion-related MSAT. Future monitoring studies and risk analyses should be able to include naphthalene and mercury, as well.

EPA is developing risk factors for criteria pollutants. The process is being undertaken in conjunction with Total Risk Integrated Methodology (TRIM) model development, for improved risk characterization. It is hoped that the risk factors will be useful for analyses outside of TRIM modeling, and the APCD is exploring this avenue.

The three TRIM models within the methodology have been the subject of peer review and publication. The method will assess risk to human health, and may be of use to supplement work regarding risk to other species.

♦ *The Air Division has committed to keeping CDOT and stakeholders apprised regarding development of risk factors for criteria pollutants and their fitness for incorporation into cumulative risk analysis work. Similarly, when TRIM or other more comprehensive risk assessment models become viable, the APCD will work with CDOT to incorporate them into cumulative risk analyses as appropriate.*

Ozone

Under the 8-hour ozone standard, EPA has deferred a nonattainment designation for an area that includes the Denver Metropolitan area, portions of Weld and Larimer counties, and an eastern portion of Rocky Mountain National Park. In spite of increasing controls on VOC's from the oil and gas industry, ozone levels measured in 2005 and 2006 were high enough that the area may be found in violation of the 8-hour standard, depending on levels recorded during the 2007 ozone season.

Numerous studies indicate there is no "safe level" of ozone inhalation for humans[4], yet the 8-hour national ambient air quality standard is currently set at 80 ppb, which is twice presumed natural background levels of 30-40 ppb, per EPA. Background levels of ozone are derived from VOC's produced by plants, and NOx from natural combustion sources such as volcanoes and wildfires.

While the 80 ppb standard is likely not protective enough of human health, it appears to be even less protective of plant life. Lichens and many plant species including crops and trees are extremely sensitive to ozone exposure.

Ozone enters leaves through stomata during normal gas exchange. A strong oxidant, ozone *at ambient levels* causes several symptoms, including chlorosis and necrosis (leaf discoloration

[4] Author's reading of EPA documents on this issue since 1997, in addition to EPA/CDC findings published in Environmental Health Perspectives, February 2006.

from damage, and death), as repeated field studies have shown. Crop yield loss is especially pronounced in dicot species, such as soybean, cotton and peanuts.[5] Fruit trees, willows, aspen, Ponderosa pine are among the 106 trees and other plants shown to be especially sensitive to ozone. Another 81 varieties are suspected of being sensitive to ozone.[6]

Summertime ozone levels are elevated at the Park, and two exceedances of the 8-hour ozone standard were recorded in the past ozone season (2006), according to National Park Service data.

♦ *CDOT and the APCD should pursue mapping of a wider variety of plant species present in transportation regions of concern, noting their sensitivity to ozone, as well as mapping of ozone levels past and projected.*

Nitrogen Deposition at Rocky Mountain National Park

Nitrogen Deposition (derived from Oxides of Nitrogen {NOx}, and Ammonia) at Rocky Mountain National Park is well studied. Several studies indicate that soils, water, aquatic life, and plant species in the Park show evidence of changes due to nitrogen deposition.[7] Current deposition levels have increased at a rate of 2% per year for the past 20 years, and are now 40 times what they were in 1950. The nitrogen over-fertilizes some plant species and causes toxic effects in others. Among the observations are:

- Increased microbial activity in soil and talus
- Grasses and sedges out-competing native flowering plants, which could reduce habitat for some animals, and may be favoring the larger-than-desired elk population
- Lake and stream fertilization and acidification leading to altered species of diatoms (oxygen-producing algae)

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[5] *Effects of Ozone Air Pollution on Plants,* US Department of Agriculture website, 12/5/06.

[6] *Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Service Lands,* NPS Air Resources Division and USF&WS Air Quality Branch, 2003.

[7] *Nitrogen Deposition: Issues and Effects in Rocky Mountain National Park: Technical Background Document*, RMNP Initiative, March 2004.

- Old-growth Engelmann spruce on the east side of the Continental Divide (which has more traffic and other anthropogenic activity) show significantly altered chemistry due to nitrogen deposition relative to the spruce west of the Divide.

Future ecosystem effects may include fish die-offs,[8] and subsequent changes in their predator species. While the NOx contribution from mobile sources is projected to decrease in the future, motor vehicles are now and will remain a significant source of Nitrogen in the Park, from NOx and ammonia. Ammonia emissions from vehicles are projected to increase. About one-third of the NOx inventory (2002) is attributed to on-road mobile sources. Ammonia from autos and other sources, including agricultural, also contribute to the elevated Nitrogen levels. Ammonia emissions are projected to increase overall because of new catalytic converters, with the mobile source sector contribution increasing to 15% (up from 12% currently). Nitrate particulate deposition in the Park is dominated by in-State sources, including traffic from I-25 North.[9]

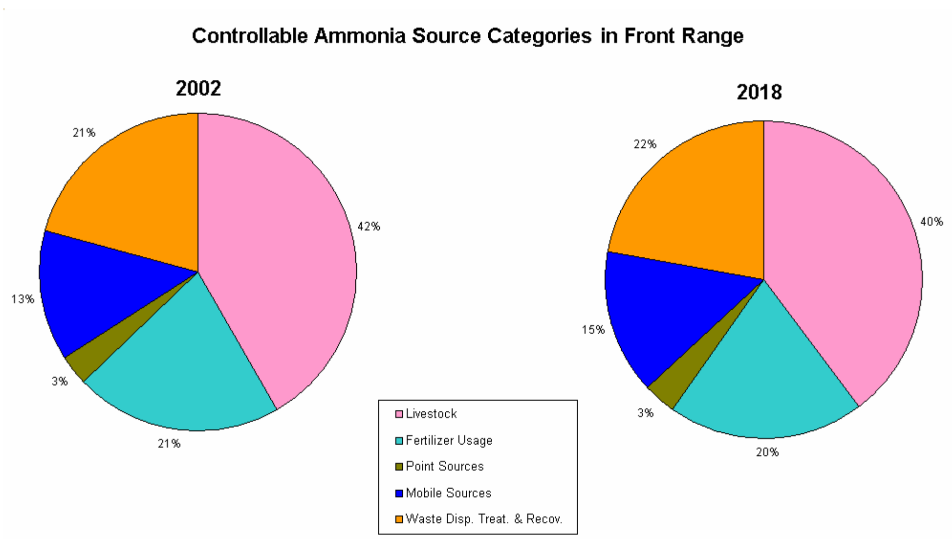

Figure 2. Controllable ammonia source categories in Front Range

Regional Haze

[8] Ibid, Executive Summary.
[9] Taipale, Curtis, 2007 Presentation of WRAP data and back trajectory analyses.

Regional Haze is another air pollutant problem at the Park and elsewhere in the State. It is thought that mobile sources contribute substantially to haze, especially with emissions of NOx and organic carbon from vehicle exhaust. The Division is preparing a Regional Haze SIP, due to EPA December 17, 2007.

Pollutant Trends

Predicted trends for many pollutants, including NOx, are downward. Monitored levels of benzene have decreased in the Denver Metro Area from the 1980's to the present. Tier II standards for vehicles and low-sulfur standards for gasoline and diesel fuels are the main controls. These standards are projected to address levels of air toxics to some degree, as well as the targeted criteria pollutants. Still, it must be noted that significant pollutant contributions from mobile sources will remain, and the APCD would urge CDOT to consider mitigation to reduce air toxics, NOx, and other pollutants beyond levels that may be achieved via EPA tailpipe and fuel standards.

Potential Mitigation Measures

An important fact to remember when considering mitigation is that when natural habitat is lost to roads (or buildings or parking lots), natural "sinks" for toxics such as wetlands disappear. Plants and trees that once converted carbon dioxide into oxygen are lost. This phenomenon compounds the effects of air pollutants then caused by vehicles (and stationary sources).

Reducing future emissions by reducing potential VMT is the primary means at CDOT's disposal. It has been demonstrated that growth in VMT follows highway expansion projects, and it has been asserted that project curtailment, or even no-build decisions may be the best means to control VMT growth and corresponding vehicle emissions. (See for example the *Handbook on Integrating Land Use Considerations into Transportation Projects to Address Induced Growth*, prepared by ICF Consulting for the American Association of State Highway and Transportation Officials, March 2005; Wagner and Oman, *The Nature of Roads, Induced Growth and the Endangered Species Act: A Practical Approach for Addressing Indirect Effects of Transportation Projects in ESA Consultations*, Road Ecology Center, University of California at Davis, 2001.)

A list of potential mitigation measures thus includes the following:

- Opting for the no-build scenario, if a project would be likely to induce traffic growth
- Project curtailment if in a sensitive area
- Mass transit alternatives in lieu of designs favoring single occupant vehicles (SOV)
- High-occupancy vehicle (HOV) lanes
- Bicycle lanes or trails
- Other multi-modal options
- Pedestrian-friendly thoroughfares
- No-drive/no parking zones near sensitive areas
- Traffic roundabouts in lieu of signage or signal lights at intersections where roads or highways do exist or must be built

Several studies in Europe and the US indicate that substantial emission reductions result when "modern" roundabouts are substituted for signage at intersections. One study looked at six intersections where roundabouts replaced stop signage—5 in Kansas and 1 in Nevada—and concluded that emissions of several pollutants were dramatically reduced in the intersection areas:

- Carbon monoxide (CO) emissions were reduced an average of 21 percent in a.m. hours and 42 percent in p.m. hours.
- Carbon dioxide (CO2) emissions were reduced an average of 16 percent in the a.m. and 59 percent in the p.m. hours.
- Average NOx emissions were reduced 20 percent in the a.m. and 48 percent in the p.m.
- Average hydrocarbon emissions were reduced 18 percent in the a.m. and 65 percent in the p.m. hours.[10]

The emission reductions are attributed to elimination, or near elimination, of idling, as stopping is generally not necessary at roundabouts. However, in very heavy traffic periods, queues could form as vehicles wait to enter a roundabout.

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[10] Mandavilli, Russell and Rys, *Proceedings of the 2003 Mid-Continent Transportation Research Symposium*, Ames, IA, August 2003.

Air Quality GIS Information Available to the CCEA Protocol

CDPHE and APCD are mapping a variety of data into GIS format, and the following is a sampling of what is currently in place, and in development. CDPHE/APCD are most willing to share data with other agencies. That which is not readily accessible via a website may be obtained by request. At this time, the APCD has fairly limited unique spatial data. Most of the data are in tabular format, which in some cases can be joined with or related to common spatial datasets (Counties, Roads, Cities, etc.). The following information regarding map sites may be of use in the CEA protocol:

- The current air quality index (AQI) data, formerly known as Pollutant Standard Index (PSI) data, has loose geographical ties to a region based on the containing metro Area (Poly) e.g., the Denver metro area, the Colorado Springs metro area, the Ft. Collins and/or Greeley and/or Loveland and Grand Junction metro area. Please see http://apcd.state.co.us/air_quality.aspx

- AQI data can also be accessed based on specific Air Quality and/or Meteorological Monitoring Site (Point), date and/or other parameters: http://apcd.state.co.us/report.aspx

- A map of Real-Time Monitoring Sites with data from AQI monitoring locations: http://apcd.state.co.us/aqi_map_ve.aspx

- An AQI map in ArcIMS: http://emaps.dphe.state.co.us/AP MonSite/viewer.htm

- Another method for accessing AQI data via an ArcIMS map interface is the Emission Inventory which is tabulated by County (Poly) though the emissions data can only barely be considered to have spatial component and only loosely be defined as having a "point-in-polygon" association. Other examples of polygon boundaries used to define and tabulate AQI data are Ozone Attainment Areas (Poly) and Class 1 Areas (Poly) or other areas where visibility is protected for recreation, e.g., Rocky Mountain National Park. http://emaps.dphe.state.co.us/apinv/viewer.htm

- There is also the APCD's Mobile Sources/DRCOG VMT Roads (Line) attributed with Vehicle Miles Traveled (VMT), a calculation which is basically [VMT = length * volume] as a part of a combined SIP with DRCOG and CDOT.

- The APCD's permitting program manages the permitted Stationary Sources (Point). There are shapefiles and KML versions of these data points, in addition to area calculations with Land Use (Grid) and pie-shaped Sectors (Poly) around a stationary source. See also the bio-terrorism modeling software and data used by our chief Meteorologist, which includes Surfer, CATS, HPAC and other tools to create plumes and back trajectories for various Emergency Response (ER) events and scenarios.

- A CDPHE link to summary Colorado health information is: http://www.cdphe.state.co.us/cohid/

- Colorado Health Institute Data-At-A-Glance: http://datacenter.coloradohealthinstitute.org/

Continued Progress with the ACCEA Protocol

As transportation of people, goods and information is necessary to our lives, and as air pollutants remain an unintended side effect of many transportation modes, the APCD commits with CDOT to further explore evolving methods for risk assessment and to develop the needed technical components for cumulative effects analyses. As mentioned earlier, this chapter should be read as a work in progress. It is hoped that the ACCEA process will proceed to Phase II.

3.4. Conclusions

The results of the workshops suggest that regional accounting is technically feasible based on availability of data, models and metrics. Although many of the detailed proposals for a regional accounting framework were controversial in the workshops, participants generally were positive about the overall approach. Possible applications of regional accounting were identified both for transportation planning and NEPA assessment. We explore these applications further through a demonstration of accounting methods in Chapter 4.

Data

We classified data into two groups: areawide and local. Areawide data can be obtained in consistent formats for the entire Denver metropolitan region. Local data are collected by jurisdiction and available only for limited areas. Each of these data types may be collected in a time series, and this time series may extend backwards to include historical data.

Areawide data are available for almost every topic examined through this project. These can be obtained with modest effort to download from public sources and collate to common formats. Time series data are not available in many of the resource areas. However, there is a number of time series data sources that have not been employed widely for regional environmental accounting. These include, for example, county assessor's files that can be used to identify past, present and future development. Issues of data consistency also emerged. While many datasets are consistent across regions (e.g., Colorado Vegetation Classification Project - CVCP) others use inconsistent attributes and collection dates (e.g., assessor datasets).

Spatial Models and Methods

We classified spatial models for analysis of environmental effects into three groups. These classes of models have varying implications for cost, likelihood of implementation, credibility and ease of understanding. (1) *Simple models* include buffers on affected areas or features, delineation of roads, trails and water features across networks, overlays of affected areas, and tabulation of affected roads and features. (2) *Mid-range models* include weighted overlays of affected areas, habitat suitability analyses (HSI), and connectivity analyses. (3) *Complex models* include impervious cover analysis, transportation/land use analysis based on traffic analysis zones, and models of urban growth dynamics.

In many cases simple models may be adequate to support the kinds of analysis required for regional accounting. Some mid-range models have been developed sufficiently so that they can be applied immediately in the region (e.g., HSI). Application of other methods (e.g, connectivity analysis) may require further research. Project participants identified policy-relevant spatial models for almost all topics addressed through the workshops. For some environmental accounting topics, sophisticated models have been developed by researchers and applied extensively in practice (e.g., water quality and transportation/land use models). These models should be used if they are credible to the technical staff of relevant agencies. Overall, however, participants emphasized the value of simple models that are broadly understandable and easy to apply. Some participants argued that spatial models in many cases are insufficient to document environmental significance under NEPA. However, most participants agreed that use of spatial models can improve CEA analysis if they help quantify regional context and delineate the contribution of individual projects to regional environmental change.

Metrics

We grouped metrics in five categories. These categories describe the policy relevance of each metric and its utility for regional accounting. *Regional standards* include those about which there is general agreement among relevant agencies across the region. These are typically defined by clear statute or administrative rule. We identified two metrics that meet this test: (1) threatened and endangered species (no take or current condition); and (2) federal-regulated wetlands (no net loss). The regional standards described below can be used immediately across the entire region in both NEPA and planning environments (although technical questions remain about their application). *Local standards* are designated in local or state statute or strong policy statements such as general plans but apply only to limited areas within the region. We identified three types of metrics that met this test: (1) water quality (e.g., CDPHE quality of stream reaches); (2) park and recreation areas (e.g., per capita land dedicated to neighborhood parks); and (3) species protection (e.g., carrying capacity for prairie dogs). Local standards can be used immediately but only as a mosaic with some areas left undefined. *Practice-based and scientific thresholds* are not defined in statute or policy but have undergone a formal process of vetting and assessment within scientific or professional communities. These may include, for example, habitat requirements for species not covered under the Endangered Species Act. These are appropriate for regional planning activities. *Benchmarks* are not defined by clear scientific or statutory thresholds but can be scaled in a meaningful fashion. We handle these metrics by proportional scaling to identify magnitudes of change in resource quality. We emphasize the five-point scale described above. These also may be useful in regional planning environments. *Metrics requiring further research and discussion* are associated with uncertainties about underlying science, measurement or scaling. These include, for example, connectivity measures for specific species such as Preble's, where migration patterns and effects of population migration are not well understood. Metrics for further research and discussion require additional vetting before they should be introduced into either NEPA or planning environments.

Workshop findings indicate that there are two spatial metrics in the set we analyzed that are generally accepted across the region, and are technically adaptable to regional accounting. Assuming that there is acceptance of the methods described in Chapter 4 of this report, these metrics should be useful immediately for project-level CEA review. A much larger number of local standards and practice-based metrics are also technically feasible in the context of NEPA analysis and regional transportation planning. These are credible for project-specific NEPA review although not yet generally-accepted; they provide a foundation for further development. In terms of regional transportation planning, local standards, practice-based metrics and benchmarks all may be suitable. Finally, metrics such as connectivity-based landscape measures should be a focus for further research in the region.

The workshops also suggest, however, that development of a range of metrics that can be applied directly to NEPA review will require significant effort. We were unable to reach agreement about thresholds (critical levels of resource quality) for many of the resources addressed in the workshops. Participants tended to agree about thresholds for resources with clear statutory or administrative guidance (e.g., threatened and endangered species). In this respect, the workshops clarified the importance of launching a collaborative effort across agencies, local governments and other stakeholders to obtain a common understanding of the data and models, establish validation of the models, acknowledge priorities and preferences of participants who would use the models, and integrate model usage into administrative processes for decisions. Coordination across agencies, local governments and stakeholders should continue to be a focus of areawide cumulative effects assessment in CDOT.

Overall, the workshops clearly demonstrate the feasibility of a regional accounting approach based on derivation of metrics from GIS data and models, and scaling of metrics to provide a consistent accounting framework across projects, resources and areas. However, the workshops also suggest that opportunities for implementation of spatial accounting methods vary significantly by resource. Regional tabulations may not be appropriate for certain resources. For example, some participants argued that water quality may be best assessed at the watershed scale and could not be accounted reliably across a region. Nonetheless, the principle of regional accounting was supported by workshop findings, and generally embraced by workshop participants.

4. ACCEA DEMONSTRATION PROJECT

4.1. Description of the Project and Potential Effects

4.1.1. Summary

In this section of the report we describe a demonstration of regional accounting methods in a case study area of the C-470 Corridor. The primary method we use for this accounting is tabulation of effects at regional, local and project scales. These tabulations are constructed on a growth model described in Section 4.2 of this report. This growth model relies on DRCOG projections to create a low-resolution allocation of population across the entire region, and builds on a high-resolution (logistic regression) model and expert judgment to assess growth patterns in the vicinity of the project that may be directly or indirectly affected by it. We discuss induced development effects in this context, although a full treatment of induced development is outside the scope of this report. We then take the population allocations of the growth model both on a regional scale and in the vicinity of the project to assess the effects of these growth patterns on extent of impervious cover, black-tailed prairie dog habitat, and Preble's habitat. We organize each of these sections according to the overall approach described in Chapter 2 of this report. We define the project, how effects are likely to occur both as a result of the project and other activities, and what areas are likely to receive effects. Then we sum affected resources by area on three scales (project area, local area and region) and calculate the contribution of the project at each of these scales.

4.1.2. Project Description

The (hypothetical) C470 corridor project from Kipling to I-70 is intended to provide the case study for the demonstration project (Figure 3). There are planning activities directed to providing highway capacity to complete the connection from I-25 south to I-70 west. The original project was built in 1980 and there are various capacity enhancements being discussed ranging from additional lanes to toll lanes only. Adding capacity to local highways is an additional option. The regional boundary for the demonstration project is taken to be a modified DRCOG urban growth boundary (Figure 4**).**

Figure 3. Demonstration project is the C470 link between Kipling (first street west of Route 121) and I-70

Land use development along the C470 corridor has changed dramatically over the past twenty years. The undeveloped lands formerly part of the area have been replaced with a significant increase in residential, commercial and office uses adjacent to the highway corridor, especially in

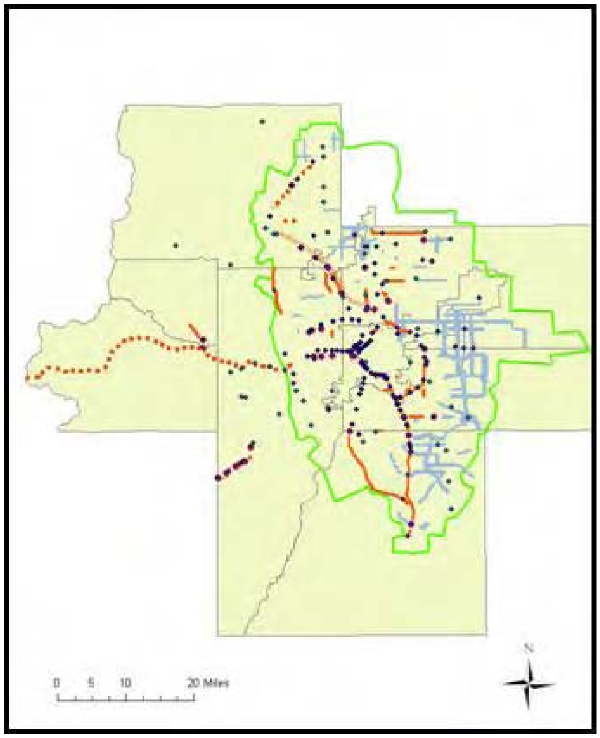


Figure 4. The regional boundary is a modified DRCOG urban growth boundary

the southern portion of the corridor. The developed land use patterns have been primarily suburban in nature with low density planned developments and an auto orientation.

Details on potential impacts (direct, indirect and cumulative) are addressed in demonstration project resource sections below. The focus of this demonstration project is to tabulate cumulative effects for the local scale and region. For this ACCEA demonstration project we focus on three realms of potential impacts: 1) land use, 2) biological resources and habitat, and 3) water quality. Our emphasis is on demonstrating the utility of GIS data management and modeling tools to develop an accounting of these resources for areas proximate to the C470 roadway right-of-way, the local area where indirect effects might occur, and the region.

4.1.3. Temporal Scope

Past, present, and reasonably foreseeable actions are considered in this report. Our determination of how far we go into the past and how far into the future is based on the nature of the project, the history of the corridor, and availability of data. We date past effects to 1980 because construction of the existing freeway began at that time, with the first segment completed in 1985 and the entire C-470 facility completed in 1990. The corridor as it currently exists has largely been shaped by this transportation investment. Our primary data sources for the past period are assessor's records and aerial photographs. Our analysis of historical development patterns between 1980 and 2000 provides the basis for our growth model. We select the period 2000 to 2005 as the present; this serves as the project baseline. A variety of data sources are available for the present period. The future time frame for this analysis is the year 2030, which is the horizon year for the DRCOG Metro Vision 2030 Regional Transportation Plan. We project population allocations and environmental conditions to this future date using models and other methods.

4.1.4. Geographic Scope

The geographic scope for C-470 cumulative effects analysis is variable depending on the resources affected by the project. For land use the geographic scope is guided by topographic and geopolitical factors such as community or county boundaries. The area of influence of a highway on urban development is guided by modeling of land allocation factors and may extend some distance from the highway interchanges. For biological resources the geographic scope is keyed to the ecosystem, habitat zone or watershed. Water quality geo-scope is typically the stream and watershed (and sub-basins). The appropriate geographic scope for cumulative effects analysis for resources and issues pertinent to the C470 demonstration project are described in the resource sections below.

4.1.5. Summary of Cumulative Effects from the C-470 Project

Our primary presentation of cumulative effects is contained in four tables that describe and compare regional, local and project-area effects. The contribution of the C-470 project to regional effects is represented by a percentage in the lower right hand corner of each table. These tables correspond to the four types of cumulative analysis described above: "Current and Forecast Urban Development at the Regional, Local and Project Scales - High-Density Growth Scenario"; "Current and Forecast Impervious Cover at the Regional, Local and Project Scales - High-Density Growth Scenario"; "Current and Forecast Acres of Black-tailed Prairie Dog Habitat at the Regional, Local and Project Scales, by Level of Habitat Quality"; and "Current and Forecast Acres of Preble's Meadow Jumping Mouse Habitat at the Regional, Local and Project Scales, by Level of Habitat Quality". These tables encapsulate the key components of the cumulative analysis.

4.1.6. Summary of Cumulative Effects from the Regional Plan

This method can be used to roll-up all proposed transportation investments in the regional plan and consider effects on primary resources simultaneously. A roll-up of this kind requires tabulations such as proposed for C-470 for each of the targeted projects in the regional plan and summation of these tables in a general accounting for the region. We argue that with development of an infrastructure of data-sharing, modeling and expert judgment, these tabulations will be much less costly than a project-by-project ACCEA effort.

4.1.7. Thresholds and Other Metrics

Our indicators describe acres and percentages of change in developed land, impervious cover and habitat. In many cases we were not able to identify thresholds to describe the importance of different levels and rates of change according to scientific knowledge or administrative practice. We did not have a strong foundation for definition of importance for all resources because participants in the workshops did not converge on agreement about thresholds in many instances. Agreement about these resources may require a concerted and probably mediated collaborative effort beyond the scope of Phase I of the project.

4.2. Land Use and Cumulative Development Effects

4.2.1. Scope

In this section we describe a method developed through the ACCEA project to evaluate cumulative effects of transportation investments on urban development patterns. In later sections of this chapter we apply this method to the hypothetical C-470 Corridor project and use it as a basis for assessing cumulative project effects on specific resources such as black-tailed prairie dog. This method relies on readily available spatial data and models as well as interviews with individuals involved in local development processes. We developed this approach drawing on methods currently used in land use planning and impact assessment practice, focusing them on the requirements of areawide CEA. An important feature of this analysis is the definition of development rules - derived from review of local and regional policies – that indicate whether or not specific parcels are likely to be built out. Because growth projections typically involve controversy and uncertainty, we incorporate information from multiple sources and seek to identify areas of agreement and disagreement. Our method has six steps: (1) inventory past and present development patterns; (2) synthesize plans and policies that guide future development; (3) create a model of primary future development; (4) create a model of induced future development; (5) ground truth model outputs with developers and planners, and (6) tabulate and compare project-based and cumulative development effects.

Land Use Inventory – The purpose of the inventory is to describe past and present development patterns. These data are then used as a basis for projecting future patterns. We employ a range of planning and land use datasets including parcel-level assessor's data, spatially-explicit land use plans, spatial outputs of DRCOG regional land use-transportation models, and parcel ownership data. These datasets are very large, on the order of several hundred thousand records per county, and are stored in a relational database (PostgreSQL). All data are indexed by our lowest-level geographic units: parcel and traffic analysis zone (TAZ). These provide the building blocks for the subsequent work in this project to account for change in habitat and environmental conditions.

Policies and Plans – Our approach to CEA focuses on development guidance provided by local and regional plans and policies. The planning and policy documents of primary interest to us are regional transportation plans, regional growth management plans, county and municipal comprehensive plans, area plans and local investment plans. We synthesize these plans in two ways: (1) generalize planning rules so that they can be used effectively as filters, and (2) overlay plans to identify areas of consonance or dissonance, agreement or disagreement. We use these overlays to structure discussion with developers and planners as described later in this document.

Growth Models – Growth models present problems of nesting, resolution, and allocation of development by land use and density. Two types of primary development models are employed in this project: a regional, large-grain model of housing and employment change; and, a local, high- resolution model of land use change. The regional model, based on Traffic Analysis Zones, is developed by DRCOG and modified by project staff to increase its resolution. The local model is built on statistical (logistic) analysis of historical land use change at a parcel level. It focuses on characteristics of the parcels themselves including transportation accessibility, and is designed as a relatively low-cost model that can be applied using information readily available to DRCOG and local governments. The two models are nested in the sense that we evaluated the TAZ population and employment allocations using our high resolution growth model. We modified resolution of the TAZ model using a high-resolution parcel-based local model, because higher resolution at both scales is necessary to support the calculations of extent of impervious cover and habitat that are described later in this chapter. **Environmental effects occur in a fine-grained pattern and cannot reasonably be captured with a coarse-grained growth model.** Allocation of development by major land use type and density are also necessary to capture the effects of development on impervious cover and habitat. We are comfortable with our selection of TAZ and logistic growth models for the purposes of this prototype, but wish to emphasize that other models could also be used if they satisfy four requirements: (1) nesting of a fine-grained local model in a coarse-grained regional model; (2) allocation of development by major land use type; (3) allocation of development by density; and (4) high (sub-TAZ or parcel) resolution.

Induced Development Models – Induced development refers to growth stimulated by road investment including residential, commercial, industrial and infrastructure developments attributable to the improved accessibility provided by a specific road project, without which the development would not occur (Ewing, 2002). These effects occur on two primary scales, local (related to streets and county roads) and regional (related to state and federal highways). We assess both types of effects in the land use change model measuring accessibility by distance to the nearest county road, state road or highway interchange. In land use/transportation analysis, development locations are a function of both travel cost and adjusted land value, which in turn are a function of accessibility. In the context of a centric region, the logic of induced development suggests that expanding accessibility is associated with increasing dispersion of development. According to this logic when a new highway is built into undeveloped areas and increases their accessibility, employers tend to seek locations in these areas in search of cheaper land (Noland and Lewison, 2001). Such effects were empirically assessed by Boarnet et al (2000) in a study of the effect of toll road construction in Orange County, CA. They found that homebuyers were willing to pay for the increased access provided by new roads, and move to places with better access. Induced development effects are complex, however. Road construction can also concentrate new development in specific areas. For example, Hansen et al determined highway expansion stimulates development activity in the expanding corridor (Hansen et al, 1988). There may also be a relationship between increasing lane miles and residential densities, workplace densities, and vehicle miles traveled (Noland and Lewison, 2001). Finally, the maturity and structure of the transportation system are important in estimating induced development effects. These and other methodological problems make it difficult to confidently estimate induced development, and the scope of the project did not permit sufficient focus on induced development to address these issues.

Expert Judgment –We also thought it important in this project to collect information from local "experts" who may have important information about proposed projects, community preferences and land market processes which are not captured in models or local and regional plans. This process enables individuals who are familiar with local situations to modify the policy information and development models described above. We used map-based interviews and a focus group to capture this information, and created a web-based interactive map intended to facilitate comments from individuals who could not attend the focus group.

Tabulation and Comparison – Finally, we developed a framework for comparing effects at regional, local and project scales. This framework supports tabulation of the contributions of the proposed project to areawide cumulative effects. This framework can also be used to evaluate the contributions of all other transportation projects in the regional plan to total cumulative effects across the region. The product of this method is a table that identifies the number of affected acres as a proportion of all affected acres across the region.

4.2.2. Data

There are four primary data sources for this project: (1) county assessor's and zoning data; (2) local and regional planning documents; (3) projections of change in residential development over the next 20 years; and, (4) projections of change in residential, commercial and industrial units over the next 20 years, as estimated and tabulated by DRCOG;

4.2.3. Project and Local Area Method

We describe a comprehensive approach below. Based on costs and specific project needs, individual activities outlined below may be truncated. We begin with the method for the project and local area, and follow with the regional method.

Step 1. Inventory Past and Present Land Uses. Build an inventory of past and present land use patterns and developable lands. This inventory relies on high-resolution spatial data. It includes two stages:

- *Past and present land use patterns* – In the first stage we map past development patterns (Figure 5) and current developed land based on the yearbuilt field in the Jefferson County assessor's data. In this model, we operate on the assumption that residential development will not be replaced unless local jurisdictions have specific plans for commercial and industrial development in that location. Using the yearbuilt field describing year of construction, these tabulations can be classified into past and present categories. In the case of Western Jefferson County (for which data are available), we have classified these as development prior to 1980 and development post between 1980 and 2000. These data provide trend information and are used in the growth model described below.

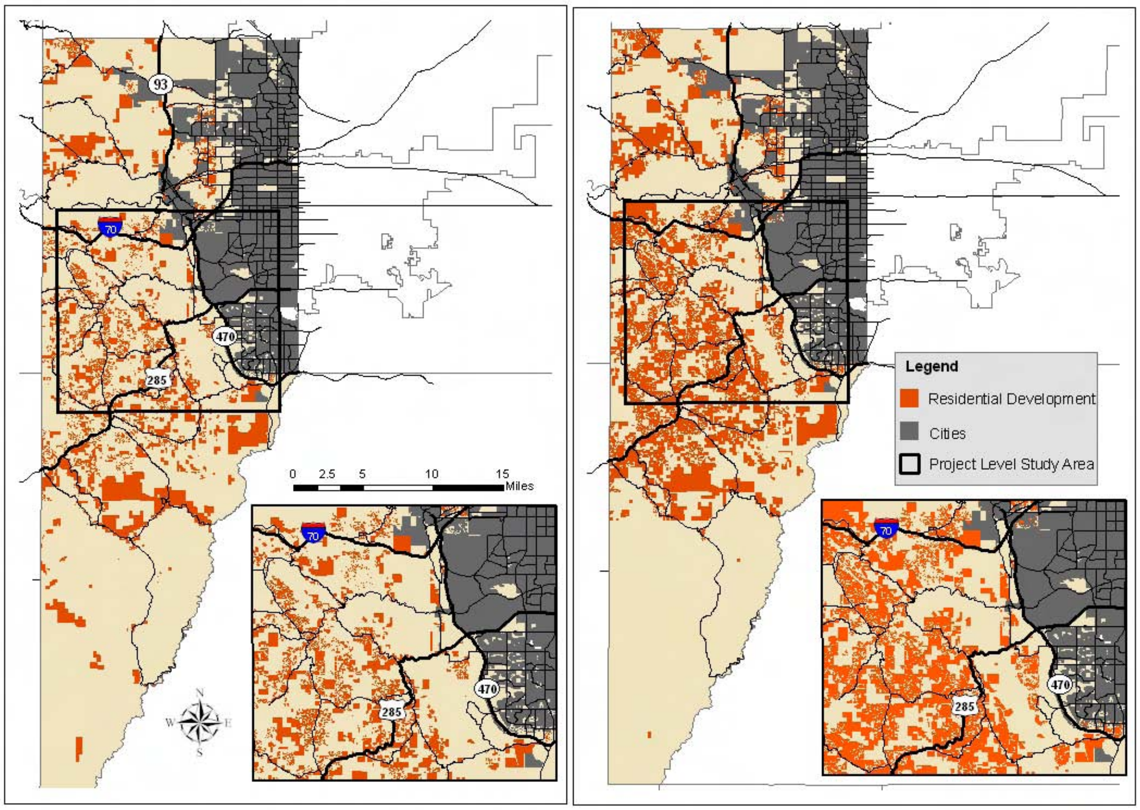


Figure 5. Past and present development, Jefferson County, 1980 (left hand map) and 2000 (right hand map)

- *Developable lands* – In the second stage we map currently undeveloped parcels available for further urban development (Figure 6). Potential for development is defined in terms of ownership pattern and property rights. We assume that parcels under federal, state and some local public ownership are unlikely to be developed. If we can identify deed restrictions in the form of conservation easements on privately owned lands, then we also constrain these lands from further development.

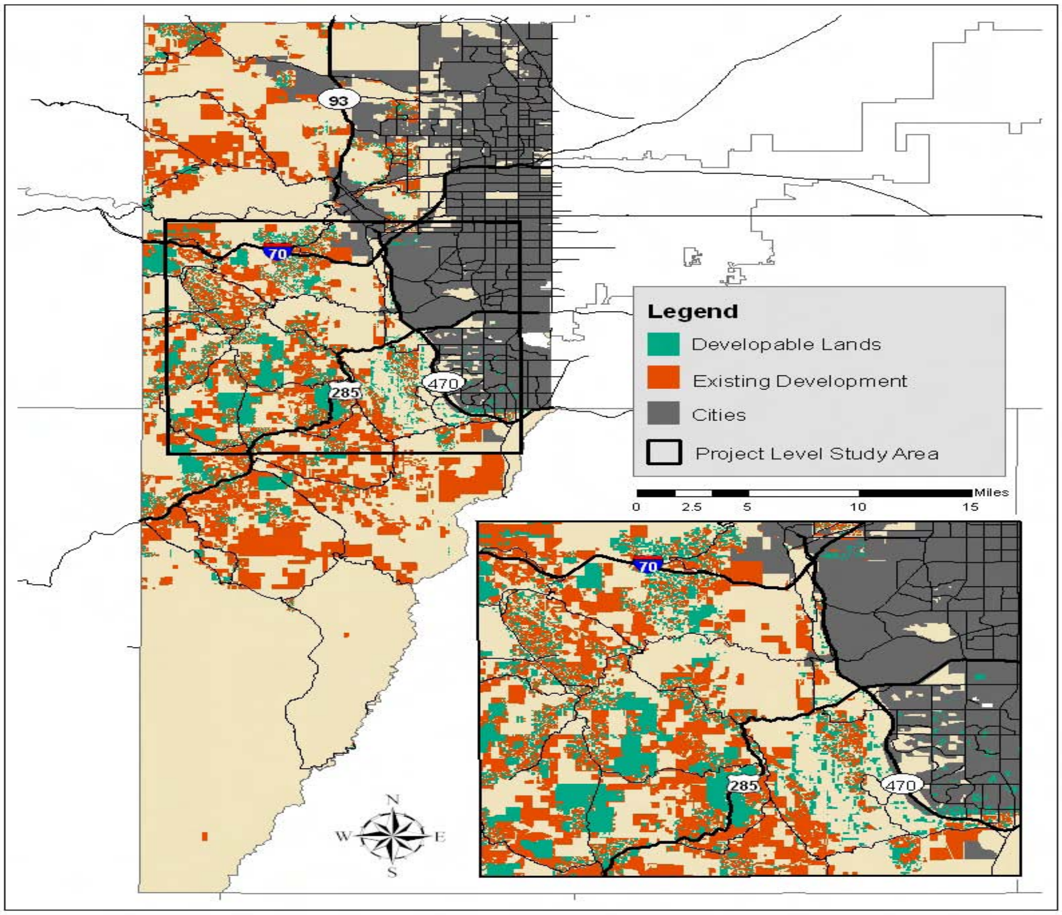


Figure 6. Current developable Parcels in Jefferson County (2000). Study area is outlined in black and presented in the inset map

Step 2. Review Local Plans and Regulations. In the first stage of this activity, we review documents of three types.

- *Local land use regulations* – In the first stage, we evaluate zoning and other land use regulations to see how these regulations effect the inventory of developable parcels for further development (as defined above). Zoning codes are reviewed. To ascertain the parameters of possible land use change on each available parcel we focused on the 'allowable uses' and the minimum lot size requirements in each zoning district.

- *Local land use plans* – including comprehensive and area plans prepared by counties and municipalities within the study area. Land use plans provide additional information about how local governments may be guiding the type and location of growth.

- *Local investment plans* – including proposed local infrastructure investments such as capital improvement projects, water, sewer and public facilities. These plans indicate where infrastructure investments are likely to occur; infrastructure investments are likely to influence growth dynamics in the project area.

Where comprehensive plans are unclear or controversial, zoning may provide the most effective guidance. After discussion with local and regional planners, we decided to focus on two local planning documents: zoning regulations and the area plan for the C-470 area. The area plan includes investment proposals. We prepared these in three steps for use in further analysis. (1) We synthesized Jefferson County zoning rules for density and use into simple categories that could be readily mapped. (2) We evaluated the C-470 Corridor Plan, concluding with the simplifying assumption that all developable lands within the corridor would be built out to a relatively high density. Finally, (3) we mosaiced zoning rules with the C-470 Corridor Plan to create a unified map of future land uses. With this map, we create a surface of local land use policies into which we can allocate future growth.

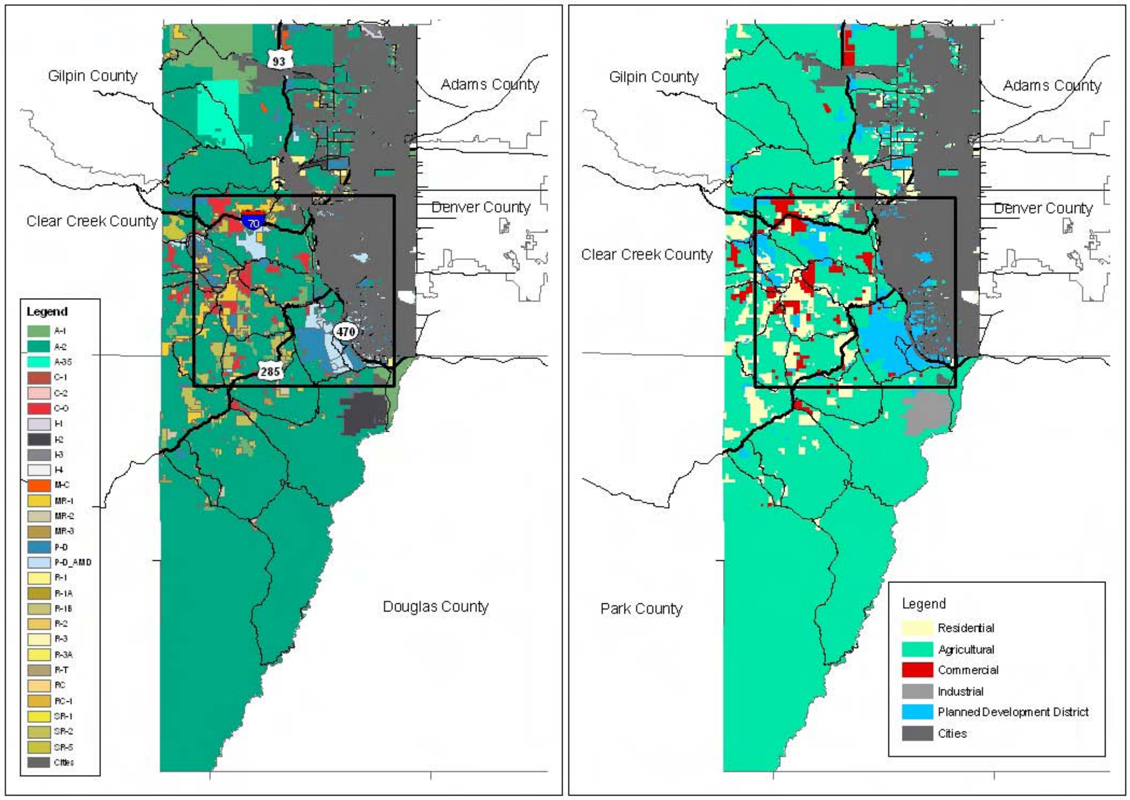


Figure 7. Zoning (Left Hand Map) and zoning simplification (Right Hand Map), Jefferson County

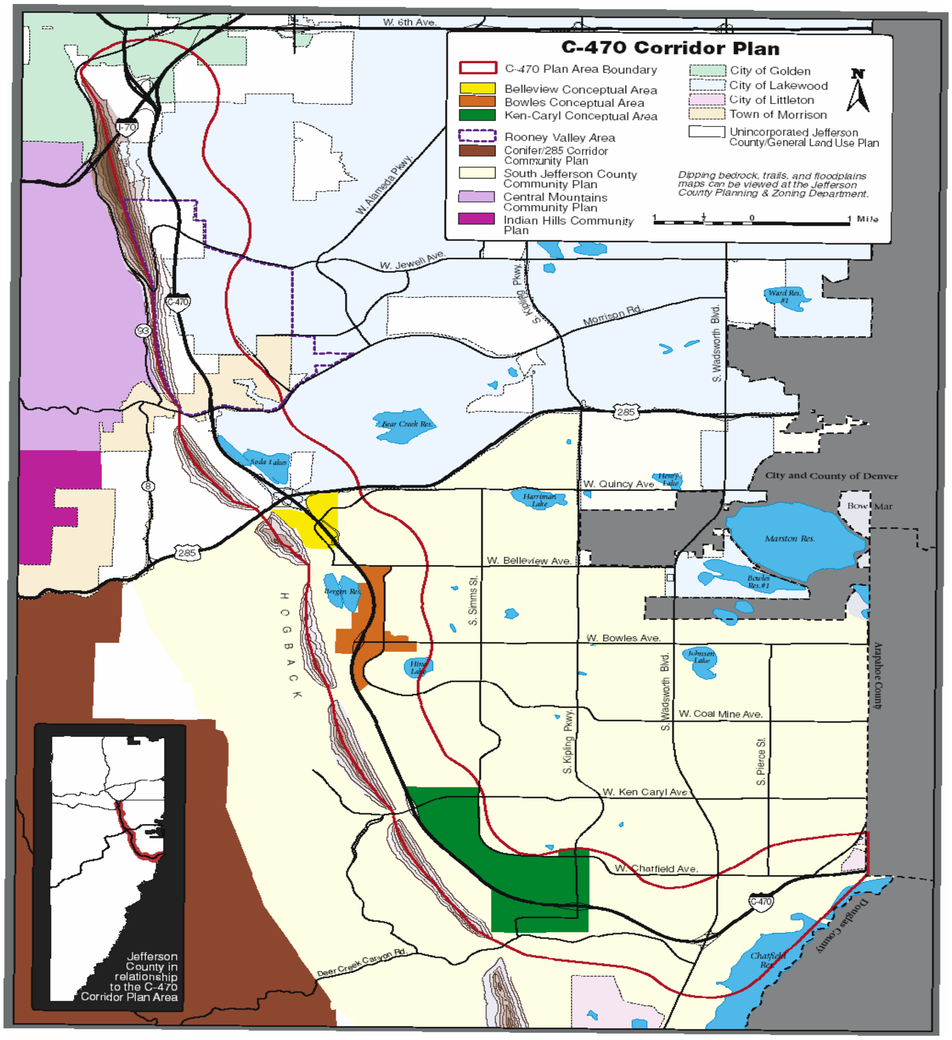


Figure 8. C-470 corridor plan, Jefferson County

Step 3. Apply Growth Model. The governmental planning framework described in Steps 2 above still provides an incomplete picture of projected growth: it is also necessary to project where market forces are likely to locate land use change. In this project, we use an historical analysis of land use change to create a base model, which is then modified by expert opinion. **This model supports impervious cover and habitat analysis at the local scale by defining which parcels are likely to be developed, with what kind of development and at what densities.** In order to create a cost-effective approach to the analysis of areawide growth processes, we use a logit regression to analyze past residential growth choices and project these into the future. This regression predicts land use change as a function of variables such as distance to local road, presence of a special district, neighborhood housing density, and distance to the nearest secondary school. It yields estimates of the probability that households will locate in a specific land unit and coefficients assigned to spatial variables. As cells are occupied they declare their status and are prohibited from accepting additional households or landowners. Thus, at each step of the model, an increment of households is distributed among a queue of eligible locations. We use three types of logistic regressions: a univariate regression on all variables; a full, multivariate model including all variables; and a reduced form of the model with key variables. Second, we reevaluate the data using a decision tree method. The first stage variables included in the model include accessibility to highway ramp, slope, jurisdiction type, and amenities such as access to open space. The reduced form of the model is as follows: Log (p/1-p) = (-2.65) + distance to road * (-1.28) + distance to low density development *(-0.98) + adjacent developed sites* (0.03) + within a special district * (0.34) + slope * (0.09). All variables are significant and the model predicts the substantial majority of development between 1990 and 2000. The accessibility to highway ramp variable is not significant, which may suggest that induced development from C-470 is not an important growth determinant. However, the variable is calculated through a network measure that may tend to dilute its explanatory value.

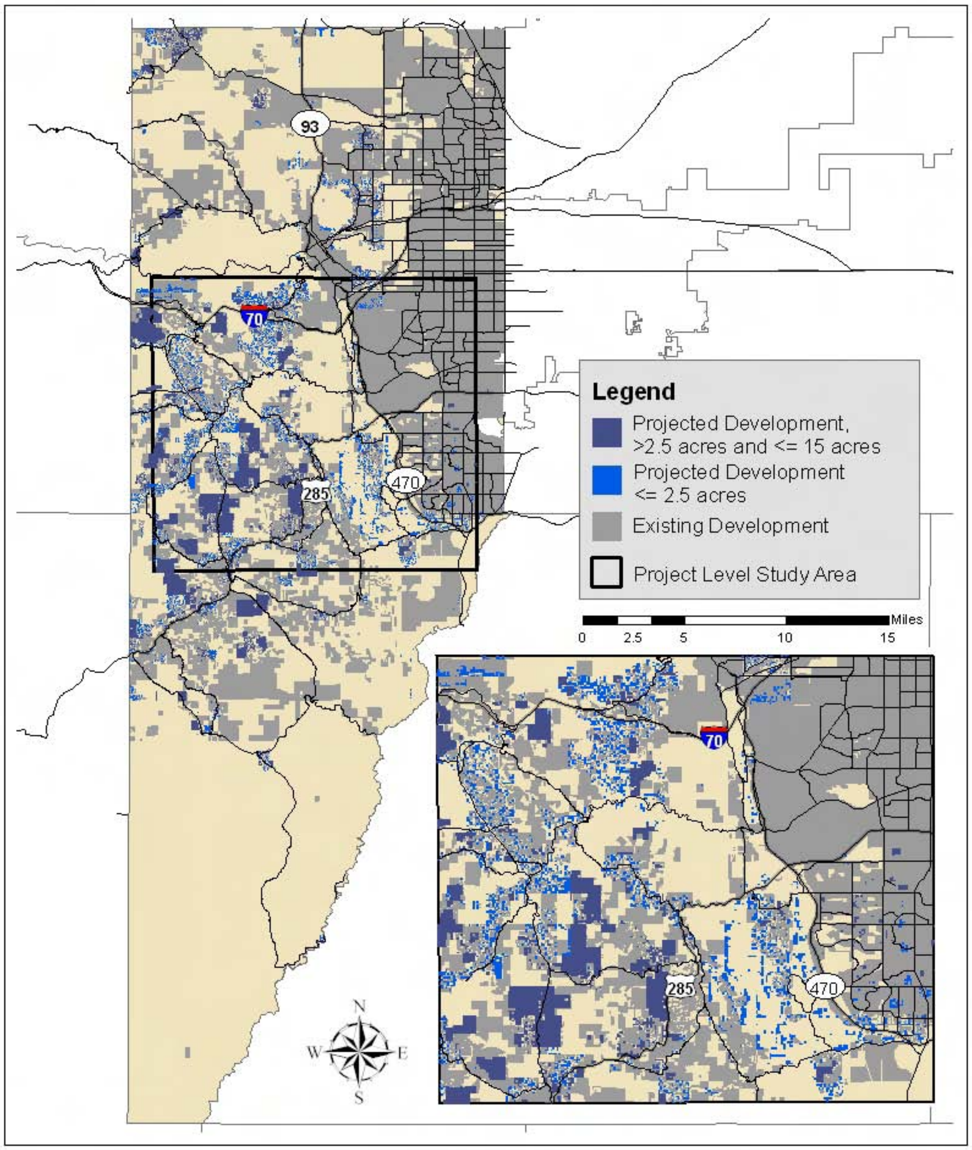


Figure 9. Land consumed by projected future development, 2020

Step 4: Apply Model of Induced Development – The model described above provides some information on the effect of induced development in the local area defined as Jefferson County. Access to local roads are highly significant as a predictor of where development is likely to occur; access to state highways and interstate ramps are not significant. We do not place a great deal of confidence in this description of induced development, however, because of the difficulty of measuring accessibility influences such as highway ramps and interstate access. Thus, we also collected expert judgment, asking planners and others about the induced development effects of previous investments in C-470. The consensus view was that the opening of C-470 had a dramatic effect on rates of large lot development in Western Jefferson County because it fundamentally reconfigured the area's accessibility. Respondents are skeptical, however, that a realignment of C-470 will have a major effect on future large lot development outside the immediate project area because C-470 congestion may not be a major factor in these location decisions. Thus we adopt two assumptions. First, at a project scale, we assume that all development is induced because project planning explicitly relies on the C-470 expansion. All parcels within the project area will be developed although the development footprint in some parcels may leave open space that provides habitat for species such as black-tailed prairie dog. Second, the realignment of C-470 will have only minor influence to stimulate development in the local project area (middle and western Jefferson County). The realignment may increase growth rates by, say, 5%. This is a small enough number that we cannot report it with any confidence; we assume for the purposes of this exercise that induced development effects outside the project area are 0. These two assumptions are based on interpretation of the mapping, modeling and interviews described above.

Step 5: Gather Expert Judgment– In this project, local information was incorporated through two sources. We conducted two interviews with Jefferson County land use planners. These provided an overview of development trends in the county. In addition, we asked planners and others familiar with local land markets to comment on our proposed development maps during the demonstration project workshop. These conversations were guided by a simple set of questions developed through the project. (1) We asked respondents to describe trends in the region, primary policies, and the induced development effect of previous highway investments in the area. (2) Respondents were given maps of new development projected for the area and asked to outline and describe other areas that were also likely to develop. (3) We presented the model weights and asked whether they seemed roughly appropriate. This interview process can be facilitated with web-based, interactive maps that describe relevant plans and model outputs, and provide a framework for planners and others to make comments on past and future development. We created a prototype version of such an interactive website, which can be found at

http://cdot.eparticipation.net. This website enables users to make comments on projected development patterns, and see comments by others. It is an example of possible uses of interactive GIS to automate and simplify the process of gathering comments. The results of ground-truthing are incorporated into a final map and database of projected development.

Step 6. Tabulate Project Effects. Finally, numbers of developed acres at primary density ranges are tabulated at project and local scales.

4.3.4. Regional Method

Step 1. Inventory Current Land Uses. In this project, we compiled an assessors' data set for each of the five-counties in the study area. This dataset describes current land uses, structure types and densities.

Step 2. Review Regional Plans and Regulations. These include transportation and land use plans, land use change models and inter-jurisdictional agreements. We considered alternative modeling options for using these data (e.g., buffers) but did not employ them because of the difficulties in estimating induced development. Inter-jurisdictional agreements include regional growth boundaries, annexation and community buffer agreements. We focus in this project on regional growth boundaries because of data availability. DRCOG growth boundaries are represented in Figure 4.

Step 3. Apply Growth Model. DRCOG currently uses a growth allocation model based on Traffic Analysis Zones (TAZs). TAZ growth rates are used to project reasonably foreseeable future projects. This approach also yields additional information including (1) residential densities by location, and (2) fine-grained development locations (assuming the approach is used in association with a growth model). The TAZ approach requires three assumptions: household size; land take by household (density); and commercial and industrial land uses associated with growth rate in numbers of firms or rates of residential development. We classify TAZs across the region by three densities (urban, suburban and rural), and based on historical data make assumptions in each of the three dimensions described above. This approach is demonstrated in tabulations of impervious cover below.

TAZs have advantages and disadvantages as a foundation for forecasting reasonably foreseeable futures. On the one hand, the land use change model group in the demonstration project workshop recommended that we use TAZ-based demographic projections because TAZs provide a consistent dataset across the region and have been subject to review by local jurisdictions and others. On the other hand, TAZs are of varying size, larger in less-populated areas and smaller in more-populated areas. Across much of the region, they have a relatively coarse spatial resolution that is inconsistent with the other environmental and social data and models used in the project. The resolution of TAZs is a drawback for their use in assessing potential environmental impacts. As of this writing, a high-resolution, regional, land use-transportation model has not yet been implemented in the Denver Metropolitan region. In search of higher-resolution, we modified the TAZ model using parcels data to identify undeveloped lands and areas not likely to be developed. We allocated the TAZ population and employment projections into these sub-TAZ areas to create a map of where development is likely to occur and of what land use type. We then divided acres of developable lands in each TAZ by their growth projections to identify potential densities for sub-TAZ areas. **The utility of this method is made clear in the following section of this chapter, where sub-TAZ areas identified by land use type and density are overlaid on watersheds to support a regional tabulation of projected change in impervious cover disaggregated by watershed**. These regional calculations rely on impervious cover factors related to land use and density, which are multiplied by sub-TAZ growth allocations to generate an regional accounting of current and forecast impervious cover.

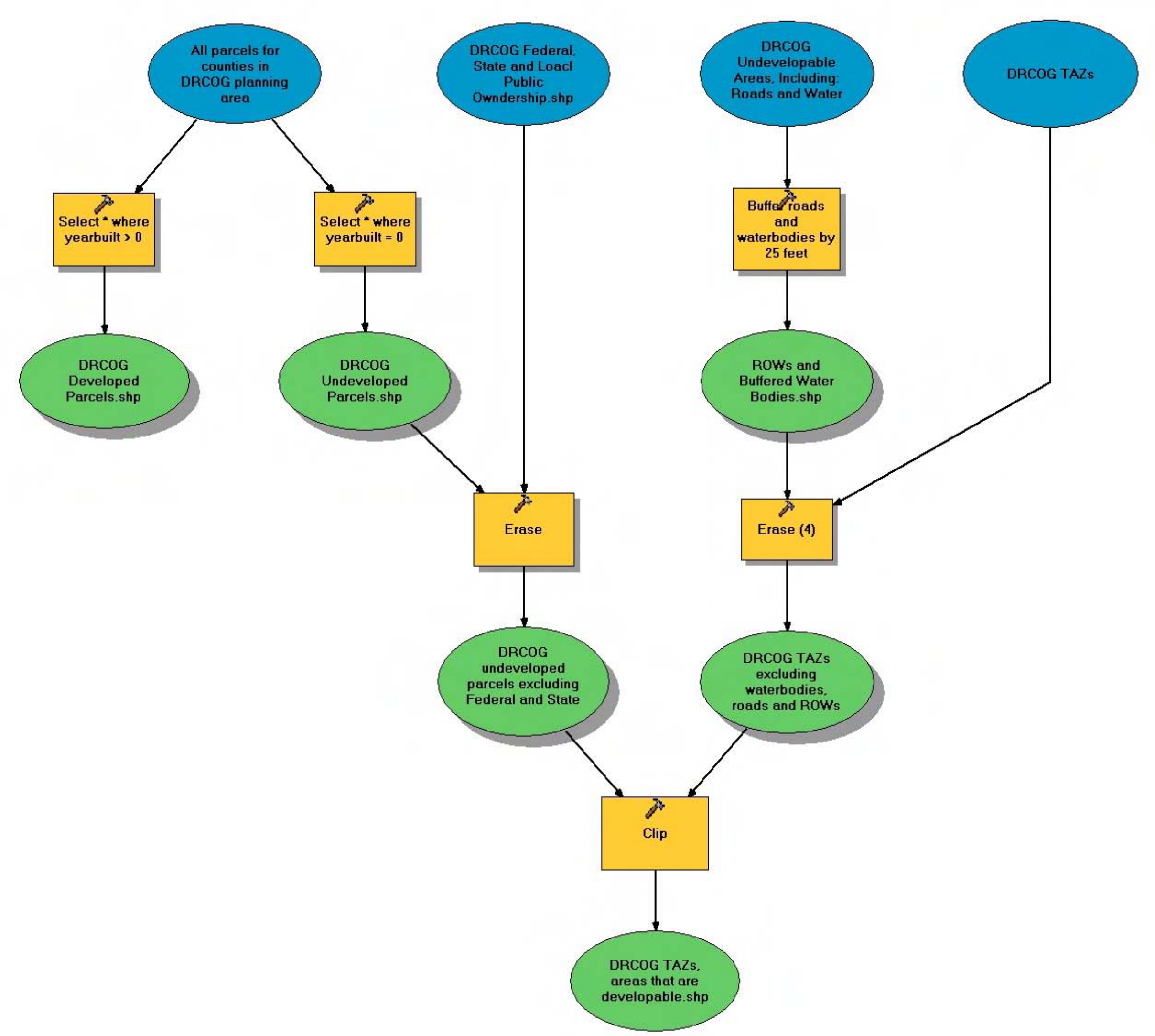


Figure 10. Model Builder diagram of regional projection method

Our method for analysis of TAZs is as follows. We obtain our parcel data from the county assessor's office. The yearbuilt field found in the parcel data set is used to determine when/if the property has been developed. Land with a "yearbuilt" equal to 0 is assumed to be undeveloped. Traffic Analysis Zone (TAZ) data are obtained from the Denver Regional Council of Governments (DRCOG). DRCOG has developed population, households, and employment projections for 2015, 2020 and 2030. It is assumed for the purposes of this exercise that reasonably foreseeable extends to 2020. The average number of households per acre is determined by dividing the number of households per TAZ by the acreage of the TAZ. The parcel data tells us the total number of undeveloped parcels and acres in each TAZ.

Projected increases in households for a particular TAZ are multiplied by the projected average density for the TAZ. The resulting number is the acreage projected to be consumed by new household development. The percentage of land acreage currently devoted to industrial and commercial uses is used to determine the percentage of land dedicated to commercial and industrial uses in the foreseeable future. On average, commercial and industrial uses consume about 15% of the total developed land in the region. Therefore, 15% of the total developable TAZ acreage is dedicated to industrial and commercial uses. The total amount of acreage currently dedicated to public uses including schools, roads, open space, and easements is determined from the parcel data set. The percentage of acreage currently dedicated to public uses is used to determine the percentage of land dedicated to public uses in the reasonably foreseeable future. On the average, public uses consume about 20% of the acreage in the region. Therefore, 20% of the total developable TAZ acreage is dedicated to public uses. The projected consumed acreage (i.e. land take) is the sum of the total acreage of land dedicated to households, commercial and industrial uses, and public lands. Land take is measured against the total amount of undeveloped land in the TAZ. Excess development (development that exceeds the available acreage in undeveloped lots) is rolled-over into developed parcels greater than one acre in size. Excess land take (or, projected development) is then quantified for each TAZ.

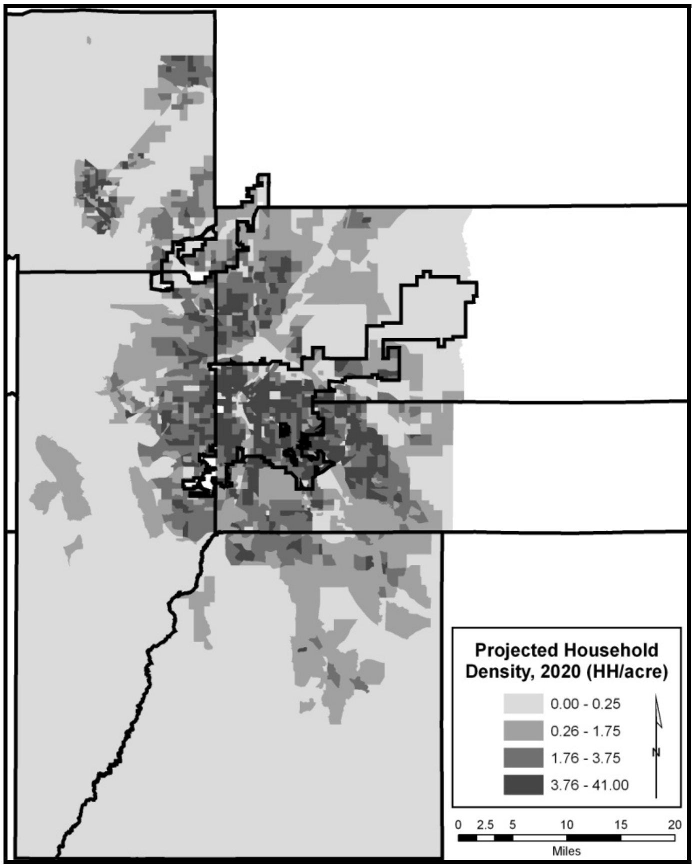


Figure 11. Projected residential density to 2020 in the regional study area

Step 4. Apply Model of Induced Development – We reviewed several options to model induced development effects of all transportation projects in the region. These include (1) assume that transportation projects induce development in nearby areas and buffer projects to capture the induced effects, and (2) increased accessibility increases regional economic activity. For example, if increased accessibility reduces driving time for truckers, and assuming these benefits are passed on to small businesses, many businesses may see increased profits. A detailed analysis of induced development suggests a complex set of problems outside the scope of this project, however. Moreover, all development at a regional scale might fall under the umbrella of cumulative effects because it is in some fashion related to past, present or future transportation investments. Thus, we do not attempt to define proportions of induced development.

Step 5. Tabulate Effects at Regional and Project Scales. Tabulation and comparison at regional and project scales occurs in two steps. First, we tabulate developed acres within the region classified by density ranges. The project and local-scale tabulations prepared above are then compared to the regional tabulation. This comparison is presented as project effects as a percentage of regional effects; it provides an indication of the contribution of the project to regional development. In order to measure cumulative effects of all projects in a regional transportation plan, the contributions of individual transportation projects are tabulated as we describe above, and then summed across the entire region.

Table 14. Current and Forecast Urban Development at the Regional, Local and Project Scales - High-Density Growth Scenario (in Acres)

	Regional		Local		Project (TAZs)**		Project (Buffer)***	
	Current Urban	Forecast Urban	Current Urban	Forecast Urban	Current Urban	Forecast Urban	Current Urban	Forecast Urban
Res.	622,225	910,145	152,847	176,769	9,288	13,808	1518	1518
Com/Ind	93,334	136,522	22,927	26,515	1,393	2,071	0	0
Total	715,559	1,046,667	175,774	203,284	10,681	15,879	1518	1518
% Urban*					1.5%	1.5%	0.2%	0.15%

*Current and forecast urban development in the project area as a percentage of current and forecast urban development in the region
**Traffic Analysis Zones (TAZs) overlapping project site
***Buffer area around C-470, calculated in GIS

4.2.5. Conclusions

In general, we project that the realignment of C-470 will have a relatively small effect on regional patterns of urbanization defined by allocation of developed lands. Under the conservative high-density scenario represented above, the regional development effect of the C-470 realignment in the project area itself, defined spatially by TAZs overlapping the project, will result in an expansion of urbanized area from 1.49% (current proportion of project to regional urbanized area) to 1.52% (forecast proportion of project to regional urbanized area). In the low-density scenario, not represented here, the proportional change is more substantial, from .81% to .95%. We did not calculate proportional change according to land use type and density but expect that proportional change in commercial and higher-density lands would be greater. In our growth projections, we anticipated at the project scale that all land that is not protected will be developed. At the local scale, which in our analysis includes all of Jefferson County, we projected significant continued growth in the valley bottoms and other accessible areas. This rate of growth in the middle and western part of the county – although not necessarily induced development according to our definition - has potential implications for water quality and biological resources to be pursued in later sections of this analysis.

The regional land take outcomes may vary significantly by scenario. For this prototype we selected a high-density, conservative scenario on the assumption that average densities across the region are increasing. We did not conduct a sensitivity analysis of different scenarios or submit our scenarios to expert review. More research is required to establish which scenarios or range of scenarios should be used as a foundation for estimating reasonably foreseeable projects.

Expert judgment was important in this project to define background assumptions. Interviews suggest that there were significant induced development effects resulting from the initial construction of C-470 and the expansion of state highway 285. These projects substantially improved commuter access to western Jefferson County. Our analysis is consonant with these comments: much of the mapped development in this region has occurred after 1980. Future induced development effects in Western Jefferson County may be less significant, however. According to the C-470 Corridor Plan much of the development occurs proximate to the project itself and its interchanges. Induced development effects may also be reduced if the project is developed as a toll road.

There was extensive discussion among project participants about the appropriate method for calculation of induced development effects. This discussion was inconclusive. For the purposes of this demonstration, we chose to evaluate all urban development at the regional and local scales in order to support an assessment of general cumulative processes with respect to impervious cover and habitat. This approach is certainly appropriate if applied to environmental assessment of the regional transportation plan. We used both model results and expert judgment to evaluate induced development at the local and project scales. As discussed above, we anticipate a small induced development effect at the local scale and a relatively large effect at the project scale. At the conclusion of this analysis, we feel some skepticism about the feasibility of reliably modeling induced development effects in the context of a Denver regional ACCEA, and some preference for an expert judgment approach.

Concerns were raised about cost of data collection and preparation. We recommend that additional research focus on the cooperative development of a data and modeling infrastructure to support cumulative effects assessment of this kind. With support of this infrastructure, data collection and modeling costs could be reduced significantly. This policy-focused land use model has been reviewed through a CDOT workshop and through discussions with project consultants and others. Reviewers generally supported the approach described above.

4.3. ACCEA for Water Quality

4.3.1. Water Quality Resources of Concern

Water quality impacts of urbanization, including transportation projects, are a priority aspect of ACCEA. Of primary interest are the impacts of non-point source pollution (NPS). Urban runoff has been found to contribute a significant amount of non-point source pollutants to receiving streams (Beach, 2002; Boyer et al., 2002; U.S. EPA, 2002). It has been well-documented that urbanization increases the volume, duration, and intensity of storm water runoff (Booth and Reinfelt, 1993).

The highest rated metric for water quality was impervious surface increases associated with transportation projects and secondary growth. We have noted in Section 3.3.2 the acknowledged relationship between impervious surfaces and the quality of runoff originating from those surfaces. Impervious surfaces are readily estimated using GIS databases, and it is possible to separate transportation project effects from other land use changes, at least for local watersheds within which highway projects occur. This ACCEA demonstration project focuses on impervious area accounting only.

GIS-based water quality models which link land use (and impervious surfaces) of non-point source water quality of runoff are well established as assessment and planning tools to identify general trends in water quality for a specific watershed. Although such models can provide statistics on the relative changes in pollutant loadings from a watershed, the use of such models to predict violations of specific water quality standards in a given stream reach is difficult and was not considered viable. Also, it was not clear watershed runoff effects on water quality can be tracked for a region given the complicating factors of stream assimilative capacity, multiple inputs changing over time, complicated water balances, biochemical reactions, and other factors. Models of water quality which can be applied across a region are considered too difficult and expensive to develop and apply in a reliable manner acceptable to regulatory authorities.

Impervious Area Threshold. The amount of urban runoff and its impacts on stream conditions and water quality have been shown to be strongly correlated with the percent area of impervious surfaces within a watershed (Schueler, 1994; Arnold and Gibbons, 1996; Clausen et al., 2003). Imperviousness influences hydrology, stream habitat, chemical water quality, and biological water-quality (Schueler, 1994; Arnold and Gibbons, 1996). This strong relationship implies impervious surfaces can serve as an important indicator of water quality, in part because imperviousness has been consistently shown to affect stream hydrology and water quality. Also, it can be readily measured at a variety of scales (i.e., from the parcel level to the watershed and regional levels) (Schueler, 1994). As noted by Schueler (1994) an impervious level of 25 percent is a threshold above which water quality would be expected to be degraded. To assess the analysis results we used the proportional threshold approach using the 5-point scaling; 1 = <5 % impervious (pristine), 2 = 5-15 % (protected), 3 = 15-25 % (impacted), 4 = 25-40 % (degraded), 5 = >40 % (severely degraded).

Spatial Boundaries. The C-470 project would potentially impact numerous waterways and drainage features that cross the existing roadway alignment. Major drainage features include Bear Creek, Mt. Vernon Creek, Turkey Creek, Dutch Creek, Deer Creek and Massey Draw.

4.3.2. Data Collection

Various data have been collected for the study area to support demonstration of water quality areawide CEA. These include watershed boundaries and stream paths, and land use for current and future conditions.

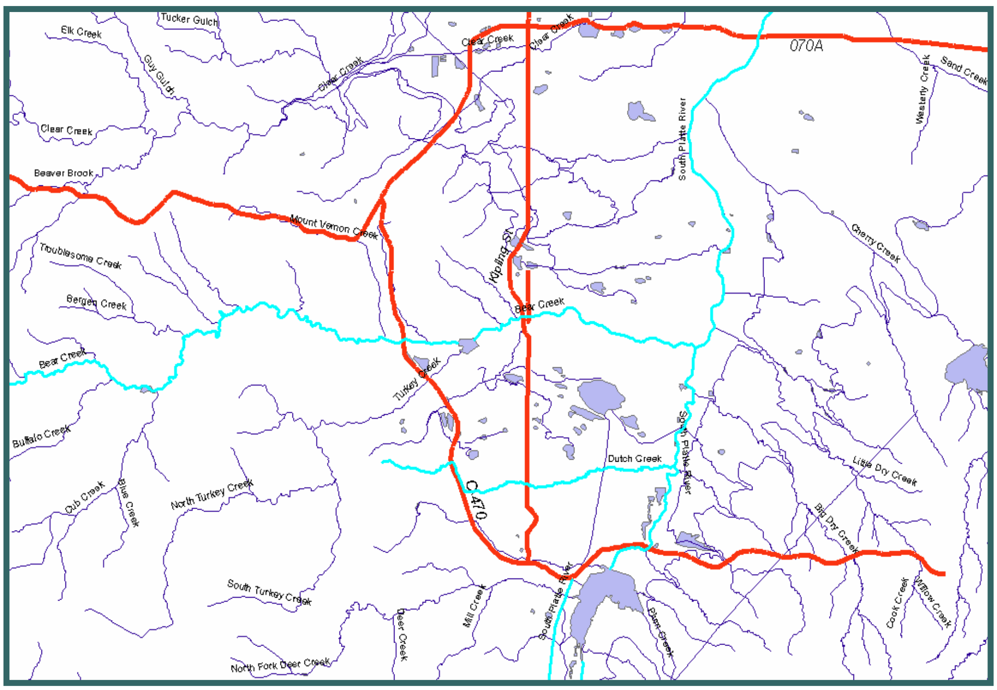


Figure 12. Major streams in the vicinity of C470 project

Table 15. Spatial and Other Data Used in Demonstration Project

No.	Data	Comment
1	Flash Flood Monitoring and Prediction (FFMP) Program Data – Watersheds	Spatial
2	CDPHE Stream Classification Data (Regulation 38)	DBF tables
3	Colorado Vegetation Classification Project Data (Land Use)	Spatial
4	Reasonable Foreseeable Future Land Use	Spatial
5	Transportation Data (CDOT)	Spatial
6	National Hydrography Dataset	Spatial
7	Colorado Division of Water Resources Data (Surface water sources, groundwater sources)	Spatial

4.3.3. Analysis of Potential Effects

Analysis of potential effects is based on the impervious area method. The (hypothetical) C470 project (Kipling to I-70) and local areas were analyzed to determine the impervious areas for current and forecast future conditions; a comparison to the regional totals was made for the current land use.

Development of a scientific basis for the relationship between land use and impervious surface has been the subject of considerable study beginning in the 1970s. In earlier studies aerial photos were used. As satellite imagery became available, supervised classification procedures were adopted and are the norm today. Typical values of percent impervious area for various land cover classes were used for the impervious area tabulation generated for the C470 watersheds. We applied the mean or mid-range of values to the land use maps for current and forecast land use conditions. There are some caveats to be acknowledged for these data, including 1) there is considerable variability within some land classes and development density, and 2) the data do not account for the drainage areas which are directly connected by storm sewers to the streams (i.e. the "effective" impervious area). These issues

Table 16. Impervious Percentages for Various Land Cover Classes

Land Cover Class	Notes	Mean	Range	Reference
Single-family residential	<0.25 acre lots	39	30-49	Alley and Veenhuis (1983)
"	0.25-0.5 acre lots	26	22-31	Alley and Veenhuis (1983)
"	0.5-1.0 acre lots	15	13-16	Alley and Veenhuis (1983)
"	Includes multi-family residential	30	22-44	Sullivan et al. (1978)
Multiple-family residential		66	53-64	Alley and Veenhuis (1983)
Medium-density residential		--	20-25	Dougherty, et al. (2004)
Low-density residential		--	5-10	Dougherty, et al. (2004)
Commercial		88	66-98	Alley and Veenhuis (1983)
"		81	52-90	Sullivan et al. (1978)
Industrial		60	--	Alley and Veenhuis (1983)
"		40	11-57	Sullivan et al. (1978)
Institutional/ commercial		--	35-55	Dougherty, et al. (2004)
Major roads w/median		--	50-70	Dougherty, et al. (2004)
Ag/forest/golf/idle		--	2-7	Dougherty, et al. (2004)
Open		5	1-14	Sullivan et al. (1978)

Adapted from Brabec, et al. (2002) and Dougherty, et al. (2004)

could be addressed with more detailed investigation. However, the impervious percent values shown are considered adequate for the ACCEA purposes at this time.

GIS procedures for computing impervious areas involved the following steps, 1) collate the GIS data on land uses; highways, local roads, arterials and collectors; and sub-basin boundaries, 2) overlay the intersection of the sub-basin boundaries onto the land use and highway coverages, 3) convert the intersected areas to raster (i.e. cell) format, 4) tabulate the areas of various land uses and highways corresponding to each sub-basin, and 5) transfer the GIS area tabulations to Excel to summarize and create graphs.

The sub-basin area and percent impervious data could be readily used as inputs to water quality simulation models, such as the Purdue Long-Term Hydrologic Impact Assessment (LTHIA) or EPA's BASINS model. This was not done for this demonstration project because the metrics of water quality parameters generated by such models were not rated as high as the impervious area metric.

Analysis Results

We conducted analyses for the local area and for the entire region for current and forecast RFF conditions. Local area results of the GIS analysis of 42 sub-basins' land use and impervious surface changes in the vicinity of the C470 project are illustrated below in Figure 12 and Figure 13. We used the 5-point proportional threshold approach to assess significance of the results.

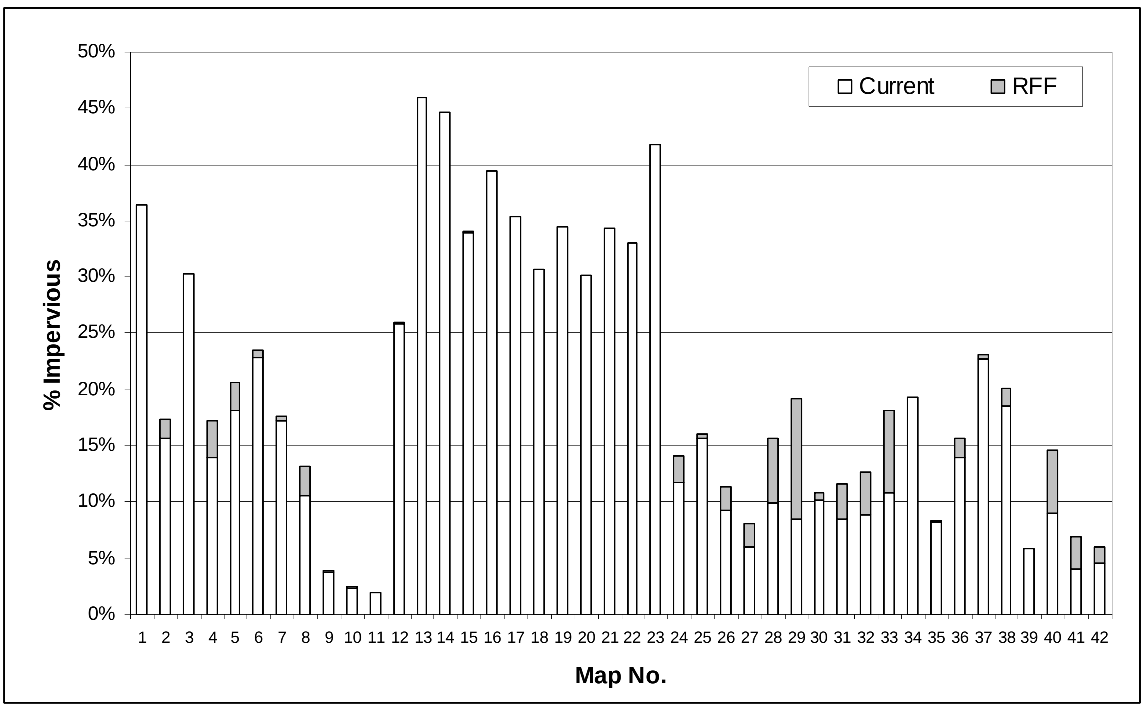


Figure 13. Percentage impervious areas of the project area watersheds

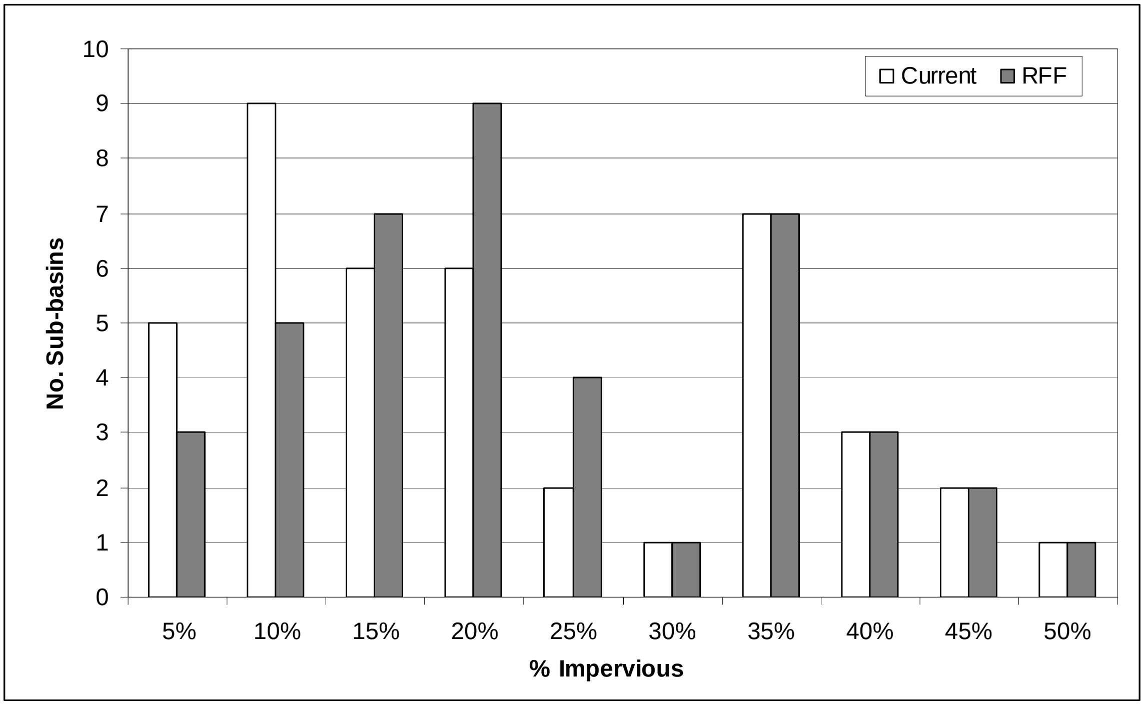


Figure 14. Number of sub-basins in interval category of % impervious

Current conditions:

- The 42 sub-basins' percent impervious values range from a low of 2% to a high of 46% with an average of approximately 19%. Current conditions indicate a relatively high level of urbanization in the study area where degradation of water quality will have already occurred.
- Three (3) sub-basins have very high percent impervious values greater than 40% and would be considered in a severely degraded condition. An additional eleven (11) sub-basins have high %impervious values greater than the 25% threshold but less than 40% and would be considered in a degraded condition. These watersheds are predominantly located in the Denver urban area where tributaries drain to the South Platte River.
- Twenty (20) sub-basins have relatively low percent impervious values less than 15% and would be considered in a protected or pristine condition. These sub-basins are predominantly located in the rural foothills.

- Eight (8) sub-basins have intermediate percent impervious values ranging from 15% to 25%. These sub-basins would be expected to be impacted and are located in the transition area between urbanized Denver and the rural foothills. These include Bear Creek and Turkey Creek and tributaries.

RFF Conditions:

- The 43 sub-basin %impervious values range from a low of 2% to a high of 46% with an average of 20.8%, an increase of 1.5%.
- The number of sub-basins having very high impervious areas in excess of 40% remains the same; the RFF growth model was not applied to these densely urban sub-basins.
- The number of sub-basins exceeding the 25% high threshold does not increase with RFF growth. However, the number of sub-basins in the impacted range of 15% to 25% increases from 8 to 13. These watersheds are predominantly located in the Denver suburban area where tributaries drain to the South Platte River where infilling development is projected to occur.
- Fifteen (15) sub-basins, a decrease of 5 from current conditions, have relatively low %impervious values less than 15% and would be considered in a protected or pristine condition. The loss of 25% of the protected class watersheds indicates encroaching urbanization in the foothills.
- Thirteen (13) sub-basins have intermediate %impervious values ranging from 15% to 25%; this is an increase of 5 from current conditions. These sub-basins are located in the transition area between urbanized Denver and the rural foothills. Portions of Cub Creek, Bear Creek and Turkey Creek and tributaries are in this category. RFF conditions indicate a relatively high level of urbanization in the study area where increased degradation of water quality is threatened.

Regional Comparison

The land use impervious area tabulation was also conducted for the region by application to the TAZ land use tabulations presented above in the land use section. The impervious area assignments were tabulated for the TAZ areas, not for the watersheds. Table 17 summarizes the results for the regional comparison.

Several conclusions can be drawn from the table.

- On the regional scale, projected RFF growth increases the %impervious from approximately 10% to 12.7%; a movement from a protected level towards impacted.
- On the local scale, projected RFF growth increases the %impervious from 13.3% to 15.7%; a movement from protected to impacted.
- TAZ areas in the vicinity of the C470 project are projected to increase from 10% impervious to 15%; a movement from protected to impacted.

Table 17. Current and Forecast Impervious Cover at the Regional, Local and Project Scales - High-Density Growth Scenario (in Acres)

	Regional		Local		Project (TAZs)**		Project (Buffer)***	
	Current	Forecast	Current	Forecast	Current	Forecast	Current	Forecast
Res.	260,175	333,123	52,956	62,461	2,106	3,152	0	0
Com/Ind	62,442	79,949	12,709	14,991	505	757	607	607
Total	322,617	413,072	65,665	77,452	2,611	3,909	607	607
Percent Impervious*	9.9	12.7	13.2	15.6	10	15	40	40

*Traffic Analysis Zones overlapping the project site
**Buffer area around C-470 Corridor, calculated in GIS
***Current and forecast impervious acres as a percentage of regional, local and project area

4.3.4. Conclusions

The demonstration project for water quality provides a basis for drawing several conclusions concerning the feasibility of such methods for ACCEA.

- The water quality demonstration project shows that GIS data are readily available to support cumulative effects analyses. The data are quite refined in spatial detail so that the various levels of scope – project, local and region – can be accommodated.

- GIS processing functions support the tabulation of land use areas of various types, and their associated impervious area characteristics. Integration of the RFF land use changes is also readily accomplished.
- The impervious area (or %impervious) metric is relatively straightforward to generate and provides an informative basis for comparison of water quality threats in specific sub-basins and for the region. Differences attributable to specific project facilities can be identified, as can changes due to anticipated secondary growth effects.
- The GIS-based methodology provides a template for inclusion of multiple projects and RFF growth effects for other specific watersheds and for an overall regional accounting.
- The methodology demonstrated does not account for mitigation measures for stormwater runoff, such as required by CDOT's participation in the metro Denver MS4 Program. However, it is possible to extend the method using simulation modeling approaches, such as the BASINS model. However, advancing the sophistication of the analysis approach would negate the simplicity of the %impervious approach, and may not be acceptable to the participating agencies.

4.4. ACCEA for Biological Resources

The ACCEA procedures utilized in the C-470 demonstration project followed the 5-step process described in Section 2: 1) describe the project components, environmental and land use setting, 2) identify resources or issues of concern, 3) identify metrics for measurement of impacts and thresholds of significance for each of the resources of concern, 4) conduct ACCEA analyses and determine if cumulative effects are significant, and 5) interpret analysis results and establish follow-up actions.

4.4.1. Scoping

Scoping of biological resources for the C-470 demonstration project was conducted in three ways: 1) from comments by participants at the ACCEA Biological Resources workshop held on October 28, 2005, 2) in consultation with the CDOT ACCEA Advisory Panel, and 3) through individual discussions with resource experts. Since the scope of the demonstration project was limited, only two species and their habitat were selected for assessment. The Federally listed

Preble's meadow jumping mouse (Preble's) and the black-tailed prairie dog (State listed as a species of concern) were chosen because they have been considered significant to other projects in the region and it was the general consensus of those individuals mentioned above, that they are important biological resources within the study region.

The workshops are described in more detail elsewhere in this report; however, the utilization of the workshops for scoping purposes will be described briefly here. Within the NEPA process, scoping usually involves a public forum as well as other sources of input from the expert community. Because time was limited, the workshops needed to fulfill both functions. Throughout the workshop, the participants were given the opportunity to indicate their opinion on a variety of topics relevant to scoping; significance of particular species, determination of temporal and geographic boundaries, approaches to data collection and analysis, among others. While in a different setting, many of the same topics were discussed with the CDOT ACCEA Advisory panel and also in communications with individual experts.

4.4.2. Spatial and Temporal Boundaries

Spatial boundaries are scale dependent for biological resources. At the "project scale", which is the scale most proximate to the project, the geographic boundaries are fundamentally defined by the ecosystems that intersect C-470 or are within the right-of-way. For this purpose we have examined an ecosystems map of the area prepared by Nature Serve. This map delineates the major ecosystems in the project area; however, the ecosystem map is quite generalized and therefore is only a guide to the extent of potentially impacted ecosystems. The spatial extent of the project CEA, therefore, could be, in a general fashion, determined by the extent of the proximate ecosystems. Figure 15 is a map showing the relationship of C-470 to the surrounding ecosystems. At the larger (regional) scale, the somewhat arbitrary boundaries of the DRCOG counties could be used for establishing a workable spatial extent. However, as with the project scale approach of using the ecosystem boundaries to determine spatial extent, the same approach could be used for regional CEA. The temporal boundaries of the project are determined by the availability of useful data. An example of this limitation is the mapped distribution of vegetation in the area that was produced from Thematic Mapper satellite imagery. Images used for this mapping were acquired for the entire state of Colorado and consist of images collected in 1993-

97. Another potential “baseline” for the study area is the EIS that was written in 1980 for the original C-470 project.

4.4.3. Resources of Concern

Because of limited time, only two species could be assessed for the C-470 project. We selected the black-tailed prairie dog and Preble’s for the study. The prairie dog was selected because it is widely distributed in the region, it is considered by many to be a keystone species, its habitat is rapidly dwindling and becoming more fragmented, and it is targeted for extermination in many areas where its habitat is too close to human habitation. The Preble’s habitat, like the prairie dog’s, is becoming scarcer and only small remnant patches remain in the region. Its preferred habitat for hibernation (riparian shrub) is even scarcer than that of the prairie dog. It is listed by the U.S. Fish and Wildlife Service as a “Threatened” species. While there is some dispute over whether it should be listed or not, it currently must be treated as a listed species. While no specimens of the jumping mouse have been trapped along the Kipling to I-70 corridor of C-470, we felt that suitable habitat was present in the vicinity. Preble’s have been encountered just to the south and just to the north of the study area.

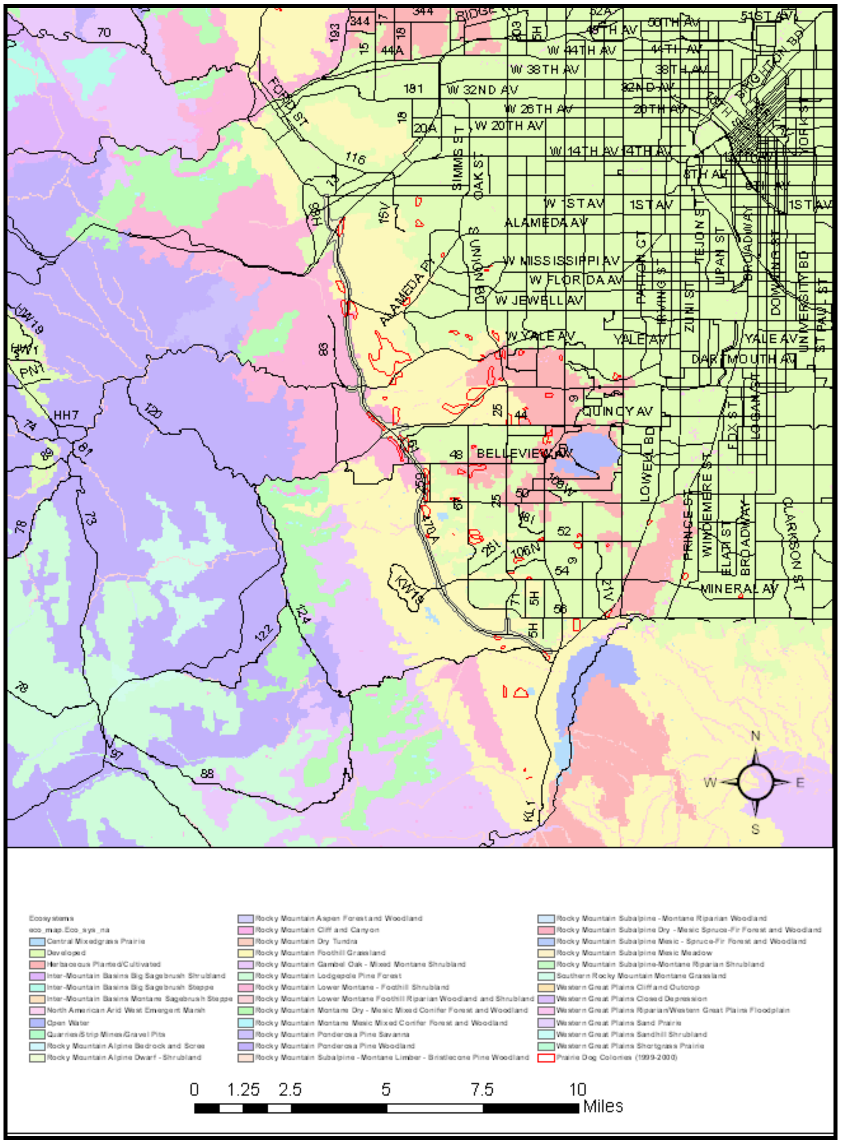


Figure 15. Ecosystems mapped by Nature Serve in the vicinity of the hypothetical C-470 project

4.4.4. Data Collection

Environmental data relevant to the investigation were acquired from the Colorado Vegetation Classification Project (CVCP), the Colorado Division of Wildlife's Riparian Mapping Project, a 10 Meter resolution digital elevation model (DEM) developed by the U.S. Geological Survey, open space distribution from DRCOG, ecosystems map produced by Nature Serve, and 2030 urban growth in the project vicinity modeled by DRCOG.

4.4.5. Analysis of Potential Effects

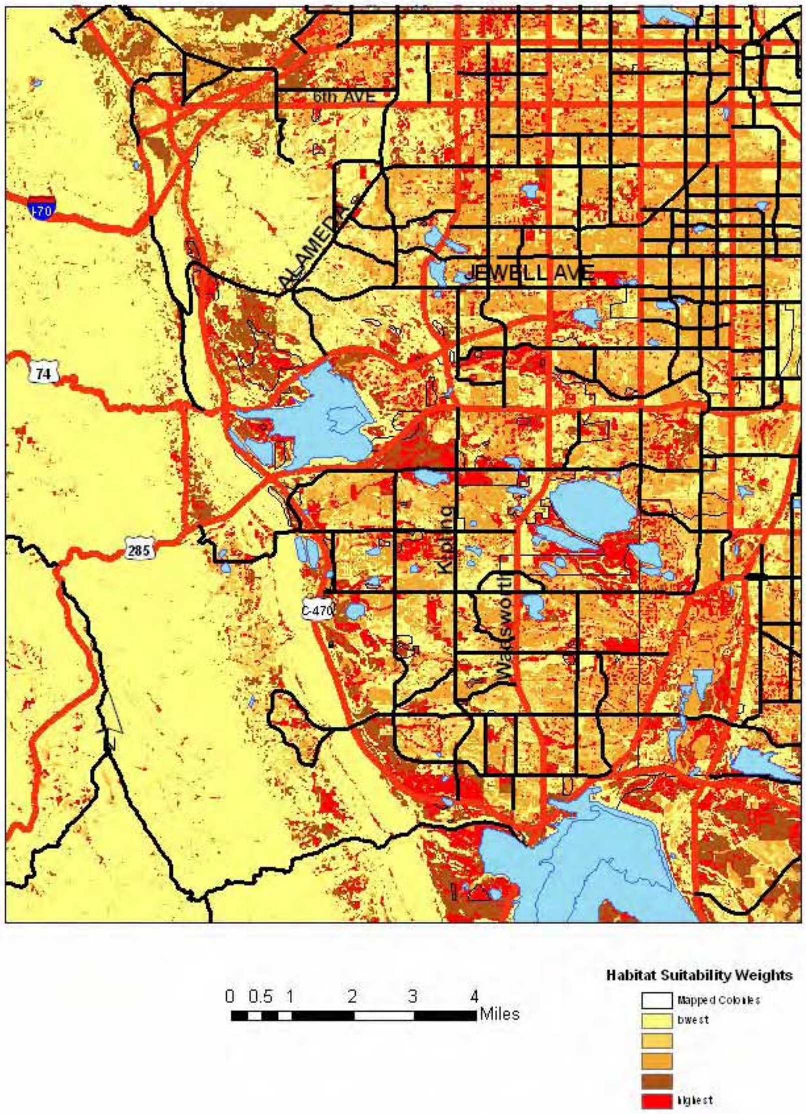
Habitat suitability Indices have proven to be useful in trying to assess the potential locations where a given species might be able to survive. These indices may also provide a means of establishing "regional accounts" where the impacts of development might be offset by enhancing "suitable" areas where a species might be introduced to balance areas where the species is being extirpated. Habitat suitability models were developed for the black-tailed prairie dog and for the Preble's meadow jumping mouse. The models were developed using the Model Builder tools in ESRI's ArcGIS. Each model relies on the environmental data mentioned in the previous section of this report and the use of weighted overlay and other functions that characterize the suitable habitat of each species.

4.4.6. Demonstration: Black-tailed Prairie Dog

The black-tailed prairie dog was once the most abundant mammal species of the native grasslands of the central U.S. Land conversion (e.g., agricultural development), pest control, and disease have reduced the black-tailed prairie dog's distribution to a fraction of its former range. In the Denver-Metro region, the prairie dog's distribution has become more and more limited as urban sprawl has eliminated colonies and fear of plague has resulted in the poisoning of many more. The C-470 corridor has many colonies directly in the right-of-way and many others are in the vicinity. Widening C-470 will result in the direct impact of those colonies located in the right-of-way.

A habitat suitability model for black-tailed prairie dogs was developed for the project area (Figure 15). This model is based upon three specific environmental variables including vegetation type, slope of terrain, and maximum elevation. The vegetation types were extracted from the Colorado Vegetation Classification Project (CVCP) classified Landsat Thematic Mapper data. The vegetation type that was given the greatest weight in the model was the grass-dominated class. Slope as an indicator of terrain steepness was determined using a U.S. Geological Survey (USGS) digital elevation model that originally had a spatial resolution of 10 meters but was aggregated to a resolution of 25 meters so that it matched the CVCP data. ArcGIS's spatial analysis includes a tool that calculates slope from DEM data. Slopes greater than 8 % were considered to be too steep for prairie dog colonies. Maximum elevation was also determined using the DEM data and was established as 2700 meters.

Suitability of Habitat for Black-tailed Prairie Dogs In the Vicinity of the C-470 Study Area



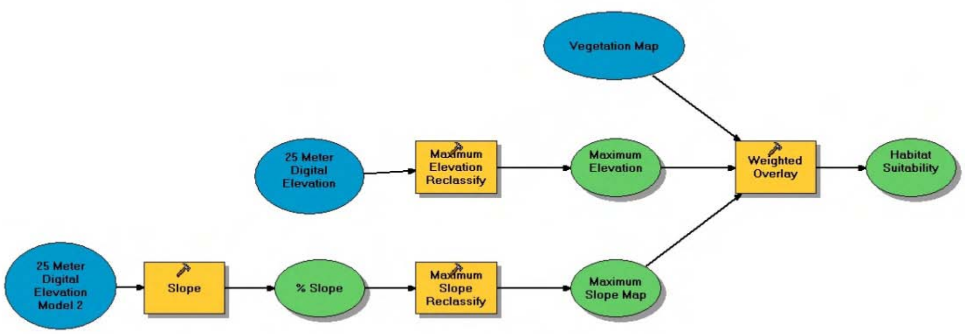


Figure 16. Black-tailed prairie dog HSI Model and its application to the vicinity of the hypothetical C-470 project area. As indicated in the legend, the darker the shading, the greater the suitability of the habitat for the prairie dog

In addition to the input of raw data, the prairie dog model utilizes a “weighted” overlay tool. This component of the model allows the user to change the importance of variables in the model. In the prairie dog model the vegetation type data were given the greatest weight in the model totaling 60% of the variation and slope and maximum elevation controlling 20% each. These weights are based on “expert” opinion, but can be changed if evidence suggests a different weighting. Within each variable (e.g., vegetation type) the value of each type must be scaled. In the prairie dog model, grass dominated is given a scale value of 10 while other types that are not likely to support prairie dogs would be given a scale value of one. The values grade from 10 to one and in areas that are uninhabitable (e.g., commercial land use) the value would be “restricted”. The result of this analysis is a habitat suitability map, which shows the distribution of habitat that meets the criteria that have been placed in the model. The map is not a distribution map since not all of the locations indicated on the map are occupied by prairie dogs; the map does show, however, the locations of sites that could potentially support a prairie dog population.

The next step in the analysis consisted of taking the habitat suitability model and forecasting what habitat would be most impacted by development by the year 2030. To do this, the Extract tool in ArcGIS was used in conjunction with the 2030 growth model (described elsewhere in this document) to form a “mask” to identify specific areas of habitat that would be impacted. The extract procedure simply takes the 2030 growth polygons and overlays them on the map of suitable habitat. The areas of predicted conflict between growth and prairie dog habitat are where the two coincide (Figure 16).

ArcGIS's Model Builder provides a set of spatial analysis tools for constructing geospatial models. Each step in the model building process is done graphically in a Model Builder window and once constructed it can be run on other data sets or it can be modified and improved. Model Builder provides a means for developing geospatial analysis procedures that will be used on a repetitive basis. The weighted overlay tool is especially well suited for developing suitability models as the weighting process allows for the inclusion of expert opinion.

The final step in the CEA for black-tailed prairie dogs was to examine the change that will occur between the baseline timeframe and the projected growth boundary of 2030 at three different scales; regional, which projects habitat decline over the entire urbanized region of the 2030 growth boundary, local, which includes habitat within Jefferson County, and project-level which projects change in the immediate vicinity of the C-470 project. Figure 17 summarizes the acreage based on the 2030 growth boundary and the area classified as prairie dog habitat from the HSI model.

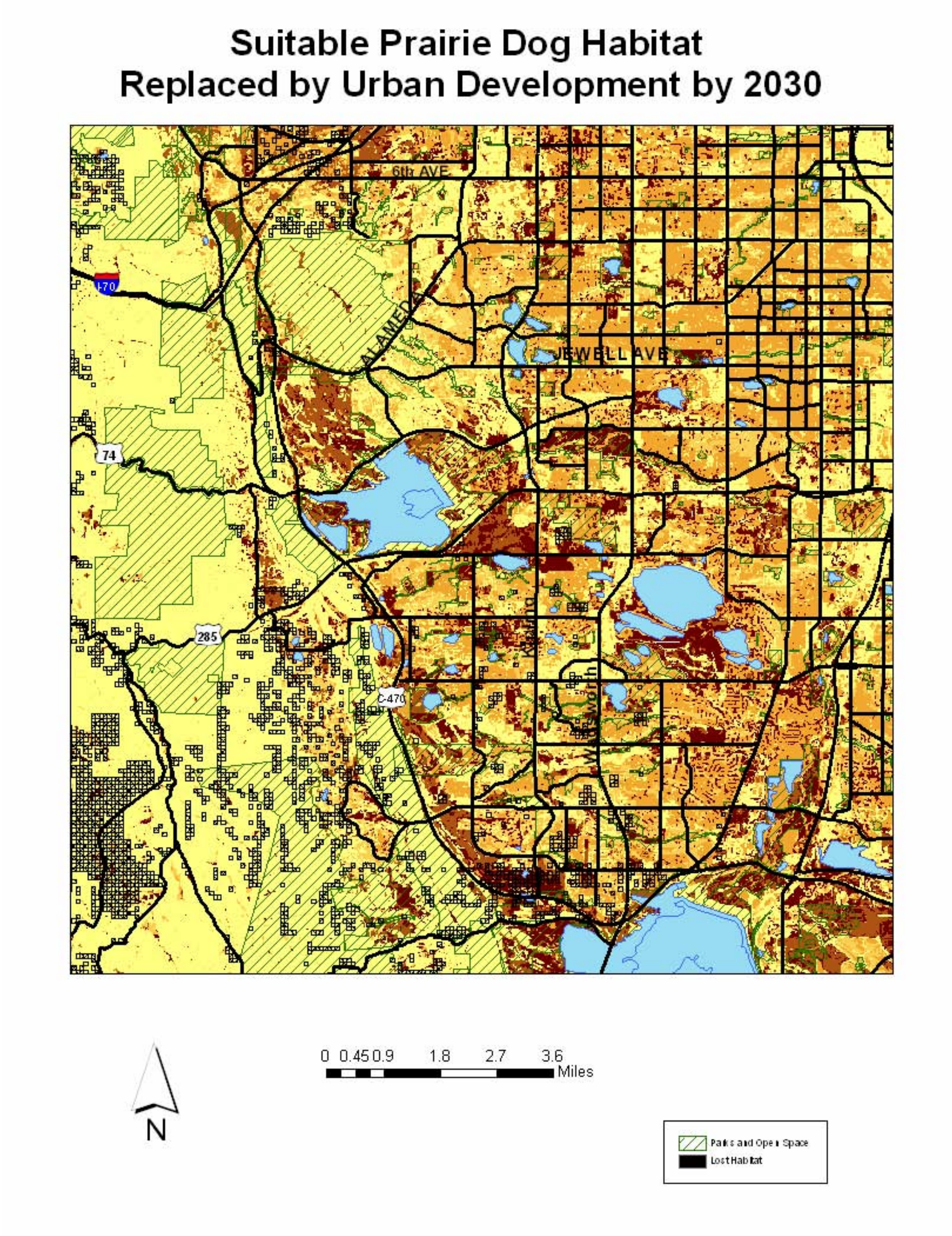


Figure 17. The 2030 urban growth model over black-tailed prairie dog habitat suitability in the vicinity of the hypothetical C-470 project area

Table 18. Current and Forecast Acres of Black-tailed Prairie Dog Habitat at the Regional, Local and Project Scales, by Level of Habitat Quality

	Regional		Local		Project			
	Current Habitat	Forecast Change*	Current Habitat	Forecast Change**	Current Habitat	% of Regional Current Habitat	Forecast Change**	% of Regional Forecast Change
Low***	208,337	43,403	52,468	16,681	837	0.4	197	0.45
Medium	669,818	112,063	77,214	17,763	505	0.07	64	0.06
High	134,367	28,229	19,296	6,632	176	0.13	49	0.17
Total Habitat	1012522	183695	148978	41076	1518	0.15	310	0.17

*Acres of habitat loss due to projected urban development within the DRCOG urban growth boundary
**Acres of habitat loss due to urban development projected by local growth model described in Section 4.2
***Level of habitat quality for Black-tailed Prairie Dog populations

4.4.7. Demonstration: Preble's Meadow Jumping Mouse

Areas adjacent to streams, rivers and lakes in addition to the uplands nearby are the primary habitat of Preble's meadow jumping mouse (Preble's). The bases of shrubs along these water bodies often are the mouse's preferred site for hibernating. Hibernation is long -- typically from October to May. Within the metro Denver area there is little habitat that is suitable for Preble's. A large part of the area has been identified as an exclusion zone, identified as a result of sampling by live-trapping and expert habitat analyses. Other areas that are outside of the exclusion zone but within the metro Denver area have limited suitable habitat.

Factors used to identify the limits to distribution of Preble's in the habitat suitability model (Figure 17) included an upper elevation limit of 7600 feet and an historic distribution only along the central and northern Front Ranges of Colorado. Also, water bodies were eliminated as potential suitable habitat. The upper elevation limit was determined using the 10 meter digital elevation model for the area, provided by the USGS and a series of GIS operations. For elevations below 7600 feet, NDIS' (CDOW) map of historic range of the mouse was used. The data were downloaded from their web site and geo-referenced to the county boundaries. The distribution limit was digitized from this data set. Above 7600 ft the distribution was limited by the calculated elevation limit. Water bodies were identified in the GIS from the USGS NHD high resolution data. Processing involved a series of steps including projection of geographical data to UTM Zone 13N for the three basins that covered Preble's range, clipping the data to the Preble's range, and then appending the data from the basins into a single feature class. Only polygonal data for water bodies were used in the analyses, i.e., water bodies and rivers whose banks were mapped. Water bodies that were mapped as single-line features in the NHD data were not dealt with in the analysis.

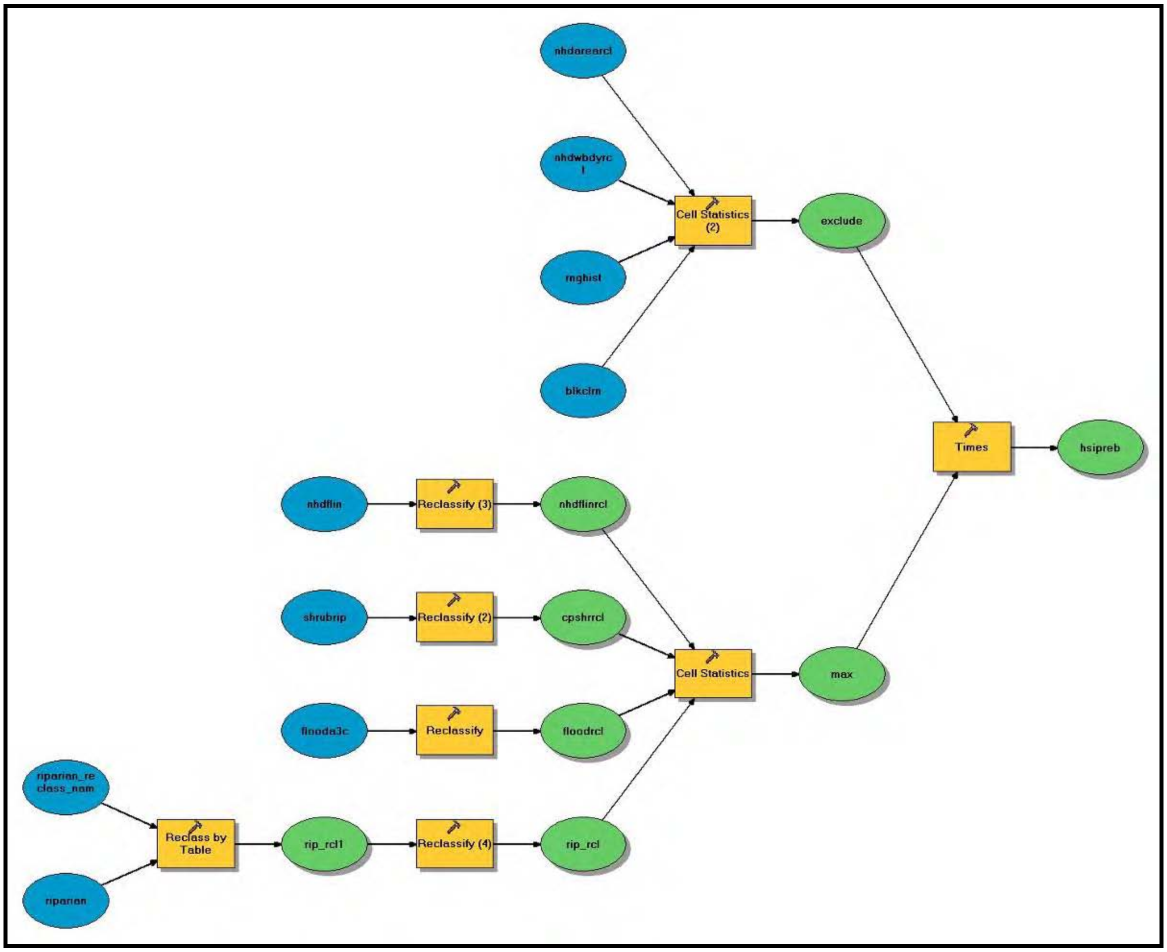


Figure 18. Model Builder diagram for Preble's meadow jumping mouse

All exclusion areas were converted to raster GIS data with a 25m cell size. For each theme, unsuitable areas were reclassified to a value of zero while suitable areas were reclassified to a value of 1. The minimum function in Spatial Analyst, applied to all exclusion rasters, created a raster of all unsuitable habitat for Preble's.

For rating habitat suitability indices for Preble's, several data sets were used: stream locations, riparian vegetation, and the 100-year flood zone. From the CVCP, a raster dataset, only the riparian shrub class was selected. The resulting raster was converted to a polygonal feature class. Riparian vegetation mapping data are concentrated on priority areas so some gaps are present in the data. The 100-year flood zones were from the FEMA.

All themes were buffered by 300 feet. The resulting polygons were converted to rasters with a 25 m cell size. A reclassify function was used to rank the suitability of the buffers or classes using a scale from 0 to 5, ranging from unsuitable habitat to highly suitable habitat, respectively. All cells containing riparian shrub as a dominant feature were ranked 5. Cells where the riparian shrubs were sub-dominant were ranked 4. Flood zone and buffer cells and stream cells and buffer were ranked 3. The resulting rasters were analyzed using the maximum function of spatial analyst, resulting in a grid with a maximum value for cell values selected from all input grids. This raster was multiplied by the exclusion raster to produce the final HSI raster for Preble's meadow jumping mouse (Figure 18).

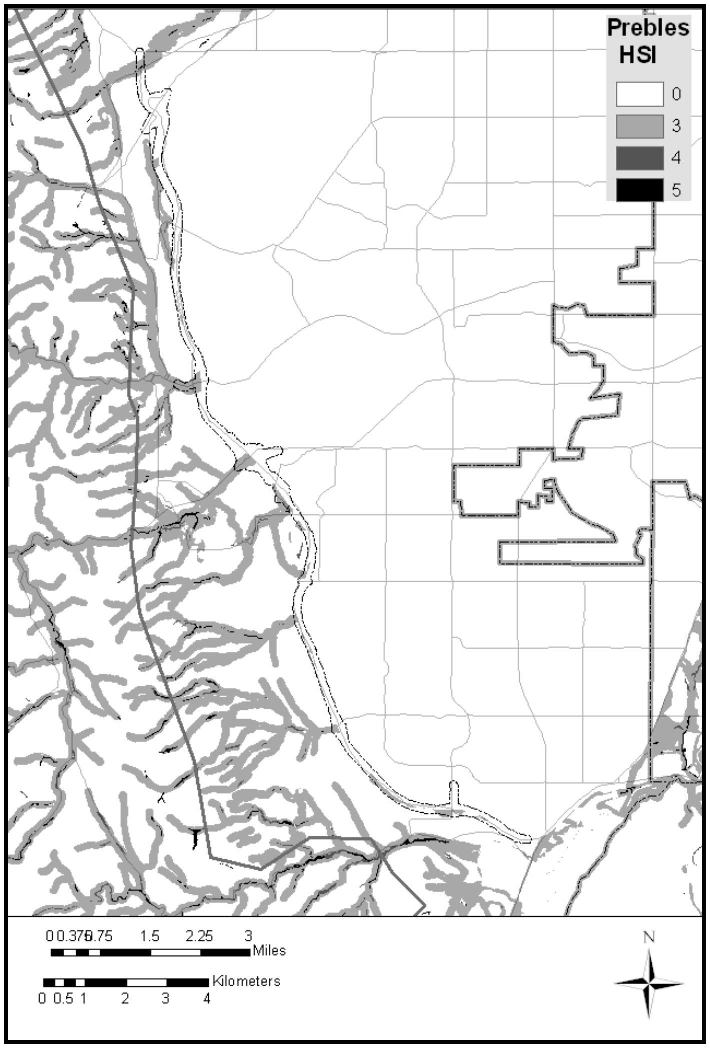


Figure 19. Preble's meadow jumping mouse HSI in the vicinity of the hypothetical C-470 project

Once the raster data sets are created, habitat ranks can be modified relatively easily using Model Builder. A new run of the model completes relatively quickly so it is feasible to use this tool for rendering and comparing scenarios during a meeting. On the other hand, modifications of the buffer width, if done in feature classes, and subsequent conversion to rasters takes a relatively long time, so is not feasible within the time-frame of most meetings.

4.4.8. Conclusions

Black-tailed Prairie Dog

The black-tailed prairie dog habitat suitability model shows graphically where potential habitat is located in the C-470 study area. Mitigation of impacts may be more easily carried out if potential sites for introduction and enhancement are known. Whether induced or not, the growth of the urban area in the vicinity of C-470 between now and 2030 will have a measurable impact on grass dominated habitat. The extract procedure has identified locations where development will replace suitable prairie dog habitat with residential land use by 2030 (Figure 20). Approximately 127 acres of grassland will be lost. Most of the remaining colonies will be located in open space or parks in this portion of Jefferson County.

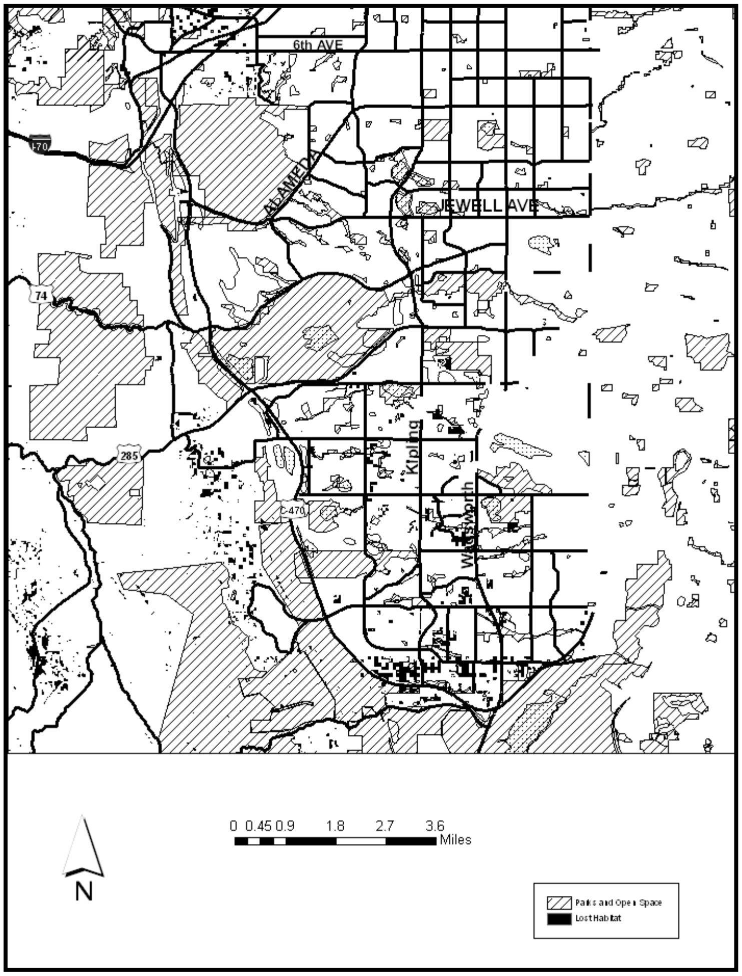


Figure 20. Suitable black-tailed prairie dog habitat replaced by urban development by 2030

Preble's Meadow Jumping Mouse

After completing the Model Builder run for the Preble's data were summarized using MS Access and MS Excel. This table shows that a relatively small area of potential habitat for Preble's is within the C-470 corridor with the predominant class having a rank of 3.

A RFF scenario in which only the parks and open space areas have potential suitable habitat for Preble's in the future may be reasonable, considering evidence from the exclusion zone immediately to the east of the corridor, and the plans of Jefferson County for major commercial development as a revenue-generating priority along the C-470 corridor in the future. If there is a significant mitigation effort, e.g., by planting shrubs in the riparian areas, then additional potential habitat would be created for Preble's in the future. On the other hand, trail development along stream corridors within parks and open spaces is expected to lead to a reduction in the amount of suitable habitat for Preble's.

Table 19. Current and Forecast Acres of Preble's Meadow Jumping Mouse Habitat at the Regional, Local and Project Scales, by Level of Habitat Quality

	Region		Local		Project			
	Current Habitat	Forecast Change*	Current Habitat	Forecast Change**	Current Habitat	% of Regional Current Habitat	Forecast Change**	% of Regional Forecast Change
Low***	203,159	49,819	29,561	10,109	214	0.11	60	0.12
Med	2,794	989	530	218	0	0	0	0
High	1,693	535	438	173	2	0.12	0	0
Total Habitat	207,646	61,333	30,529	10,500	216	0.23	60	0.12

*Acres of habitat loss due to projected urban development within the DRCOG urban growth boundary
**Acres of habitat loss due to local and project-area urban development projected by calculations described above
***Level of habitat quality for Preble's Meadow Jumping Mouse populations

Table Assumptions:

- All areas that are suitable habitat for Preble's within the existing parks and open space areas will be maintained as such.
- No additional parks and open space areas will be created in the RFF within the UGB area
- All areas that are suitable habitat for Preble's outside of the DRCOG parks and open space areas will be converted to habitat that is not suitable.
- All areas away from the floodplains and riparian corridors have an HSI of 0.

A decision on mitigation priorities would have to involve several factors including the fact that no Preble's individuals have been trapped in the area of the C-470 buffer. One consideration is the fact that the lack of habitat for Preble's in the exclusion zone can be expected to prevent migration among the populations to the north of the exclusion zone and those to the south (Figure 20). There is a possibility that migration among these populations could occur at higher

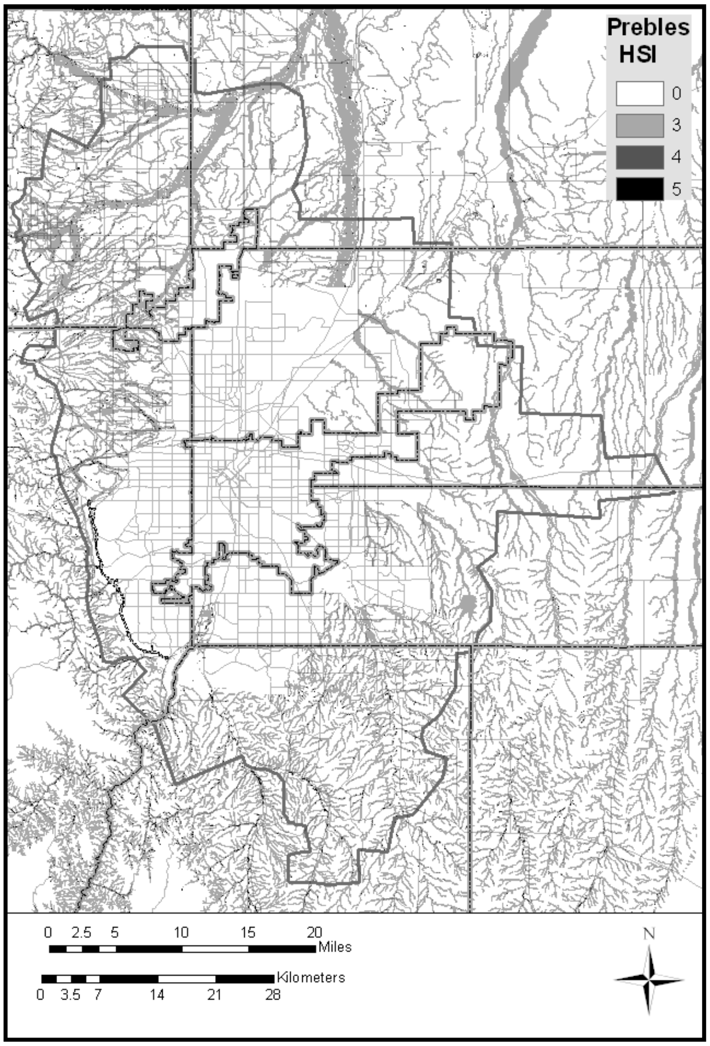


Figure 21. North-south movement of Preble's meadow jumping mouse is restricted

elevations, but this remains to be demonstrated by research. Lack of higher-elevation connections might justify more efforts at providing habitat at lower elevations.

5. CONCLUSIONS

We were tasked in this project to assess the usefulness of GIS technology in providing a means for comprehensive integration across a region of information on the environment, transportation projects, land use and changes associated with other development, jurisdictions and population characteristics. Based on project results, we argue that ACCEA is feasible and will provide valuable support to both project-specific assessment of cumulative impacts and regional transportation planning. Opportunities for regional CEA may be characterized as “supply-push” in that the availability of GIS technology provides a means to accomplish cumulative effects analysis in a manner not possible before.

- Data to support areawide CEA are generally available from public sources based on a modest effort to download data and collate to common formats. There are gaps in data collection and problems of access to published datasets. Historical data are not available for all resources, and workshop participants made a variety of recommendations for further data collection. Considering these issues however, we consider data resources to be adequate to support areawide CEA.
- Spatial models provide an enhanced means to predict environmental consequences of transportation projects individually and collectively across a region. Based on the model review undertaken in this project, it is clear that some CEA-related models are controversial; others have been used extensively in research and practice. Many participants argued that CEA spatial models are necessary to generate new information on resource usage, environmental impacts, and usage forecasts. Participants emphasized the value of simple models that are understandable and easy to apply.
- Metrics can be based on GIS data and models, and organized to provide a comprehensive means for accounting of resources across a region. For the water resources domain, for example, it has been demonstrated that a regional accounting of impervious areas can be obtained from GIS data and processing. The resolution of the data is detailed enough such that specific characteristics of individual transportation projects can be tabulated and portrayed, and these project-scale characteristics can be accounted across an entire region for a collection of planned projects and associated related land use changes.

- Regional accounting opportunities vary by resource. Some participants commented that regional tabulations may not be appropriate for certain resources. For example, water quality may be best assessed at the watershed scale. Issues of data consistency also emerged. While many datasets are consistent across regions (e.g., CVCP), others use inconsistent attributes and collection dates (e.g., assessor datasets). Nonetheless, the principle of regional accounting was supported by project findings and particularly through the demonstration project.
- Stakeholder involvement is necessary to obtain a common understanding of the data and models, establish validation of the models, acknowledge priorities and preferences of participants who would use the models, and integrate model usage into administrative processes for decisions. It is these administrative procedures for model acceptance and integration that remain somewhat elusive.

5.1 Workshops

5.1.1. Major Findings

We were generally successful in obtaining participation in the workshops by environmental professionals from the various agencies and consultants involved with CEA. Major outcomes of the workshops include (1) development of a common understanding of relevant regulatory requirements and potential impacts, and (2) identification of acceptable methods for characterizing cumulative effects at different scales. We found that GIS and remote sensing tools are an effective method for integrating data and models in most of the resource areas we examined, and they provide a useful framework for analysis of cumulative effects. For the most part data were generally available and usable for ACCEA, and most participants had a fundamental understanding of how GIS tools could be applied to ACCEA. Feedback from participants indicated some general guidance for GIS data and models acceptance, including the use of simplified models which can be dovetailed with agencies' practice.

5.1.2. Land Use

Data on past and present land uses are relatively widely available; one of the most comprehensive is the CVCP. A variety of competing models has been developed for assessment of energy effects. Participants focused on the LESA model for measurement of cumulative effects related to agriculture. Many metrics were proposed in the workshop for measuring the cumulative impacts related to land use, agriculture, mining and energy. The metrics included conversion of private open space or agricultural lands, loss and increase of land values, fragmentation, air quality, noise level, and the change in the ratio of developed land to recreational, agricultural and open space lands. Some participants argued that a rating system should be developed to assess the value and type of agricultural, recreational, mining and open space land. Guidelines and standards should be locally defined based on national metrics such as the National Park and Recreation Association (NRPA) standards including the ratios of use per acre of recreation and open space and desired future conditions.

5.1.3. Water Resources

Water supply and demands were rated highly relevant to transportation project and areawide CEA in recognition of their importance to sustaining growth and environmental values in Colorado. However, it was felt that complications of technical, legal and administrative aspects make tracking of water supply and demand too difficult for transportation ACCEA purposes. Flood runoff and drainage were rated highly relevant to transportation projects and ACCEA in recognition of the influence that highways have on flood runoff due to increases in impervious surfaces. Secondary growth influences of highways leading to residential and commercial development also increase impervious surface areas and can lead to increases in flood runoff in comparison to natural conditions. However, separating the influence of highways from secondary growth is difficult and is not considered a reasonable means for conducting ACCEA. Water quality concerns were rated as the most relevant of the three water resources sub-domains. The highest rated metric for water quality was impervious surface increases associated with transportation projects and secondary growth. Impervious surfaces are readily estimated using GIS databases and it is possible to separate transportation project effects from other land use changes, at least for local watersheds within which highway projects occur.

5.1.4. Biological Resources

Ranking of species to be considered was accomplished in the workshop and through meetings with attendees following the workshop. The ranking was influenced by the importance of each species in terms of transportation projects. Habitat suitability models were suggested as one of the best ways of characterizing the distribution of habitat of T & E species, and other species of concern, on a regional basis. These suitability models can be generated by a GIS that contains relevant environmental data for each species. The Colorado Vegetation Classification Project data (CVCP), developed from satellite data by the Colorado Division of Wildlife and the Bureau of Land Management, is perhaps the best dataset available for assessing habitat of T & E species and species of concern. Models can be developed using Habitat Suitability Indices for select species found in the region.

5.1.5. Cultural Resources

Roads and associated development may have cumulative negative effects on the quality of cultural resources through noise levels generated by multiple roads, visual changes in the character of urban settings, and in general increasing urban density. Data for ACCEA analysis of cultural resources is limited, however. The Cultural Resources database in the State Historic Preservation Office (SHPO) is not comprehensive but rather an accumulation of project-specific survey results. In addition to SHPO, there are other data sources such as assessor's data that could be integrated into CEA-related project analysis, at least in the scoping stage. Thresholds for CEA analysis are also controversial because of what workshop participants' described as the uniqueness of cultural resources. However, there is a useful precedent for ACCEA-type analysis in the context studies already performed as a part of cultural resource assessments. Finally, there are opportunities for inter-agency agreements. Participants commented, for example, that a data-sharing agreement between SHPO and CDOT may be useful.

5.1.6. Community Impacts

CEA analysis of community and environmental justice encompasses issues such as effects on specific populations, health, community cohesion and loss or gain of certain types of businesses. Participants asserted that cumulative effects of transportation investments on communities or specific populations may be both positive and negative. Much of the discussion in the workshop focused on data development including (1) applications for existing tabular data that are not typically organized in a GIS, and (2) methods for collection of raw data such as windshield surveys. There was agreement that there is a large number of underutilized data sources that could be tapped for environmental justice analysis. With respect to regional accounts, some participants argued that they are useful for environmental justice CEA because they provide an opportunity to mitigate on a regional scale, not project-by-project. Other participants emphasized the technical difficulties in accounting for community or environmental justice impacts on a regional scale.

5.2 Demonstration Project

5.2.1. General

For this ACCEA demonstration project we focused on three realms of potential impacts: 1) land use, 2) biological resources and habitat, and 3) water quality. Our emphasis is on demonstrating the utility of GIS data management and modeling tools to develop an accounting of these resources for areas proximate to the C470 roadway right of way, the local area where indirect effects might occur, and the region.

5.2.2. Land Use

Several participants suggest that there were significant indirect development effects (induced development) resulting from the initial construction of C-470 and the expansion of US Highway 285. Future indirect development effects of the project itself in western Jefferson County may be less significant. Nonetheless, overall rates of development are substantial. In our growth projections, we anticipate at the project scale that all land that is not protected will be developed. At the local scale, which in our analysis includes all of Jefferson County, we project significant continued growth in the valley bottoms and other accessible areas. For this demonstration of an ACCEA, we have adopted the most inclusive definition including all past, present and future urban development of any kind. Using this approach, an ACCEA can support whatever definition is adopted at the individual project level. Finally, concerns were raised about cost of data collection and preparation. We recommend that Phase II of this project include the cooperative development of a data and modeling infrastructure to support cumulative effects assessment of this kind.

5.2.3. Water Resources

The demonstration project for water quality provides a basis for drawing several conclusions concerning the feasibility of such methods for ACCEA. The water quality demonstration project shows that GIS data are readily available to support cumulative effects analyses. The data are quite refined in the level of spatial detail so that the various levels of scope – project, local and region – can be accommodated. GIS processing functions support the tabulation of land use areas of various types, and their associated impervious area characteristics. Integration of the RFF land use changes is also readily accomplished. The impervious area (or %Impervious) metric is relatively straightforward to generate and provides an informative basis for comparison of water quality threats in specific sub-basins and for the region. Differences attributable to specific project facilities can be identified, as can changes due to anticipated secondary growth effects. The GIS-based methodology provides a template for inclusion of multiple projects and RFF growth effects for other specific watersheds and for an overall regional accounting. The demonstrated methodology does not account for mitigation measures for stormwater runoff, such as required by CDOT's participation in the metro Denver MS4 Program. However, it is possible to extend the method using simulation modeling approaches, such as the BASINS model. However, advancing the sophistication of the analysis approach would negate the simplicity of the %impervious approach, and may not be acceptable to the participating agencies.

5.2.4. Biological Resources

GIS modeling of species appears to be a viable approach for characterizing their distributions and the relative abundance of suitable habitat. The development of habitat suitability indices using ArcGIS's Model Builder provides a GIS tool for developing geospatial models that once developed, will provide a means for future analyses. The black-tailed prairie dog is widespread in the region and in the C-470 project area. The habitat suitability model developed for the prairie dog indicates that there are many habitat fragments present in the vicinity of the project and throughout the region; however, the majority of these habitat patches are unoccupied. Presence of unoccupied habitat indicates the potential for regional accounting and the possible use of unoccupied habitat for impact mitigation through species introduction and habitat enhancement. The Preble's model indicates that there is a relatively small amount of habitat for Preble's in the project area. The dominant rank of habitat is a 3 (a 1 to 5 scale with 5 being the best) in the project area. One reason why no Preble's have been found in previous studies of the same area might be that immigration routes to the east have been effectively cut off by urban development and there is little chance of migration between drainages at higher elevations to the west of the project area. Considering the rate and degree of development that is taking place in the west metro area, the only truly suitable habitat for the long term may be in dedicated open space.

5.3 Recommendations

Based on the outcomes of Phase I, we consider the general outlines for Phase II, as described in the ACCEA Statement of Work Request for Task Proposal, to be feasible and appropriate. The following additional recommendations for Phase II and Phase III emerged from the demonstration project and workshops.

1. Create tools including a web-based infrastructure to support ACCEA (Phase II and III). The data and linked models should be made available through a web interface to provide easy means for download of data, access to or transfer of models, and upload of project-specific information by project consultants. We developed a prototype component of web-based infrastructure to support expert participation in land use projections; this is posted at http://cdot.eparticipation.net. A workshop program should also be instituted to develop capacity among CDOT and contractor staff to undertake ACCEA data management and CEA modeling tasks.

2. Build agency support for ACCEA. There are significant planning process issues associated with development and implementation of an ACCEA database and models that are truly usable by the involved parties. It is recommended that Phase II incorporate directed activities to help ensure "buy-in" by agency managers and staff. These might include, for example, designation of a key staff member from each agency that would be integrally involved with the ACCEA project development, who would serve as the agency point of contact, and who would conduct within-agency activities to transfer the developed ACCEA database and models functionality into agency operations.

3. Establish interagency agreements regarding data-sharing and analysis protocols. In certain areas, data-sharing agreements could be forged to create better access to data for CEA analysis. These include (1) agreements related to historic structures between the state historic preservation office and CDOT; and (2) agreements regarding a range of datasets between DRCOG and CDOT.

4. Improve access to CEA-related data through further construction of datasets, data portals, and data agreements. Data used for the ACCEA project should be incorporated into an ESRI geodatabase compatible with other CDOT GIS data. Simple and easily applied habitat suitability index models should be developed for select biological resources in the region, utilizing GIS technology. Wetland banking should be looked at as a viable mitigation methodology. GIS and other data should be archived into a geodatabase to make the data available for CDOT personnel, consultants and others concerned with cumulative effects assessment.

5. Create inter-agency and inter-governmental working groups to further develop CEA-related protocols in key areas. In Phase II of the project, interagency working groups should be established focusing on key analysis protocols for areawide CEA. These working groups should address further development of agreements about data, models and metrics.

6. Focus on key resources in the Phase II assessment. Based on the findings of Phase I, key resources should be identified for analysis of the Denver Metro RTP in Phase II. Cultural resources, for example, may not be deemed appropriate for an areawide CEA in this region.

7. Create inter-agency and inter-governmental working groups to further develop areawide priorities for ACCEA related to key resources. In Phase II of the project, interagency working groups should be established focusing on resource priorities for areawide CEA. These working groups should focus on further development of priorities about resources that should be considered in areawide CEA.

8. Explore how CDOT can provide guidance to contractors for the implementation of protocols, priorities and other frameworks developed through Phase II of the project. Where possible, Phase II should be structured to define specific ways in which CDOT can structure the work of contractors related to CEA, either through contract language or other types of guidance.

9. *Explore opportunities for integration of CEA-related information into the regional transportation planning process, including initiatives such as the Strategic Transportation, Environmental and Planning Process for Urbanizing Places* (*STEP UP) initiative for Colorado.* Finally, Phase II of the project should explicitly examine the regional transportation process and the potential for integration of areawide CEA-related information and analysis into that process.

10. *Explore collaborative development of resources for ACCEA-type projects*. At present there do not appear to be adequate resources in Colorado to support meaningful regional accounting. Additional effort should be undertaken in Phase II to organize cross-agency discussion about funding for collaborative development of ACCEA infrastructure.

LIST OF ACRONYMS AND ABBREVIATIONS

AAP	Agency Advisory Panel
ACCEA	Areawide Coordinated Cumulative Effects Analysis
APCD	Air Pollution Control Division
BASINS	Better Assessment Science Integrating Point and Nonpoint Services
BLM	Bureau of Land Management
BTPD	Black-tailed Prairie Dog
CDOT	Colorado Department of Transportation
CDOW	Colorado Division of Wildlife
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Discharge Permit System
CDRMS	Colorado Division of Reclamation Mining & Safety
CEA	Cumulative Effects Analysis
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CNHP	Colorado Natural Heritage Program
CO	Colorado
CVCP	Colorado Vegetative Cover Project
DEM	Digital Elevation Model
DOLA	Department of Local Affairs
DRCOG	Denver Regional Council of Governments
ESA	Endangered Species Act
ESRI	Environment System Research Institute
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GIS	Geographic Information System
GISST	GIS Screening Tool
GWL	Ground Water Levels
HSI	Habitat Suitability Index
HSI	Health and Safety Improvement Program
IMP	Information Management Platform
LTHIA	Long Term Hydrologic Impact Assessment
NCWCD	Northern Colorado Water Conservancy District
NEPA	National Environmental Policy Act
NRCS	Natural Resources Conservation Service
NRPA	National Park and Recreation Association
NWI	National Wetlands Inventory
PMJM	Preble's Meadow Jumping Mouse
QUAL2K	River and Stream Water Quality Model

RFF	Reasonably Foreseeable Future
RTP	Regional Transportation Plan
SHPO	State Historic Preservation Officer
SSURGO	Soil Survey Geographic Database
STEP UP	Strategic Transportation, Environmental and Planning Process for Urbanizing Places
STIP	Science Technology and Innovation Policy
SWSI	Statewide Water Supply Initiative
T&E	Threatened and Endangered Species
TAZ	Traffic Analysis Zones
TMDL	Total Mass Discharge Loading
UCD	University of Colorado Denver
UDFCD	Urban Drainage and Flood Control District
URO	Utilization Review Organization
USACE	United States Army Corps of Engineers
USC	United States Code
USGS	United States Geological Survey

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Recreation and Open Space					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Undeveloped land per resident	CVCP, assessor and parcel records	Mosaic of undeveloped land datasets; tabulation by jurisdiction or neighborhood.	Acres of undeveloped land per resident; overall description of landscape openness	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%	High
Future area per projected resident	Various county and city datasets	GIS overlay of projected area and projected populations	Acres of lands per resident by jurisdiction or area	Not determined	High
Sports field area	Various county and city datasets	Mosaic of local parks data; tabulation by jurisdiction or neighborhood.	Acres per resident; describes developed and organized recreational opportunities	Professional standards (e.g.,american planning association); local planning guidelines	Low
Recreational centers	County and city datasets	Measurement; description of facilities	Number per resident; resources per resident	Not determined	Low
Neighborhood park area	Various county and city datasets	Mosaic of local parks data; tabulation by jurisdiction or neighborhood.	Acres per resident; describes recreational opportunities for families with children	Professional standards (e.g.,APA); local planning guidelines	High
State park areas	State data; park data	Count; analysis of resources and use	Acres; acres per resource; use statistics	Not determined	High

Recreation and Open Space					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Hiking/biking trail length	Various county and city datasets	Trail network measurement; tabulation by jurisdiction or neighborhood.	Miles per resident; describes availability of hiking and biking recreation	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%	High
Picnic areas	Various county and city datasets	Measurement; tabulation by jurisdiction or neighborhood	Number of picnic areas per resident	Not determined	Low
Sports field use	Various county and city datasets	Measurement; tabulation by jurisdiction or neighborhood	Hours per resident	Not determined	Low
Recreational center use	Various county and city datasets	Measurement; tabulation by jurisdiction or neighborhood	Hours per resident	Not determined	Low
Neighborhood park use	Various county and city datasets	Measurement; tabulation by jurisdiction or neighborhood	Hours per resident	Not determined	Low
State park visitation	Various county and city datasets	Measurement; tabulation by jurisdiction or neighborhood	Number of visitors	Not determined	High
Hiking trail use	Various county and city datasets	Measurement; tabulation by jurisdiction or neighborhood	Hours per resident	Not determined	Low
Biking trail use	Various county and city datasets	Measurement; tabulation by jurisdiction or neighborhood	Hours per resident	Not determined	Low

Recreation and Open Space					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Picnic area use	Various county and city datasets	Measurement; tabulation by jurisdiction or neighborhood	Hours per resident	Not determined	Low
Continuous trails	State parks, front range trail, city and county datasets	Measurement; tabulation by jurisdiction or neighborhood	Miles per resident	Longer than a specified threshold	Medium
Open space area	CVCP, DRCOG open space data, county and city datasets	Mosaic of open space data; tabulation by jurisdiction or neighborhood.	Acres of dedicated open space lands and conservation easements per resident; describes availability of protected open space	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%	High
Noise levels	State and local noise assessments	Surveys and compilation of survey data; tabulation by jurisdiction or neighborhood	Acres affected at different decibel levels; describes noise impacts on recreational experience	Local, state and federal statutory thresholds	Low
Mountain backdrop unobstructed view	Visual assessments	Measurement; tabulation by jurisdiction or neighborhood	Acres with unobstructed view	Not determined	High
Natural visual context	Visual assessments		Acres in a visually natural setting	Not determined	High

Recreation and Open Space					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Open space accessibility	Various county and city datasets; us population and housing census	Buffer or network measures; tabulation by jurisdiction, sub-region or neighborhood	Population within 15 minute drive of contiguous open space; accessibility measure	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%	High
Trail accessibility	Various county and city datasets; us population and housing census	Buffer or network measures; tabulation by jurisdiction, sub-region or neighborhood	Population within 15 minute drive of continuous trails; accessibility measure	Proportional 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = <90%	High
Neighborhood park accessibility	Various county and city datasets; us population and housing census	Buffer or network measures; tabulation by jurisdiction, sub-region or neighborhood	Population within 15 minute walk of a neighborhood park; accessibility measure	Professional standards (e.g.,APA); local planning guidelines	High
Developed facility accessibility	Us population and housing census	Not determined	Population within 10 minute drive of developed facilities (e.g, sports fields)	Not determined	High
Neighborhood park accessibility – EJ populations	Us population and housing census	Not determined	EJ population within 15 minute walk of a neighborhood park	Not determined	High
Developed facility accessibility – EJ populations	Us population and housing census	Not determined	EJ population within 10 minute drive of developed facilities (e.g, sports fields)	Not determined	High

Recreation and Open Space					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Bicycle transit access	Not determined	Not determined	Not determined	Not determined	Not deter-mined

Agriculture					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Irrigated agriculture class	CVCP	Reclassification, time-series analysis	Total acres, maximum size, minimum size, average size, modal size. From 1993-97 Landsat	Not applicable	High
Agriculture class (not irrigated)	CVCP	Reclassification, time-series analysis	Total acres, maximum size, minimum size, average size, modal size. From 1993-97 Landsat	Not applicable	High
Prime farmland	SSURGO	Mosaic, reduction, reclassification, time-series analysis	Total acres, maximum size, minimum size, average size, modal size. Potential based on site characteristics	Not applicable	High.
Agricultural zoning	Zoning maps	Digitizing, scanning, mosaic, selection, time-series analysis	Total acres, maximum size, minimum size, average size, modal size. Identifies jurisdictional plans	Not applicable	High
Acres irrigated	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low
Average farm size	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low
Major crops	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low
Farmable land in government jurisdiction	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low

Agriculture					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Amount of farmland as defined in fppa	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low
Name of land evaluation system used	LESA	Query on database	Usually LESA	Not applicable	Low
Name of local site assessment system	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low
Total acres to be converted directly	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low
Total acres to be converted indirectly, or to receive services	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low
Total acres in corridor	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low
Total acres prime and unique farmland	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low
Total acres statewide and local important farmland	LESA	Query on database	Acres; completed by NRCS	Not applicable	Low

Agriculture					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Percentage of farmland in county or local government unit to be converted	LESA	Query on database	%; completed by NRCS	Not applicable	Low
Percentage of farmland in government jurisdiction with same or higher relative value	LESA	% calculation	Acres; completed by NRCS	Not applicable	Low
Land evaluation information criterion; relative value of farmland to be serviced or converted	LESA	Evaluation;	Acres; completed by NRCS; maximum 100 points	Not applicable	Low
Area in nonurban use	LESA	Area calculation	Completed by federal agency; maximum 15 points	Not applicable	Low
Perimeter in nonurban use	LESA	Perimeter calculation	Completed by federal agency; maximum 10 points	Not applicable	Low
Percentage of corridor being farmed	LESA	% calculation	Completed by federal agency; maximum 20 points	Not applicable	Low

Agriculture					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Protection provided by state and local government	LESA	Scoring	Completed by federal agency: maximum 20 points	Not applicable	Low
Size of present farm unit compared to average	LESA	Ratio calculation	Completed by federal agency; maximum 10 points	Not applicable	Low
Creation of nonfarmable farmland	LESA	Area	Completed by federal agency; maximum 25 points	Not applicable	Low
Availability of farm support services	LESA	Evaluation	Completed by federal agency; maximum 5 points	Not applicable	Low
On-farm investments	LESA	Calculation	Completed by federal agency; maximum 20 points	Not applicable	Low
Effects of conversion on farm support services	LESA	Evaluation	Completed by federal agency; maximum 25 points	Not applicable	Low
Compatibility with existing agricultural use	LESA	Evaluation	Completed by federal agency; maximum 10 points	Not applicable	Low
Total score	LESA	Summation	Completed by federal agency; maximum 260 points	Not applicable	Low

Agriculture					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Availability of irrigation water	Colo. DNR – DWR and CWCB – irrigated lands.	GIS and database tabulations.	Irrigation supply; volume/acre	TBD; water rights priority	Low

Mining					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Aggregate mines; source of construction materials	CDRMS; USOSM; local data	GIS and database tabulations; time series analysis.	Tons per year; number of new mines; acres; acres by area or jurisdiction.	TBD; important for riparian areas.	High
New coal mines	CDRMS; USOSM; local data	Database compilation; GIS and database tabulations; time series analysis.	Tons per year; number of new mines; acres; acres by area or jurisdiction.	TBD; link to Energy category.	Low
New mineral mines	CDRMS; local data	Database compilation; GIS and database tabulations; time series analysis.	Tons per year; number of new mines; acres; tabulations by area or jurisdiction.	TBD	Low
New mine expansions	CDRMS; USOSM; local data	Database compilation; GIS and database tabulations; time series analysis.	Tons per year; number of new mines; acres; acres by area or jurisdiction.	TBD	High
Reclaimed land	CDRMS; USOSM; local data	Database compilation; GIS and database tabulations; time series analysis.	Acres by area or jurisdiction.	TBD; important for riparian areas.	High
Open pit mining	CDRMS; USOSM; local data	Database compilation; GIS and database tabulations; time series analysis.	Tons per year; Area (acres); percentage of mines; time series – total, regional, watershed, project.	TBD; important for riparian areas.	Medium
Underground mining	CDRMS; local data	Database compilation; GIS and database tabulations; time series analysis.	Tons per year; percentage of mines; total, by region, by watershed, by project.	TBD	Low

Mining					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Dollars spent on wastewater treatment (water bodies adjacent to a mine site)	CDPHE; local data	Database compilation; database tabulations.	$$$ (dollars); time series of expenditures – total, by region, watershed, project.	TBD	Low
Dollars spent on sound insulation at mine sites	Local data	Database compilation; database tabulations.	$$$ (dollars); time series of expenditures – total, by region, watershed, project.	TBD	Low
Vehicle flow per day (in and out of a mine site)	CDOT, local traffic count data	Database compilation; GIS and database tabulations; time series analysis.	Traffic counts; time series.	TBD	Low
Subsidence (surface deformation) at mining site	CDRMS; USOSM; local data; satellite imagery	Database compilation; image processing; terrain modeling.	Meters in feet; time series.	TBD	Low
Dollars spent on EIS studies of mining sites	CDRMS; local data	Database compilation and tabulations.	$$$ (dollars); totals, by region, watershed, project; time series.	TBD	Low
Annual production of mineral waste	CDRMS, CDPHE, USOSM, local data	Database compilation; GIS and database tabulations; time series analysis.	Million tons; totals, by region, watershed, project; time series.	TBD	Low
Mining area restored per year	CDRMS, USOSM, local data	Database compilation; GIS and database tabulations; time series analysis.	Hectares in acres	TBD	Low
Smoke - density of aerosol particulates	CDPHE; USEPA; local data	Database compilation; GIS and database tabulations; time series analysis.	Grams per cubic meter (g/m3)	TBD; very site specific	Low

Mining					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Dust - weight of particulates	CDPHE; USEPA; local data	Database compilation; GIS and database tabulations; time series analysis.	Microgram per cubic meter (µg/m3)	TBD; very site specific	Low
Heavy metals in air	CDPHE, USEPA, local data	Database compilation; GIS and database tabulations; time series analysis.	Moss is used as measurement technique; Percentage (%) settled on mosses.	TBD; very site specific	Low
Sulphur dioxide (SO_2)	CDPHE, USEPA, local data	Database compilation; GIS and database tabulations; time series analysis.	Parts per billion 'or' parts per million 'or' µg/m3 'or' milligrams per cubic meter	TBD; very site specific	Low
Pollution emission at source	CDPHE, USEPA, local data	Database compilation; GIS and database tabulations; time series analysis.	$100(M_a/M_c)$; Ma = mass emission rate by area (grams) & Mc = mass emission rate as concentration (grams)	TBD; very site specific	Low
Aquatic community diversity – for water body adjacent to mining area	CDPHE, DOW, USEPA, USGS, local data	Database compilation; GIS and database tabulations; time series analysis.	$d = (S - 1/\log_c N)$, where d = community diversity index, s = number of species & n = number of organisms.	TBD; very site specific	Low
Toxic unit (Tu) of an organism - water body adjacent to mine site	CDPHE, DOW, USEPA, USGS, local data	Database compilation; GIS and database tabulations; time series analysis.	Milligrams per litre (mg/l);	TBD; very site specific	Low

Mining					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Organic pollutants in water body adjacent to a mine site	CDPHE, DOW, USEPA, USGS, local data	Database compilation; GIS and database tabulations; time series analysis.	Mg/l	TBD; very site specific	Low
Oils in water body adjacent to a mine site	CDPHE, DOW, USEPA, USGS, local data	Database compilation; GIS and database tabulations; time series analysis.	Thickness of the oil film on water; Inches (in) ‘or’ centimeter (cm)	TBD; very site specific	Low
Hydrogen potential (ph) in a water body adjacent to a mine site	CDPHE, DOW, USEPA, USGS, local data	Database compilation; GIS and database tabulations; time series analysis.	Number	TBD; very site specific	Low
Base metals, fluoride, dissolved solids - adjacent to a mine site)	CDPHE, DOW, USEPA, USGS, local data	Database compilation; GIS and database tabulations; time series analysis.	Mg/l	TBD; very site specific	Low
Color (of a water body adjacent to a mine site)	CDPHE, DOW, USEPA, USGS, local data	Database compilation; GIS and database tabulations; time series analysis.	Platinum – cobalt units	TBD; very site specific	Low
Noise level (areas adjacent to a mine site)		Database compilation; GIS and database tabulations; time series analysis.	Decibels (db)	TBD; very site specific	Low

Energy					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Person miles travel demand (pmt)	CDOT, DRCOG, FHWA, local data.	Database compilation; GIS and database tabulations; time series analysis.	Pmt/capita; total, by region, jurisdiction; time series.	Not identified	Low - energy use affects not a NEPA priority.
Energy per unit area of installed roadway	CDOT, DRCOG, FHWA, local data.	Database compilation; database tabulations; computation of unit energy use.	Kj/area; total, by region, jurisdiction; time series.	Not identified	Low
Transportation cost as % of income	CDOT, DRCOG, FHWA, U.S. Census, local data.	Database compilation; database tabulations; computation of unit energy use.	Percentage; total, by region, jurisdiction; time series.	Not identified	Low
Vehicle energy intensity (vei)	CDOT, DRCOG, FHWA, local data.	Database compilation; database tabulations; computation of unit energy use.	Kj/vmt; total, by region, jurisdiction; time series.	Not identified	High
Modal energy intensity (mei)	CDOT, DRCOG, FHWA, local data.	Database compilation; database tabulations; computation of unit energy use.	Kj/pmt; total, by region, jurisdiction; time series.	Not identified	High
Transportation system energy intensity (tsei)	CDOT, DRCOG, FHWA, local data.	Database compilation; database tabulations; computation of unit energy use.	Kj/capita; total, by region, jurisdiction; time series.	Not identified	High

Water Resources – Demands And Supplies

Metric name	Dataset	Analytical methods	Metric description	Thresholds	Utility
Water supplies compared to water demands –ratio (ws/wd)	USGS, Denver Water, water providers, CWCB/SWSI; difficult to collate various sources with demands.	Geodb compilation; time series analysis; GIS displays. Comprehensive comparison of supplies and demands quite complicated.	Amount of water withdrawn for water supply, by source – time series and % change (+/-) normalized by demands. Time series of deliveries, totals and by source; % change (+/-)	Ws/wd: 1 = >120% 2 = 110-120 3 = 100-110 4 = 90-100 5 = < 90%	High, but difficult to obtain data & limited applicatio n for trans.
Total water demand (twd)	DRCOG, Denver Water, water providers, CWCB-SWSI.	Geo database compilation, time series statistics, GIS displays	Indicates magnitude of water use over time and forecasts to 2030. % change based on time series; map display of twd & % change at time increments	Twd % change: 1 <= 0% 2 = 0 - 5% 3 = 5 -10% 4 = 10-20% 5 = >20%	High, but no single source of data & limited for trans.
Per capita water demands (WD/P)	DRCOG, Denver Water, water providers, census pop (P).	Geo database compilation, compute wd/p as twd/p; wdr as regional ratio wdr/pr	WD/P indicates intensity of water use which limits water for other uses. Regional variations show differences. Map display of ratio of wd/p to region per person average wdr/pr	Wd/p/ wdr/pr: 1=<-20% 2=-20to-5% 3=-5to+5% 4=+5to20% 5=>20%	Medium; limited for trans.

Water Resources – Demands And Supplies					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Water conservation – amount conserved (wc)	DRCOG, Denver Water, water providers; forecast to 2030?	Geo database compilation, tabulation of types and amounts; wc%= wc/twd*100; GIS displays	Percent of total water supply which is conserved; higher conservation reduces overall demands. Map display of wc%	Wc%: 1=30% 2=20to10% 3=10to5% 4=5to2% 5=<2%	Medium; partial picture of water balance.
Water conservation – water metering (wm)	Pop. Forecasts of DRCOG, Denver Water, water providers. Forecasts to 2030?	Geo database compilation; wm% = metered/total connections; GIS displays	Metering supports multiple conservation outcomes – pricing, codes and regulations. Wm%; displayed as GIS map	Wm%: 1=>50% 2=30to50% 3=20to30% 4=10to20% 5=>10%	Medium; partial picture of water balance.
Water recycling (wr):	DRCOG, Denver Water, water providers. Forecast to 2030.	Geodb compilation; wr% = wr/twd*100; GIS displays	Percent of total water supply which is recycled. Water recycling reduces demand. Wr%, displayed as map.	Wr%: 1=>50%, 2=30-50, 3=20-30, 4=10-20, 5=>10%	Medium; partial picture of water balance.
Consumptive use (CU):	Temperature and cropping (updated periodically by dwr); CWCB/SWSI	Geodb compilation, blaney-criddle model; GIS displays	Amount lost to atmosphere from irrigation, cooling, etc. Reduction in consumptive use reduces demand. Tabular, GIS map of cu (in)	CU: 1=<5 in, 2=5-10, 3=10-15, 4=15-20, 5=>20 in	High, but limited applicatio n for trans.

Water Resources – Demands And Supplies					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Water supply deliveries (ws):	DRCOG, Denver Water, CWCB/SWSI, water providers; single source?	Geodb compilation; time series analysis; GIS displays	Water deliveries by suppliers; 2030 forecasts. Increases in supplies indicate reduced flows in source basins. Time series of deliveries; totals and by service provider; % change (+/-)	Ws % change: 1=<0%, 2=0-5%, 3=5-10%, 4=10-20%, 5=>20%	High, but limited applicatio n for trans.
Surface water supply by source (sws):	USGS, Denver Water, water providers, CWCB/SWSI	Geodb compilation; time series analysis; GIS displays	Amount of water withdrawn for water supply, by source. – time series and % change (+/-).time series of deliveries; totals and by source; % change (+/-)	Sws % change: 1=<0%, 2=0-5%, 3=5-10%, 4=10-20%, 5=>20%	High, but limited applicatio n for trans.
Water supply source versus native supply (swn):	USGS, Denver Water, water providers, CWCB/SWSI	Geodb compilation; compute delta source vs withdrawals - time series analysis (% +/-); GIS displays.	Comparison of supply diversions to native supply. Indicates impact on source; % basin. Time series of differences; totals and by source; % change (+/-); GIS displays	Swn % change: 1=>50%, 2=50-20%, 3=20-10%, 4=10-5%, 5=<5%	High, but limited applicatio n for trans.

Water Resources – Demands And Supplies					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
River flows (rf):	USGS, USFWS, dow	Geodb compilation, time series, flow frequency analyses, GIS display	River flows in segments sustaining sensitive and endangered species. Flow time series, flow frequency analyses, GIS display of flow metric [cfs]	Rf: 1=>500cfs, 2=500-200, 3=200-100, 4=100-50, 5=<50 cfs	High, but limited applicatio n for trans.
Groundwater withdrawals, by source (gws):	USGS, DRCOG, water providers	Geodb compilation, time series of well withdrawals; statistics; GIS maps of drawdowns	Withdrawals by sector and sources. Large and long-term withdrawals deplete supply. Tabular, GIS map of withdrawals for area; time series and % change (+/-)	Gws % change: 1=<0%, 2=0-5%, 3=5-10%, 4=10-20%, 5=>20%	High, but limited applicatio n for trans.
Groundwater levels (gwl):	USGS, DRCOG, Denver Water, water providers, CWCB/SWSI	Geodb compilation, time series of water levels & statistics - % change (+/-); by source and indicator wells.	Gw levels indicate the state of remaining supplies from the aquifer; decreasing levels indicate supply depletion. GIS maps of drawdown areas [ft]	Gwl change: 1=<20, 2=20-50, 3=50=100, 4=100-250, 5=>250	High, but limited applicatio n for trans.

Water Resources – Demands And Supplies					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Groundwater recharge (gwr):	USGS, DRCOG, Denver Water, water providers, CWCB/SWSI	Geodb compilation, time series of gw recharges - % change (+/-); by source and indicator wells.	Gw recharge efforts indicate intent to maintain supply capacity and long term sustainability. Tabular, GIS map of gw recharge for area; time series and % change (+/-)	Gwr: 1=>50%, 2=30-50, 3=20-30, 4=10-20, 5=<10%	High, but limited applicatio n for trans.
Agricultural lands (al):	USGS nat'l land cover database	GIS clipping of ag lands to area.	Ag lands classed as irrigated nurseries, orchards, pasture/hay, crops, and grains. Higher % of ag lands in area indicates potential for loss of prime farmland. % of area	Al%: 1=<5%, 2=5-10, 3=10-20, 4=20-30, 5=>30%	Medium

Water Resources – Floods And Drainage					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Flood plains proximity (fpp)	Fema flood plain maps - dfirms not available for all jurisdictions	Geodb compilation, GIS map of flood plains, buffering for proximity.	Proximity to or presence in 100 year flood plain indicates threat of flooding. Proximity of flood plains to transportation projects [miles]	1=>2mi, 2=2-1mi, 3=1-1/2mi, 4=1/2-1/4mi, 5=<1/4mi	Medium; proximity may relate to flood runoff.
Floodplain encroachment (fpe):	USGS nhd, satellite imagery. Fema and local jurisdiction flood plain maps	GIS processing for buffers around flood plains and proximity of development and highway projects	Highways and development can encroach on flood plains which can be associated with flood and habitat threats. % of area of projects and development in proximity of floodplains	1=<5%, 2=5-10, 3=10-20, 4=20-30, 5=>30%	High; key factor in design of trans. Facilities; mitigated.
Urban and highway runoff quantity (uro):	USGS, dwr, udfcd	Geodb compilation, GIS-55 model has demonstrated computation of flood peaks	Flood flows – peaks and volumes for past, current and future conditions – at selected locations. Flood peaks as % increase from base line.	1=<5%, 2=5-10, 3=10-20, 4=20-30, 5=>30%	Medium; factor in design of trans. Facilities.

Water Resources – Floods and Drainage					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Impervious lands (imp):	Land use data (USGS, counties, cities), satellite imagery; current and forecast.	Geodb compilation, image processing, image statistics	Urbanization results in increased impervious surfaces; associated with increased flood runoff and water pollution. Impervious areas as % of total area	1=<5%, 2=5-15, 3=15-25, 4=25-40, 5=>40%	High; readily measured and acceptable .
Channel erosion (ce):	USGS, dwr, udfcd (data on eroding channels and concerns of this)	Geodb compilation, GIS map of channels with erosion potential.	Increased peak flows cause channel erosion and down cutting, creating sediment loading on streams and structural threats. % of stream channels length having erosion potential; proximity to corridors and projects.	1=<5%, 2=5-10, 3=10-20, 4=20-30, 5=>30%	Medium; difficult to predict.

Water Resources – Water Quality					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Water quality listing (wq303(d))	CDPHE listing of impaired and threatened waters, DRCOG status summaries.	Cw act, sect. 303(d) segments; GIS map of stream segments with classifications.	Clean water act section 303(d) segments – state priority data identify segments that are wq limited, use protected and no degradation; also CDPHE monitoring and evaluation (m&e) lists. Number of segments and status tabulation over time; length and % supporting designated use; complied by CDPHE/DRCOG.	Regulatory: Number of segments and status tabulation over time; length and % supporting designated use; complied by CDPHE/DRCOG.	High; but wq assess-ments by tmdl modeling too complex.
Water quality assessments (wq305(b))	CDPHE integrated reports (ir) include categorization of designated (beneficial) use support status for surveyed waters.	305(b) stream status categorization data are available in GIS formats keyed to river segments.	CDPHE 305(b) update reports provide statewide assessment and the extent of protection for "fishable" and "swim-mable" beneficial uses. Number of segments and status tabulation over time; length and % supporting design-nated use; complied by CDPHE/DRCOG.	Regulatory: Number of segments and status tabulation over time; length and % supporting designated use; complied by CDPHE/DRCOG.	Wq assess-ments by tmdl modeling too complex.

Water Resources – Water Quality					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Water quality (wqsegs):	Epa 305(b) impaired waters, USGS	Length and % supporting designated use	Clean water act section 303(d) segments – state priority data. Length and % supporting designated use	1=>99%, 2=98-77%, 3=no data, 4=75-50%, 5=<50%	High: wq assess-ments by tmdl modeling too complex.
Water quality – state assessment:	Epa nwqd; cwa 305(b) reports, with data manipulation, describe the surface water quality for 8 digit hucs	GIS buffering to show proximity to projects and priority per designated use.	CDPHE assessments identify segments that are wq limited, use protected and no degradation. GIS buffering to show proximity to projects and priority per designated use.	3-point per state priority; 1=low, 2=medium, 3=high	High; wq assess-ments by tmdl modeling too complex.
Water quality (storet data):	Epa storet database	Exceedances are storet sampling station data reporting chemical concentration greater than the sdwa mcls.	National primary drinking water standards, established under sdwa, are compared to storet ambient water data. Exceedances are storet sampling station data reporting chemical concentration greater than the sdwa mcls.	1=<10, 2=10-100, 3=101-200, 4=201-500, 5=>500	Medium; large data review too complex.

Water Resources – Water Quality

Metric name	Dataset	Analytical methods	Metric description	Thresholds	Utility
Rainfall (p):	Noaa rainfall data.	Area average rainfall [in]	The greater the annual rainfall, the more infiltration to the groundwater, and the greater the pollution threat. Area average rainfall [in]	1=<5 in 2=5-10, 3=10-20, 4=20-40, 5=>40 in	Low; little variability in region.
Wastewater releases (wwr):	M&I discharge permits	GIS based statistical analysis – cumulative frequency graphs	Ww releases to waters within the project area can have a negative impact upon water quality. GIS based statistical analysis – cumulative frequency graphs	1=<0.3m, 2=0.3-1m, 3=1-2m, 4=2-5m, 5>5m	High; part of tmdl process.
Surface water quantity (wsq):	USGS streamflow records	Total miles in a watershed or project having average flows [cfs]	Surface water flows are tabulated for stream segments; lower flows indicate lower dilution. Total miles in a watershed or project having average flows [cfs]	1=>500cfs, 2=500-200, 3=200-100, 4=100-50, 5=<50 cfs	Medium; link to tmdl model too complex.
Distance to surface water (swd):	USGS nhd stream paths, CDOT roadway networks	Distance to stream courses [miles]	Proximity to surface water indicates threats of roadway drainage and contamination. Distance to stream courses [miles]	1=>2mi, 2=2-1mi, 3=1-1/2mi, 4=1/2-1/4mi, 5=<1/4mi	High; GIS buffer easy to do but link to wq too complex.

Water Resources – Water Quality					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Ground water quality threat (gwt).	USGS gw resources data; colo. Dwr; NRCS statsco soils data; pollution sources	Pollution sources within 500 ft of gw depth.	Contamination potential is indicated by shallow depth to gw and proximity to pollution sources. Pollution sources within 500 ft of gw depth.	1=>50, 2=50-30, 3=30-15, 4=15-8, 5=<8	Medium; not related to trans. Projects.
Ground water quality (gwq)	Aquifer nitrate data from CDPHE, EPA, USGS.	Nitrate concentration [mg/l]	Gw quality expressed as nitrate; mcl is 10 mg/l by swda. Nitrate concentration [mg/l]	1=<3, 2=3-4.5, 3=4.5-6, 4=6-7.5, 5=>7.5 mg/l	Medium; not related to trans. Projects.
Ground water quality threat – septic tanks (gws):	Non-sewered areas from counties	Intersection of non-sewered areas overlain on shallow aquifers; % of area.	Shallow aquifers prone to pollution from drainage and septic tanks. Intersection of non-sewered areas overlain on shallow aquifers; % of area.	1=<5%, 2=5-10, 3=11-20, 4=21-30, 5=>30%	Medium; not related to trans. Projects.
Septic tank use (stu):	Census block group data	% population with septic tanks; map display	Septic tanks are assumed to have a higher failure rate than public systems; also are a threat to gw quality. % population with septic tanks; map display	1=<15%, 2=16-25, 3=26-35, 4=36-45, 5=>5.0 mlbs	Medium; not related to trans. Projects.

Water Resources – Water Quality					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Individual well water (gwi):	Census block group data	% population with individual water source; map display	Individual well supplies are typically shallow and more prone to contamination. % population with individual water source; map display	1=<10%, 2=10-19, 3=20-29, 4=30-39, 5=>40%	Medium; not related to trans. Projects.
Toxic releases (tri).	Epa toxic releases inventory(tri1)	Amount of trs in area [million lbs]	Us epa requires manufacturing industries to estimate their annual releases of specific hazardous chemicals to water. Amount of trs in area [million lbs]	1=<0.3, 2=0.3-1m, 3=1-2m, 4=2-5m, 5=>5m	Medium; not related to trans. Projects.
Highway density (hwd):	CDOT transportation geodb	Road density [mi/mi^2]	Density of roads in an area indicative of water pollution potential. Road density [mi/mi^2]	1=<1, 2=1-=5, 3=5-10, 4=10-20, 5=->20 mi/mi^2	Medium; general indicator but %imp. Better.
Water pollution costs associated with number of vehicles over a square mile area of a highway.	CDOT transportation geodb	$/vehicles/mi^2	$/vehicles/mi^2	1=<1, 2=1-=5, 3=5-10, 4=10-20, 5=->20 $/vehicles/ mi^2	Medium; model availabilit y?

Water Resources – Water Quality					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Average area of parking facilities over an area:.	CDOT transportation geodb	% of area	Vehicles at parking facilities are found to be one of the major contributors to water pollution by fhwa. % of area	1=<5%, 2=5-10%, 3=10-20%, 4=20-30%, 5=->30%	High; part of overall %imp account.
Motor vehicle emissions (mve):	CDOT transportation geodb	Tons/sq. Mi.	Emissions by motor vehicles over an area (study area). Tons/sq. Mi.	1=<1, 2=1-5, 3=5-10, 4=10-20, 5=>20 t/mi^2	Medium; how relate to wq ?
Number of motor vehicles maintained (serviced) and used in study area:	CDOT transportation geodb	No. Of maintained vehicles / mi^2	The higher the vehicle maintenance the lower the impact on surface water pollution. No. Of maintained vehicles / mi^2	1=100, 2=100-50, 3=50-10, 4=10-5, 5=<5 vehicles/mi^2	Medium; how relate to wq ?

Biological Resources – T&E, Listed Species					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
black-tailed prairie dog	Input data based on model parameters	GIS analysis; temporal/spatial modeling; HSI	G3G4 S3; concern (state); USFS sensitive; acres per class connectivity index; count by size class	Carrying capacity of managed units	High
Preble's meadow jumping mouse	CNHP elements; input data based on model parameters	GIS analysis; temporal/spatial modeling; HSI	G5T2 S1; threatened (PDL national state); acres per class; connectivity index; count by size class	Current condition (no loss)	High
northern pocket gopher subsp.	CNHP elements	GIS analysis; temporal/spatial modeling; HSI	G5T1 S1; concern (state)	TBD	Low
Townsend's big-eared bat subsp.	CNHP elements	GIS analysis; temporal/spatial modeling; HSI	G4T4 S2; concern (state); BLM/USFS sensitive	TBD	Low
American peregrine falcon	CNHP elements	GIS analysis; temporal/spatial modeling; HSI	G4T3 S2B; concern (state); USFS sensitive	TBD	Low
American white pelican	CNHP elements	GIS analysis; temporal/spatial modeling; HSI	G3 S1B; BLM sensitive	TBD	Medium
bald eagle	CNHP elements; NDIS; local surveys; land use plans	GIS analysis; temporal/spatial modeling; HSI	G5 S1B S3N; threatened (national state) nest sites; counts; distribution; proximity to food sources	Current condition (no loss)	High

Biological Resources – T&E, Listed Species					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
burrowing owl	CNHP elements; NDIS; local surveys; land use plans	GIS analysis; temporal/spatial modeling; HSI	CNHP not listed; threatened (state); counts; distribution	TBD	High
ferruginous hawk	CNHP elements; NDIS; local surveys; land use plans	GIS analysis; temporal/spatial modeling	G4 S3B; counts; feeding habitat area and distribution	TBD	High
long-billed curlew	CNHP elements	Data gathering stage	G5 S2B; concern (state); BLM/USFS sensitive	Limited in area	Low
Mccown's longspur	CNHP elements	GIS analysis; temporal/spatial modeling	G4 S2B; USFS sensitive	TBD	Low
mountain plover	CNHP elements	Data gathering stage	G2 S2B; concern (state); BLM/USFS sensitive	Limited in area	Low
plains sharp-tailed grouse	CNHP elements; NDIS; local surveys; land use plans	GIS analysis; temporal/spatial modeling	Counts; habitat area and distribution	Carrying capacity of managed units	High
arogos skipper	CNHP elements	Data gathering stage	G3G4 S2;	TBD	Low
Colorado blue	CNHP elements	Data gathering stage	G3G4T2T3 S2;	TBD	Low
hops feeding azure	CNHP elements	Data gathering stage	G2G3 S2	TBD	Low
Lusk's pinemoth	CNHP elements	Data gathering stage	G4 S1?;	TBD	Low

Biological Resources – T&E, Listed Species					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Moss's elfin	CNHP elements	Data gathering stage	G4T3 S2S3	TBD	Low
moth sp	CNHP elements	Data gathering stage	GNR S1	TBD	Low
mottled dusky wing	CNHP elements	Data gathering stage	G3G4 S2S3	TBD	Low
Ottoe skipper	CNHP elements	Data gathering stage	G3G4 S2; USFS sensitive;	TBD	Low
Pawnee montane skipper	CNHP elements	Data gathering stage	G4T1 S1; threatened (national)	TBD	Low
regal fritillary	CNHP elements	Data gathering stage	G3 S1; USFS sensitive	TBD	Low
stonefly sp1	CNHP elements	Data gathering stage	G3 S2	TBD	Low
stonefly sp2	CNHP elements	Data gathering stage	G3 S2	TBD	Low
tiger beetle sp	CNHP elements	Data gathering stage	G4 S1?	TBD	Low
tiger moth sp	CNHP elements	Data gathering stage	G2G3 SNR	TBD	Low
northern redbelly dace	CDOW	Data gathering stage	G5 S1; endangered (state); USFS sensitive; counts	No loss of habitat?	High
bigmouth shiner	CDOW	Data gathering stage	Counts	TBD	High
common shiner	CDOW	Data gathering stage	Counts	TBD	High
Iowa darter	CDOW	Data gathering stage	Counts	TBD	High
orangespotted sunfish	CDOW	Data gathering stage	Counts	TBD	High

Biological Resources – T&E, Listed Species					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
plains topminnow	CDOW	Data gathering stage	Counts; distribution	TBD	High
spotted sunfish	CDOW	Data gathering stage	Counts; distribution	TBD	High
stonecat	CDOW	Data gathering stage	Counts; distribution	TBD	High
suckermouth minnow	CDOW	Data gathering stage	Counts; distribution	TBD	High
banded physa	CDOW	Data gathering stage	G2 S1; counts; distribution	TBD	Low
Colorado butterfly weed	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	High
Ute ladies tresses	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	High
Bell’s twinpod	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	High
lavender hyssop	CNHP; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
lesser panicled sedge	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
livid sedge	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
many-headed sedge	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
New Mexico cliff fern	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
peck sedge	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
Porsild’s WhitLow-grass	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium

Biological Resources – T&E, Listed Species					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Porter feathergrass	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
prairie moonwort	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
Rocky Mountain cinquefoil	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
Selkirk violet	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
slender cottongrass	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
southern Rocky Mountain cinquefoil	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
sweet flag	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
Torrey sedge	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
Weber's monkey-flower	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium
white adder’s-mouth	CNHP elements; land use plans	Data gathering stage	Counts; habitat area; habitat distribution	TBD	Medium

Biological Resources – Plant Communities					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
short grass and mixed grass prairie	CNHP elements;	GIS analysis; temporal/spatial modeling	Total area of prairie; average, modal, minimum, maximum patch size; connectivity; perimeter/area ratio	1=<=0% 2=1-5% 3=5-10% 4=10-20 5=>20%	High
plains cottonwood riparian woodland	CNHP elements;	GIS analysis; temporal/spatial modeling	Total area; average, modal, minimum, maximum patch size.	1=<=0% 2=1-5% 3=5-10% 4=10-20 5=>20%	High
riparian shrub and herbaceous communities	CNHP elements;	GIS analysis; temporal/spatial modeling	Total area; average, modal, minimum, maximum patch size	1=<=0% 2=1-5% 3=5-10% 4=10-20 5=>20%	High
Mesic Tallgrass Prairie	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S1S2 Total area; average, modal, minimum, maximum patch size.	1=<=0% 2=1-2% 3=2-3% 4=3-4 5=>4%	High
Xeric Tallgrass Prairie	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S1S2 Total area; average, modal, minimum, maximum patch size.	1=<=0% 2=1-2% 3=2-3% 4=3-4 5=>4%	High

Biological Resources – Plant Communities					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Mixed Foothill Shrublands	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S2 Total area; average, modal, minimum, maximum patch size	Not determined	Medium
Foothills Pinyon-Juniper Woodlands/Scarp Woodlands	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Montane Grasslands	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Montane Riparian Woodland	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Ponderosa Pine/Thin Leaf Alder	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Foothills Ponderosa Pine Scrub Woodlands	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S2? Total area; average, modal, minimum, maximum patch size	Not determined	Low
Foothills Riparian Woodland (wetland)	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low

Biological Resources – Plant Communities					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Montane Riparian Forests	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S1S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Mixed Foothill Shrublands	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Great Plains Mixed Grass Prairie	CNHP elements;	GIS analysis; temporal/spatial modeling	G2 S2 Total area; average, modal, minimum, maximum patch size	Not determined	High
Foothills Shrubland	CNHP elements;	GIS analysis; temporal/spatial modeling	G2G3 S2S3 Total area; average, modal, minimum, maximum patch size	Not determined	High
Mixed Foothill Shrublands	CNHP elements;	GIS analysis; temporal/spatial modeling	G2G3 S2S3 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Plains Cottonwood Riparian Woodland	CNHP elements;	GIS analysis; temporal/spatial modeling	G2G3S2 Total area; average, modal, minimum, maximum patch size	Not determined	High
Strapleaf Willow-Coyote Willow	CNHP elements;	GIS analysis; temporal/spatial modeling	G2G3 S2S3 Total area; average, modal, minimum, maximum patch size	Not determined	Low

Biological Resources – Plant Communities					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Montane Willow Carr	CNHP elements;	GIS analysis; temporal/spatial modeling	G2G3 S2S3 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Narrowleaf Cottonwood/Common Chokecherry	CNHP elements;	GIS analysis; temporal/spatial modeling	G2Q S1 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Western Slope Sagebrush Shrublands	CNHP elements;	GIS analysis; temporal/spatial modeling	G3 S1S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Foothills Riparian Shrubland	CNHP elements;	GIS analysis; temporal/spatial modeling	G3 S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Lower Montane Riparian Shrublands	CNHP elements;	GIS analysis; temporal/spatial modeling	G3 S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Lower Montane Forests	CNHP elements;	GIS analysis; temporal/spatial modeling	G3 S1 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Montane Riparian Forests	CNHP elements;	GIS analysis; temporal/spatial modeling	G3 S1 Total area; average, modal, minimum, maximum patch size	Not determined	Low

Biological Resources – Plant Communities					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Peachleaf Willow Alliance	CNHP elements;	GIS analysis; temporal/spatial modeling	G3 S1 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Lower Montane Riparian Shrublands	CNHP elements;	GIS analysis; temporal/spatial modeling	G3? S1S2 Total area; average, modal, minimum, maximum patch size	Not determined	High
Montane Willow Carrs	CNHP elements;	GIS analysis; temporal/spatial modeling	G3? S2 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Montane Floating/Submergent Wetland	CNHP elements;	GIS analysis; temporal/spatial modeling	G3? S1 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Montane Grasslands	CNHP elements;	GIS analysis; temporal/spatial modeling	G3G4 S2? Total area; average, modal, minimum, maximum patch size	Not determined	Low
Shortgrass Prairie	CNHP elements;	GIS analysis; temporal/spatial modeling	G4 S2? Total area; average, modal, minimum, maximum patch size	Not determined	High
Lower Montane Woodlands	CNHP elements;	GIS analysis; temporal/spatial modeling	G4 S2? Total area; average, modal, minimum, maximum patch size	Not determined	Low

Biological Resources – Plant Communities					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Montane Floating/submergent Palustrine Wetlands	CNHP elements;	GIS analysis; temporal/spatial modeling	G4 SU Total area; average, modal, minimum, maximum patch size	Not determined	Low
Foothills Ponderosa Pine Savannas	CNHP elements;	GIS analysis; temporal/spatial modeling	G4G5 S2S3 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Montane Grasslands	CNHP elements;	GIS analysis; temporal/spatial modeling	G5 S2S3 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Montane Floating/Submergent Wetland	CNHP elements;	GIS analysis; temporal/spatial modeling	G5? S1 Total area; average, modal, minimum, maximum patch size	Not determined	Low
Quaking Fen	CNHP elements;	GIS analysis; temporal/spatial modeling	GU SU Total area; average, modal, minimum, maximum patch size	Not determined	Low
Montane Woodlands	CNHP elements;	GIS analysis; temporal/spatial modeling	GU SU Total area; average, modal, minimum, maximum patch size	Not determined	Low
Montane Woodlands	CNHP elements;	GIS analysis; temporal/spatial modeling	GU SU Total area; average, modal, minimum, maximum patch size	Not determined	Low

Biological Resources – Plant Communities					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Plains Cottonwood/Choke Cherry	CNHP elements;	GIS analysis; temporal/spatial modeling	GU SU Total area; average, modal, minimum, maximum patch size	Not determined	High
Mesic Oak Thickets	CNHP elements;	GIS analysis; temporal/spatial modeling	GU SU Total area; average, modal, minimum, maximum patch size	Not determined	Low

Biological Resources --Wetlands					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**High**
Regulated wetlands	USACE sec. 404 permit points; SURGO; boulder cnty GIS; riparian vegetation, CVCP, nwi; USGS; land use plans	GIS analysis; temporal/spatial modeling; photo interpretation; remote sensing	Acres, maximum, minimum, average, modal; count, count; frequency table; temporal change	1=<=0% 2=1-2% 3=2-3% 4=3-4 5=>4%	High
Unregulated wetlands	SURGO; boulder cnty GIS; riparian vegetation, CVCP, land use plans	GIS analysis; temporal/spatial modeling	Acres, maximum, minimum, average, modal; count, count; frequency table; temporal change CDOT policy is no net loss	Not determined	High
Built wetlands	USACE; CDOT; ducks unlimited?	GIS analysis;	Acres, maximum, minimum, average, modal; count, count; frequency table; temporal change	Not applicable	High
Regulated wetlands connected to riverine and lacustrine systems	SURGO; habitat maps, flood zone maps, hydrological maps	GIS analysis, temporal/spatial modeling	Acres; acres connected to riverine; acres connected to lacustrine; temporal change	1: =0% 2: >0 – 1% 3: >1 – 3% 4: >3 – 5% 5: >5%	High
Water quality mitigation function class	CDPHE impairment data. Epa? Effects of planned infrastructure on impairment, land use plans	GIS analysis, temporal/spatial modeling	Sediment, nutrient, toxicant retention. Removal of sediment, nutrient, toxicant from water inflow source	TBD	High

Biological Resources --Wetlands					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**High**
Floodwater retention function class	Urban drainage and flood control. Riparian vegetation classification. Floodplain mapping. Wetland mapping	GIS analysis, temporal/spatial and system models (capacity to reduce flow, floodwater retention, groundwater recharge)	Floodwater retention/attenuation Groundwater recharge. Sediment control, stabilization of banks Flood conveyance	TBD	High
Habitat function class	T&E species surveys, trapping data riparian vegetation classification, weed surveys, land use plans		Waterfowl feeding and nesting Feeding, resting, reproductive habitat for upland and wetland species Fish habitat	TBD	High
Human utility class	Recreational user and use surveys; land use plans	User surveys; use monitoring; economic models; temporal/spatial models	scenic beauty rating; recreational use	TBD	High

Cultural Resources					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Loss of national register-eligible districts	SHPO, CDOT, Local Associations, Assessor Offices	Project Buffers and Overlays; Time Comparisons	Number of districts lost integrity	Not determined	High
Loss of other national register-eligible resources	SHPO, CDOT, Local Associations, Assessor Offices	Project Buffers and Overlays; Time Comparisons	Number of buildings, structures, sites, objects lost integrity	Not determined	High
Loss of contributing buildings or features within national register-eligible districts	SHPO, CDOT, Local Associations, Assessor Offices	Project Buffers and Overlays; Time Comparisons	Percentage of contributing resources found non-contributing upon re-survey	Not determined	Medium
Substantial degradation of national register-eligible buildings, structures, sites or objects	SHPO, CDOT, Local Associations, Assessor Offices	Project Buffers and Overlays; Time Comparisons	Number of buildings, structures, sites, objects with substantial loss of character-defining features, etc.	Not determined	Medium
Threatened degradation of national register-eligible properties	SHPO, CDOT, Local Associations, Assessor Offices	Project Buffers and Overlays; Time Comparisons	Number of threatened properties	Not determined	Low
Loss of listed resources of national importance	SHPO, CDOT, Local Associations, Assessor Offices	Project Buffers and Overlays; Time Comparisons	Number of listed resources lost integrity	Not determined	High

Cultural Resources					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Loss of listed resources of statewide importance	SHPO, CDOT, Local Associations, Assessor Offices	Project Buffers and Overlays; Time Comparisons	Number of listed resources lost integrity	Not determined	High
Loss of listed resources of local importance	SHPO, CDOT, Local Associations, Assessor Offices	Project Buffers and Overlays; Time Comparisons	Number of listed resources lost integrity	Not determined	Medium

Community Impacts					
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**	**Utility**
Proportionality of direct effects on low-income and minority populations	Us population and housing census, school data, data from community institutions such as churches,, regional plans, stip/tip	Tabulations of census data; statistical analyses; creation of projected population surfaces	affected low-income and minority populations as a proportion of overall population in a reference area	Disproportionate share of adverse effects in low-income or minority populations	High
Vulnerability levels of low-income and minority populations	Census and community data sources to identify age, gender, and other socio-demographic characteristics	Tabulations of census data; statistical analyses	Presence of other characteristics of potentially vulnerable populations	Disproportionate % of non-native English speakers, older persons, & other potentially vulnerable populations	High
Interacting effects of previous investments	Data from various sources regarding air and water quality, noise, safety, hazardous materials, visual quality, and community cohesion.	Tabulations of census data; tabulations of local environmental data; statistical analyses	Accumulating effects of previous transportation or industrial investments and other unwanted land uses on low-income and minority communities	Not determined	High

Air Quality				
Metric name	**Dataset**	**Analytical methods**	**Metric description**	**Thresholds**
Hazard Index	Air Quality Index	Air Quality Index	Air Quality Associated with Geographic Feature	Per Chemical; Hazard Index of 1 is Safe
Hazard Index	Emission Inventory	Emissions Monitoring	Emissions Associated with Geographic Feature	Per Chemical; Hazard Index of 1 is Safe
VMT	VMT (Vehicle Miles Travelled)	Calculated VMT	VMT Associated with Road Features	
Hazard Index	ER (Emergency Response)	Plume and Trajectory Models	Plumes and Trajectories Associated with Emergency Response Events	

NOTES

Colorado Natural Heritage Program. 2005. Elements by 7.5 Minute USGS Quadrangle. Biodiversity Tracking and Conservation System. Colorado State University, Fort Collins, Colorado, U.S.A. Data exported 07/21/2005.

G1 - Globally critically imperiled; typically 5 or fewer EOs and/or very few remaining acres or very vulnerable to elimination throughout its range due to other factor(s)
G2 - Globally imperiled; typically 6 to 20 EOs and/or few remaining acres or very vulnerable to elimination throughout its range due to other factor(s)
G3 - Globally rare or uncommon; typically 21 to 100 EOs; either very rare and local throughout its range or found locally, even abundantly, within a restricted range or vulnerable to elimination throughout its range due to specific factor(s)
G4 - Globally widespread, abundant, and apparently secure, but with cause for long-term concern; uncommon but not rare (although it may be quite rare in parts of its range, especially at the periphery); typically > 100 EOs; apparently not vulnerable in most of its range
G5 - Globally demonstrably widespread, abundant and secure; common, widespread, and abundant (although it may be quite rare in parts of its range, especially at the periphery); not vulnerable in most of its range

S1 - State critically imperiled; typically 5 or fewer Eos
S2 - State imperiled; typically 6 to 20 Eos
S3 - State rare or uncommon; typically 21 to 100 EOs

Concern (state) is not a statutory category

Paul Winkle, CDOW, personal communication, Oct 24, 2005, Roundtail Chub is a west slope species. Southern Redbelly Dace is in the Arkansas system. These species have been removed from the above table. The Hornyhead Chub has been extirpated from the area (SX, CNHP) but is common in other areas (G5, CNHP). It is also not on the above table.

Shannon Albeke, CDOW, personal communication, Oct 25. 2005 added a number of fish species that should be considered in the CEA. These are indicated in the tables of this Appendix by the absence of a CNHP rating.