Aquifer Protection and Community Viz™ in Albany County, Wyoming

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Abstract

This paper describes the results of an alternative futures analysis for implementation of a joint city/county aquifer protection plan in Albany County, southeastern Wyoming, U.S.A. The ArcView-based Community Viz™ planning support system software was used to evaluate major environmental, economic and social indicators impacted by three different scenarios: continuation of existing trends, aquifer protection, and density shift. Indicators were compared and contrasted across scenarios. Results will provide local decision makers with sound, quantifiable and reproducible information to assist in implementing future land use policy. The project was completed under phase I of the Wyoming Community Viz™ Partnership, a public / private effort to promote the use of decision support systems in planning in Wyoming.

Introduction

This paper documents the process and results of the Wyoming Community Viz™ Partnership's Phase I Albany County Pilot Project. The purpose of the pilot project was to serve as a "proof of concept" in demonstrating how the Community Viz™ planning support system software might be incorporated into a small town planning process in Wyoming. The application focus of the pilot project involved planning issues associated with implementation of a joint city/county aquifer protection plan for the City of Laramie in Albany County in southeastern Wyoming. The project analyzed three possible alternative future land use scenarios in the vicinity of municipal well fields and groundwater recharge areas and their impacts on water quality and related resource indicators.

Decision Support Technologies for Planning Applications

First developed for business applications in the 1970s, decision support systems (DSSs) are computer-based software applications which integrate database management systems, analytical models, and graphics to improve decision-making processes (Densham 1991). Spatial decision support systems (SDSSs) are a special type of DSS focused on addressing problems with a spatial component and/or utilizing spatial analysis techniques in their approach (Malczewski 1999). Development of SDSS applications has advanced significantly over the last decade, following the increased accessibility of desktop geographic information system (GIS) technology.

Planning Support Systems (PSSs) are a specific type of SDSS which "involve a wide diversity of geo-technology tools ...developed to support public or private planning processes (or parts thereof) at any defined spatial scale and within any specific planning context," (Geertman and Stillwell 2003: 5). Typically GIS-based, PSSs are unique in their focus on planning needs and planning process-driven tools (Batty 1995). Unlike complex land use or resource modeling software, PSSs often take the form of a toolbox from which decision-makers can draw for assistance in decision management, providing tools for modeling, analysis and design, as well as communication, visualization, and information dissemination functionality (Klosterman 1997; Batty 2003).

CommunityViz™

An example of a recent PSS application which bridges the gap between modeling and communication is Community Viz™, developed by the Orton Family Foundation (Rutland, VT). A modular system built on the ArcView GIS platform (ESRI, Inc.; Redlands, CA), Community Viz™ includes three integrated components: Scenario Constructor; 3D ModelBuilder; and Policy Simulator. Scenario Constructor provides functionality for assessing the potential impacts of specific, proposed land use actions by monitoring change in a series of associated indicators. 3D Modelbuilder allows for 3-dimensional display of landscape and structure information with real-time movement and object manipulation in a photorealistic setting. Policy Simulator uses agent-based modeling to forecast probable land use, and demographic and economic changes given alternative governmental and community choices (Kwartler and Bernard 2001).

Since its release, Community Viz™ has been utilized in many planning applications from rural growth management (Mullen 2001) to urban redevelopment (Wendt 2002) and watershed modeling (Prisloe and Hughes 2002). The project focused on the Scenario Constructor component of the software. Scenario Constructor allows quantitative comparison of specific land-use alternatives using a "spatial spreadsheet" that can perform numerical computations on geographic data. "What if..." types of questions can be asked and evaluated by quantitatively and visually comparing different scenarios. Scenarios may be thought of as a group of alternate future conditions which, though all plausible, are each structurally different in form (van der Heiden 1996; Avin and Dembner 2001).

Regional Setting

The study area for the project was focused on the primary groundwater recharge area delineated for the City of Laramie / Albany County, Wyoming's aquifer protection plan. Albany County is located in the high plains region of southeastern Wyoming (Figure 1). Most of the county is located in a cool and arid basin (< 12 inches of precipitation annually) containing the Laramie River watershed, a major tributary to the North Platte River system. The county is flanked on the west by the Medicine Bow Mountains and on the east by the Laramie Range. 27,204 of the county's 31,742 people reside in the city of Laramie (US Census Bureau, 2003), the county seat of government and home to the University of Wyoming. Interstate 80 runs east-west through the county. The Denver metropolitan area is centered 130 miles to the south along the fast growing Front Range region of Colorado.

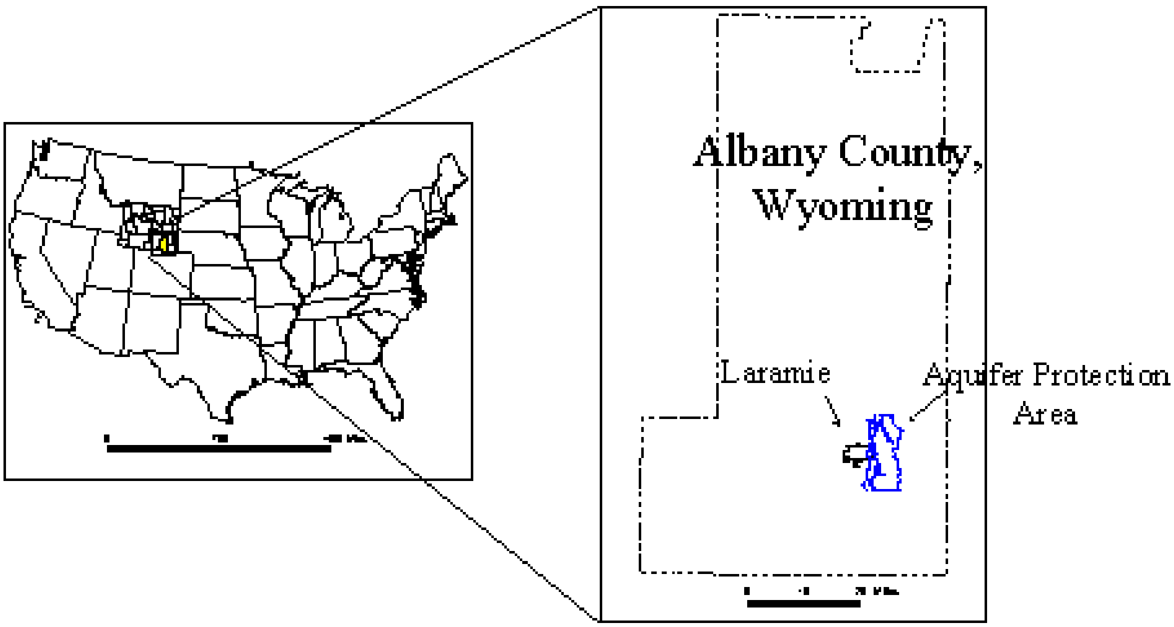

Figure 1 Location Map

Land Use Impacts on Groundwater Quantity and Quality

The primary issue addressed in this project was land use impacts on groundwater quality. In 2002, the city of Laramie approved the implementation of an overlay zone based on the Casper Aquifer Protection Plan. In early 2003 Albany County approved a similar overlay zone. These are continued steps in a 17-year effort to protect the quality of the county population's largest source of drinking water[1].

The Casper Aquifer is the primary groundwater source of drinking water for the City of Laramie. It supplies approximately 50% of the city's drinking water and 100% of the drinking water to rural homeowners living on the Casper Aquifer[2]. Normally, the city supplements its drinking water supply using treated water from the Laramie River. However, in times of drought, all of the city's water needs must be met using groundwater from the Casper Aquifer (Welker 2002).

The purpose of the Casper Aquifer Protection Plan is to protect the recharge area of the Casper Aquifer, located along the western foothills of the Laramie Range mountains bordering the eastern edge of the Laramie city limits. The Plan follows requirements defined in the Wyoming Wellhead Protection Guidance Document (Wyoming Department of Environmental Quality 1998). Three different aquifer protection zones are delineated in the plan, accompanied by descriptions of known and potential contaminant sources within each zone and associated area-specific management guidelines (Welker 2002).

Groundwater from the Casper Aquifer is obtained through four different well fields. Figure 2 presents the City's well fields and their locations relative to the city limits and to the Casper Aquifer recharge area. All well fields are on fenced property owned and controlled by the City of Laramie. The well fields from north to south are: Spur Ridge, Turner, Pope Springs and Soldier Springs.

The aquifer protection area is divided into three zones (Figure 2). Zone 1 is located around each of the well fields and consists of a protection area with a 100 foot minimum fixed radius around each well. Zone 2, known as the primary protection area because of its greater degree of vulnerability and the greater number of existing wells, is located at the western end of the delineated aquifer protection area. The remainder of the delineated aquifer protection area is zone 3, known as the secondary protection area.

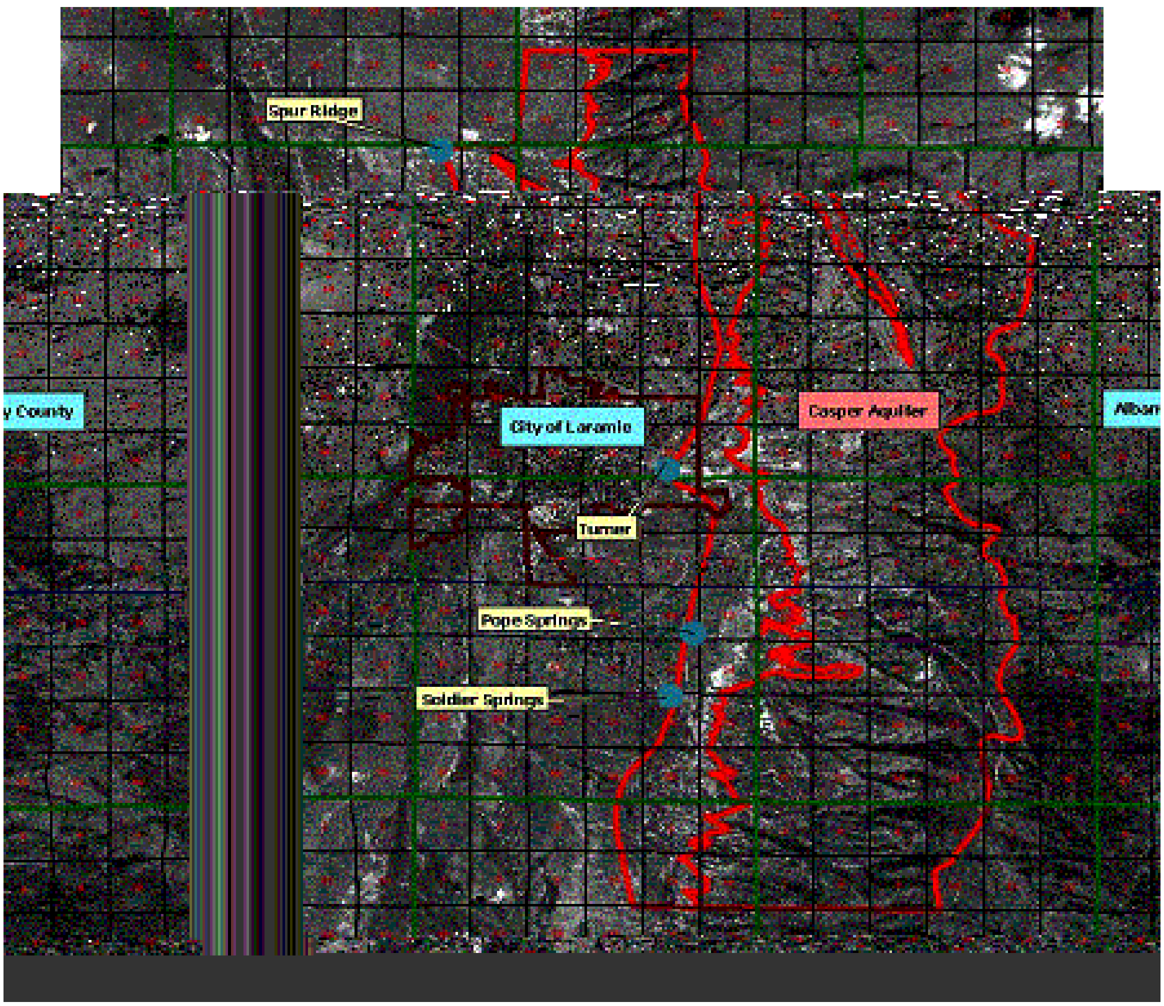

Figure 2 Aquifer delineation and protection zones

A critical aspect of maintaining an aquifer is responsible community development. Development over an aquifer should keep the aquifer protection area free from additional contamination sources and free from excessive draw-down. Current development trends in the Laramie area may be putting the quality of its drinking water at risk. The county has for some time been seeing an increase in rural residential development in the recharge area of the aquifer. Residential growth in the Casper Aquifer is happening in the primary recharge zone due to the popularity of rural residences and the suitability of soils for development in this area. These developments are not connected to city water or city sewer. Consequently, each rural residence built in the aquifer recharge area has both a well and a septic system. The potential problems of treating sewage in a septic system in the aquifer recharge area are readily apparent. Of specific concern is an increase of nitrate levels contributed by rural residential septic systems in the groundwater.

Methods

Scenario Development. Community Viz™ was used to develop one current and three possible future land use scenarios for the City of Laramie / Albany County aquifer protection overlay zone. Scenarios, from the Community Viz™ perspective, represent different patterns of development and in this case provide a way of quantifying and informing decision makers about the implications of each planning approach on the aquifer recharge area. Four scenarios were created: (1) current conditions; (2) continuation of existing trends; (3) aquifer protection; and (4) density shift. Current conditions was based on data from the year 2000. The other three scenarios project year 2000 data into the future based on different development patterns. All scenarios reflecting future development were based on an increase of 1,331 new residences (calculated based on growth from 1990 - 2000) and are directly comparable. The increase in the number of new residences remains constant; the difference is in comparing and contrasting development patterns.

The scenarios were based on two critical criteria. First, renewable resources such as groundwater require a long-term view to maintain. Consequently, the planning horizon of the Albany County Pilot Project is 50 years. The scenarios project what the impacts of growth will be, based on different development patterns in the year 2050. The second criteria used in creating scenarios was the rate of growth of residences in the delineated aquifer protection area. Albany County Assessor's data showed that residential development within the aquifer protection area increased at an annual rate of 2.5% between 1990 and 2000. The 2.5% growth rate would, over the course of the planning horizon, amount to an increase of 1,331 new residences in the aquifer protection area. This was the number of new parcels that were added to each scenario for future development.

Depicted in the current conditions scenario are the current land use, subdivisions and ownership patterns in the study area in the year 2000. For a map of current conditions, see Figure 3.

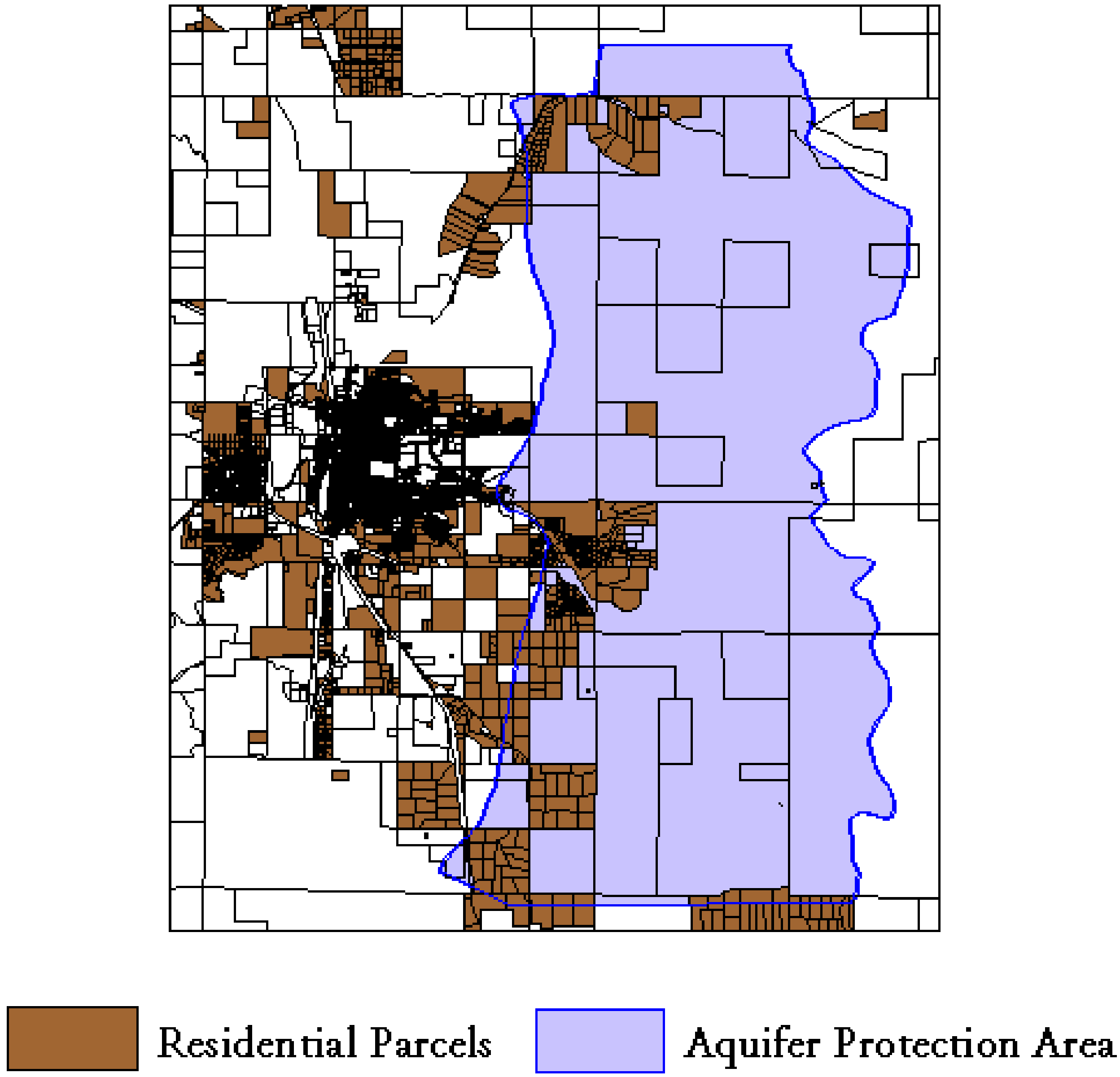

Figure 3 Current Conditions in the year 2000

The continuation of existing trends scenario projected current trends through 2050. Development continues on the western edge of the aquifer protection area due to suitability of soils for building, favorable slopes, and proximity to town. The map of this scenario (Figure 4) shows the increase in rural subdivisions in Albany County in the study area. Lot sizes in this scenario are based on the Albany County land use regulations:

1. Agricultural minimum lot size is thirty-five (35) acres.

2. Commercial minimum lot size is one (1) acre.

3. Industrial minimum lot size is one (1) acre.

4. Residential minimum lot size is five (5) acres.

In this scenario, proposed subdivisions contain parcels ranging in size from 5 to 40 acres. What are currently state-owned sections have been subdivided in this scenario based on the probability that these sections may be sold within the next 50 years.

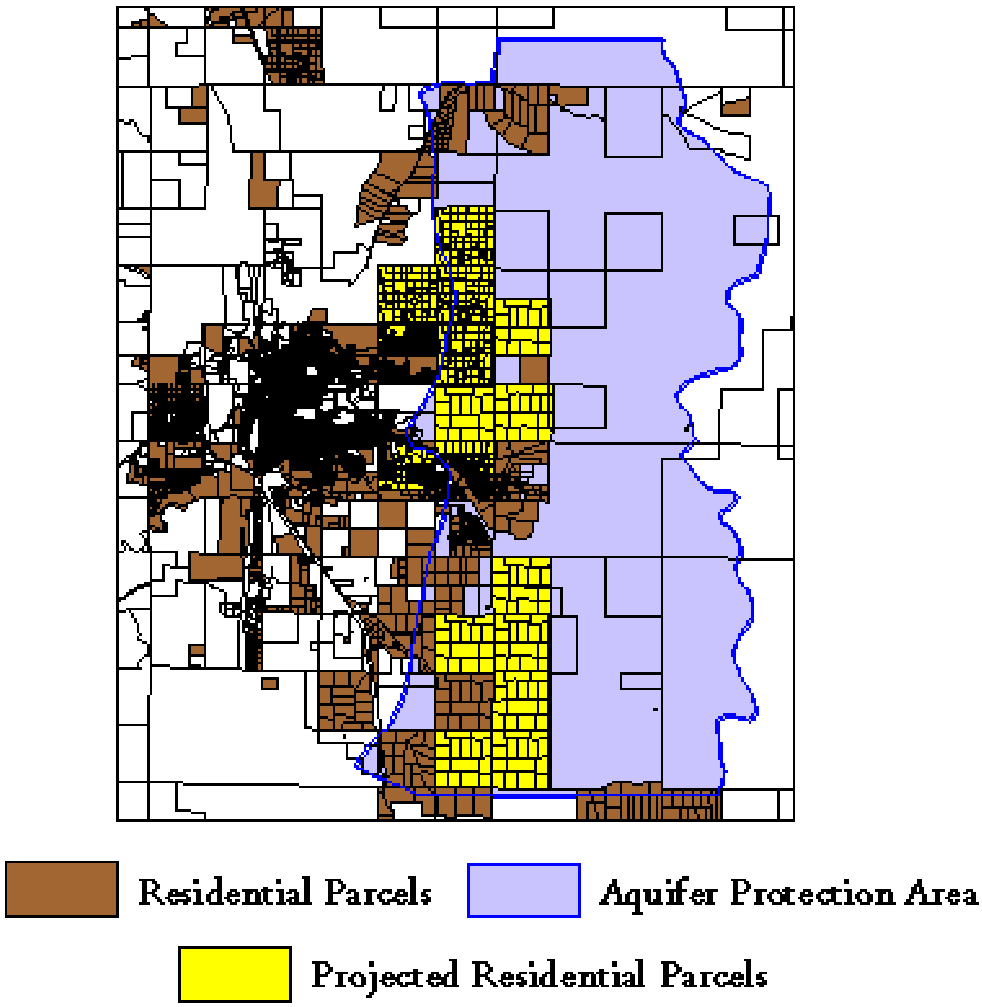

Figure 4 The Continuation of Existing Trends Scenario

The aquifer protection scenario is a more environmentally conscious approach to planning. The scenario is based on recommendations found in the Casper Aquifer Protection Plan for an overlay zone designed to protect groundwater from contamination (Figure 5).

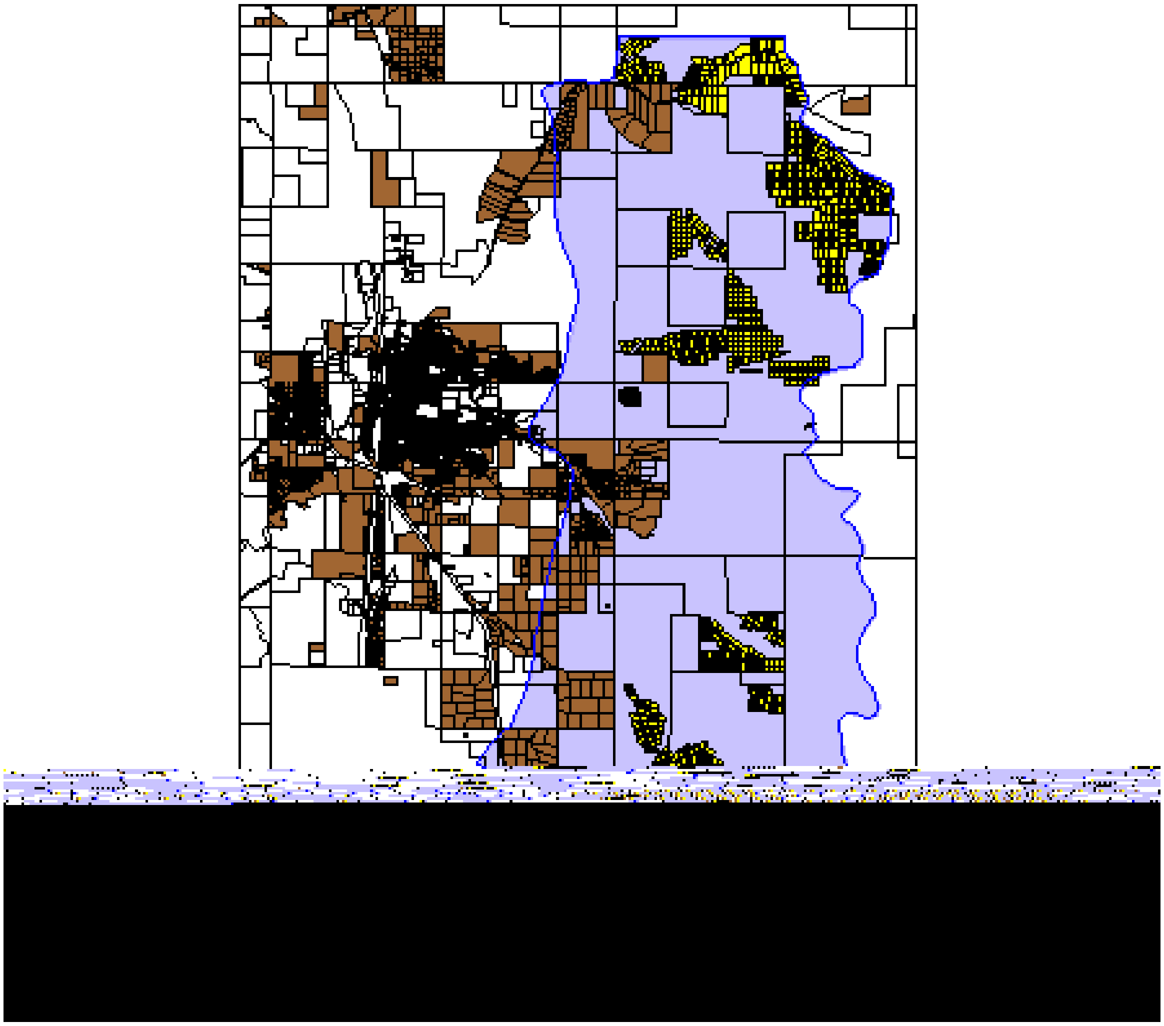

Figure 5 The Aquifer Protection Scenario

Development impacts on vulnerable features (such as faults, hydrological features, etc.) are mitigated through careful placement of new residences on the landscape. Based on recommendations in the Casper Aquifer Protection Plan, subdivisions near city limits are annexed into the city so they may be connected to city water and sewer. Development is (a) kept 100 feet from recharge features, (b)100 feet from faults and (c) built on suitable soils using a grater than 2% slope in consideration for the requirements of building mound-type septic systems. These criteria are generally site-specific. Results could be altered with improved site-specific data.

In the density shift scenario (Figure 6) projected subdivisions were placed completely outside the Aquifer Protection Area just north of current city limits. A single landowner owns the majority of the delineated aquifer protection area. Rather than spreading development across the area, the possibility exists of shifting the owner's development rights to just one portion of their land. This type of development is often referred to as cluster development, smart growth or traditional neighborhood design. It is a compact plan that has the same number of housing units as the other scenarios but in a smaller area with limited lot sizes. This results in a higher but very livable density. Such developments take advantage of density, which creates a concentrated demand for city services and amenities including local schools, shopping and places of worship.

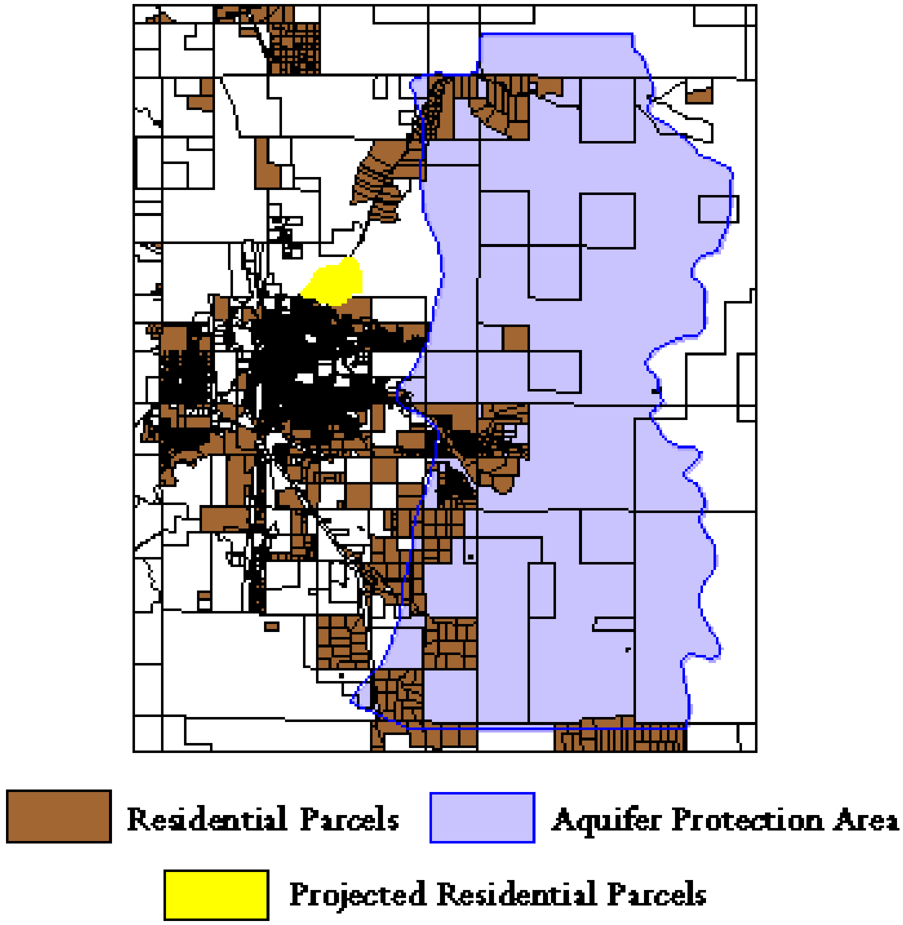

Figure 6 The Density Shift Scenario

Scenario Indicators. In the Scenario Constructor module of Community VizTM results are measured quantitatively using indicators. Although the emphasis was on groundwater protection, it is recognized that land use decisions rarely are made on a single issue. For this reason a wide range of indicators were evaluated, encompassing water and other natural resources factors as well as economic and social concerns. Indicators included:

Quality of Water (Nitrate Levels) -- summarizes the pollution implication of nitrates due to septic system failure.

Quantity of Water -- summarizes the water used by the community as measured in gallons per day.

Local Tax Revenues -- summarizes current government revenues and anticipated increases.

Cost of Community Services -- summarizes costs of services.

Traffic Impacts -- indicates the effects on traffic within the community as measured in vehicular miles traveled per day.

Wildlife Habitat -- summarizes the impacts on predicted terrestrial vertebrate species habitat.

Recreation Access -- summarizes access to public recreation lands.

Visual Impact -- summarizes aesthetic impacts.

Riparian Area -- summarizes the impacts on acres of riparian area.

Quality of water summarizes projected increases in nitrate levels based on increases in rural residences for the three scenarios. *Quantity of water* summarizes the water used by the community as measured in gallons. *Local tax revenues* summarizes current government revenues and anticipated increases in revenues. *Cost of community services* summarizes the cost of services the community is paying currently and can expect to pay. *Traffic impacts* measures changes in traffic volume as measured in vehicular miles per day per household. *Wildlife habitat* summarizes the impacts on predicted terrestrial vertebrate species habitat. *Recreation access* compares access to public lands suitable for recreation. *Visual impact* summarizes the visual and aesthetic impacts of the three scenarios. The indicator takes a quantitative approach to visual quality by looking at possible impacts to view sheds as seen from road networks in the study area. *Riparian area* summarizes impacts on acres of riparian area.

Results

In evaluating the results it is important to keep in mind three ideas. First and foremost, the future is a variable that citizens and decision makers control. Second, as previously mentioned, the planning horizon for this study is 50 years. All results were projected to the year 2050. Increases in nitrate levels and changes in other variables will be incremental over the course of the planning horizon and will continue to change as development continues in the years beyond 2050. Finally, the scenarios accommodate the same increases in growth and are directly comparable.

The evaluation of indicators resulted in numerical results specific to each indicator for each scenario. Nearly each indicator was measured using different units. For example, nitrate levels are in parts per million, traffic impacts are in vehicle miles traveled and revenues are in dollars. Presented here, as they directly reflect the health of the aquifer, are the results from the quality of water and quantity of water indicators.

Quality of Water. Figures 7a through 7d present nitrate concentrations in parts per million (ppm) at the four wellheads producing water for Laramie residents. The four wellheads are Pope, Soldier, Spur and Turner. Water quality results are similar at all but the Turner wellhead, where the nitrate concentration for the continuation of existing trends scenario is significantly higher. The Turner wellhead is located near Grand Avenue on the eastern edge of Laramie where growth pressure is considerably higher than in areas surrounding the other wellheads. As water movement through water-bearing strata over longer distances has a cleansing affect on water quality, the nitrate model weighs development near wellheads higher than development that is farther away. This suggests buffer areas around each wellhead are very important and activities that occur upslope (east) of these wells need to be closely monitored to protect the water resource.

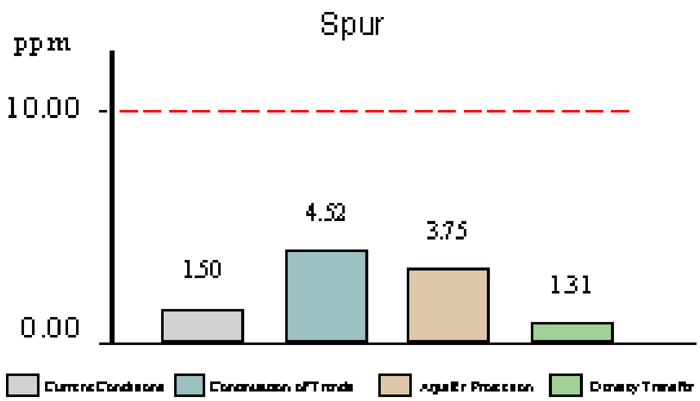

Figure 7a Nitrate Levels at the Spur Wellhead

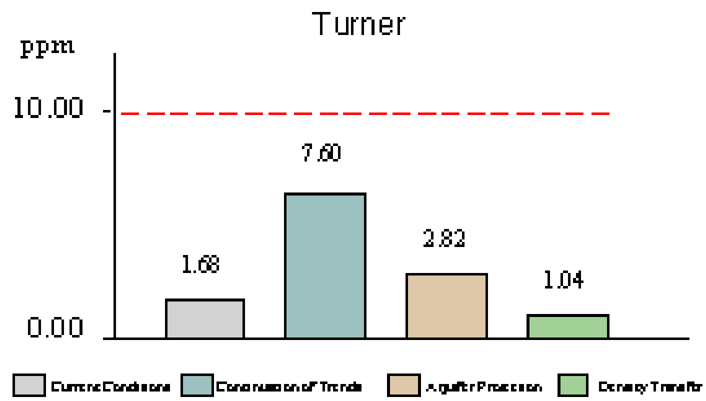

Figure 7b Nitrate Levels at the Turner Wellhead

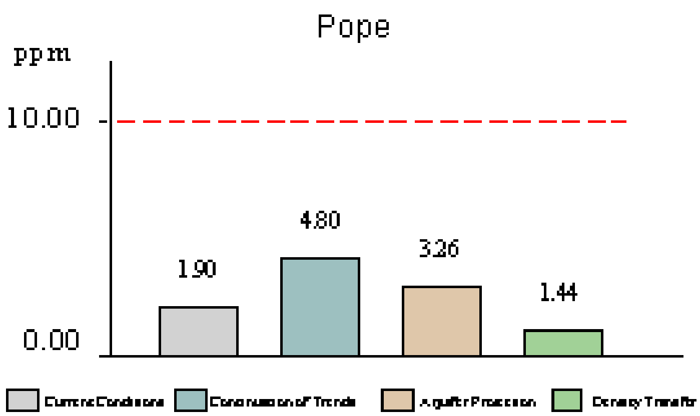

Figure 7c Nitrate Levels at the Pope Wellhead

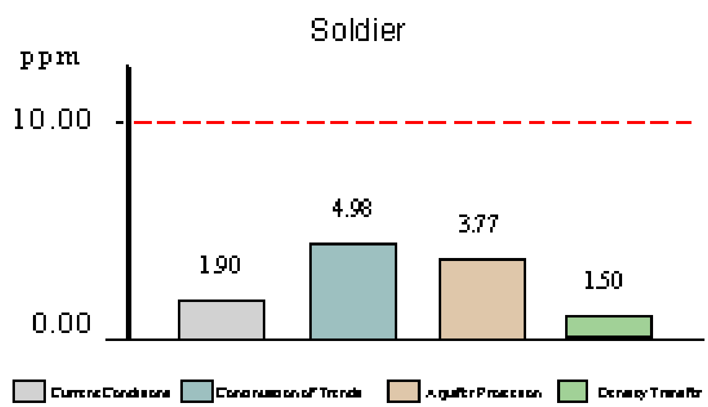

Figure 7d Nitrate Levels at the Soldier Wellhead

The continuation of existing trends scenario yielded the worst results at every wellhead. If the long-term value of this water resource is going to be retained, a planned approach to managing the resource will have to be adopted. The United States Environmental Protection Agency defines a nitrate threshold of 10 parts per million where water is unfit for human consumption. Every wellhead is rapidly approaching that threshold within the next fifty years in the continuation of existing trends scenario.

The aquifer protection scenario demonstrates significantly better results at the Turner wellhead, while it appears to not solve the long-term problem at the other three wellheads. The density shift scenario yielded the best results at all four well heads, yet this scenario presumes that development would not occur anywhere else in the aquifer protection zone and the concentrated development north of Laramie is all on city sewer and water. Cultural preferences suggest this scenario may be more difficult to implement than the others.

The continuation of existing trends scenario has expanded the city limits to include proposed development immediately southeast of Laramie known as the Turner Tract Area. Under this scenario, if the Turner Tract Area was developed using city water and sewer, the development would not contribute to increased nitrate concentrations at the Turner wellhead. However, since the Turner Tract Area is located very close to the Turner well field, if this proposed development was not included in the city limits and services were not extended (i.e. these homes were developed using individual wells and septic systems) the impacts to water quality, mainly the nitrate levels, at the Turner well would be significant. Figure 8 depicts the results of excluding this development from city services (by placing them outside the city limits) in terms of nitrate concentrations at the Turner well. The result of this change pushes the level of nitrates above 10 ppm, thus making the water unfit for domestic use. The Turner Tract Area does not cover a large area, however the effect this development could have illustrates how vulnerable water quality is to land uses near the city well heads.

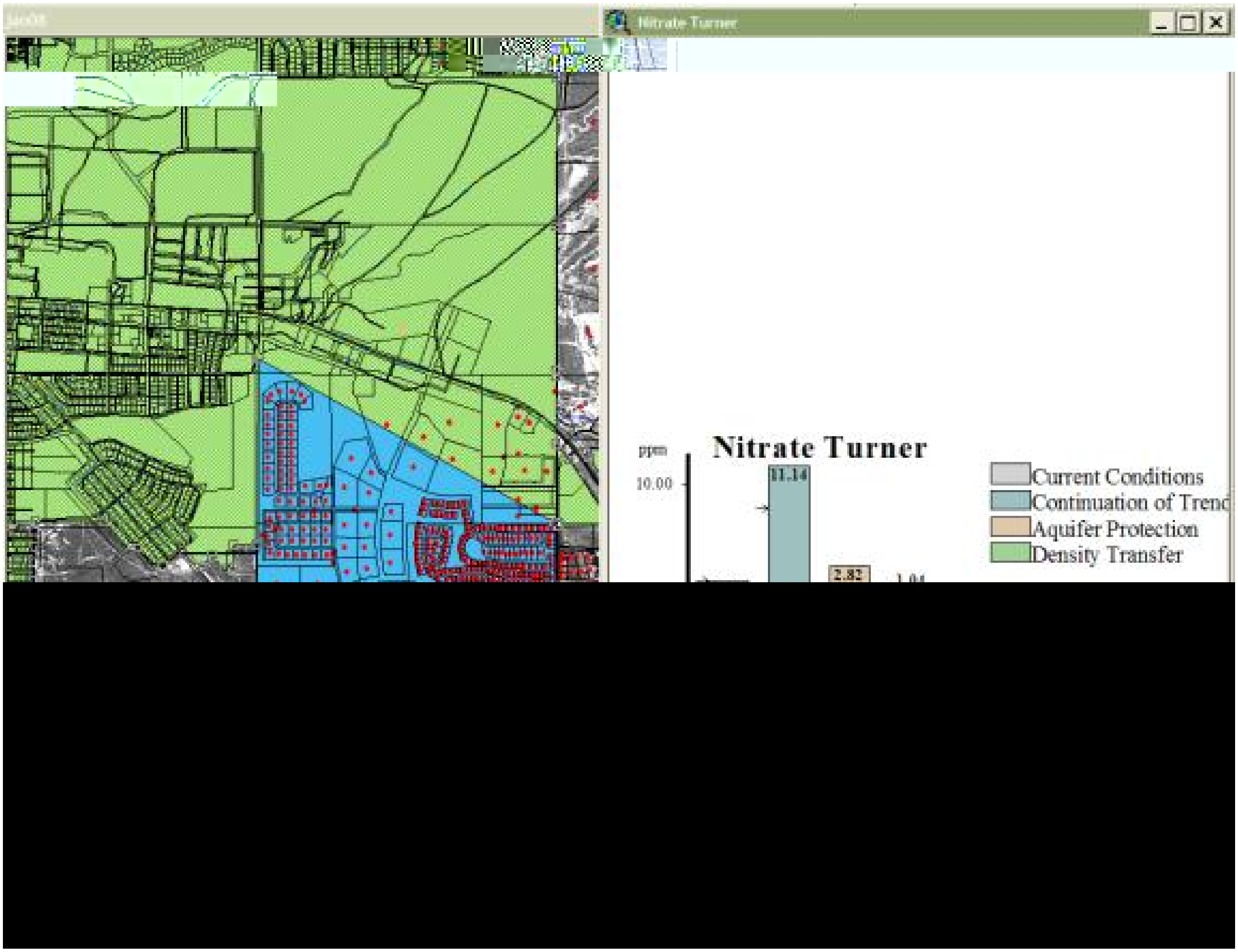

Figure 8 Modified Continuation of Existing Trends Scenario

The blue area reflects where city limits were adjusted to not include homes (red dots), thus development contributes to nitrate levels at Turner wellhead. This causes the nitrate levels to jump from 7.6 ppm to 11.14 ppm, significantly above the 10 ppm threshold for human consumption. The water resource is very vulnerable, as this blue area is presently outside the city limits and, based on this study, needs to be included at some point to avoid nitrate contamination of the aquifer.

Quantity of Water. The table below (Figure 9)reflects water consumed by area residents in the summer when water usage is at its highest due to watering of lawns and other outdoor watering activities not associated with winter water use.

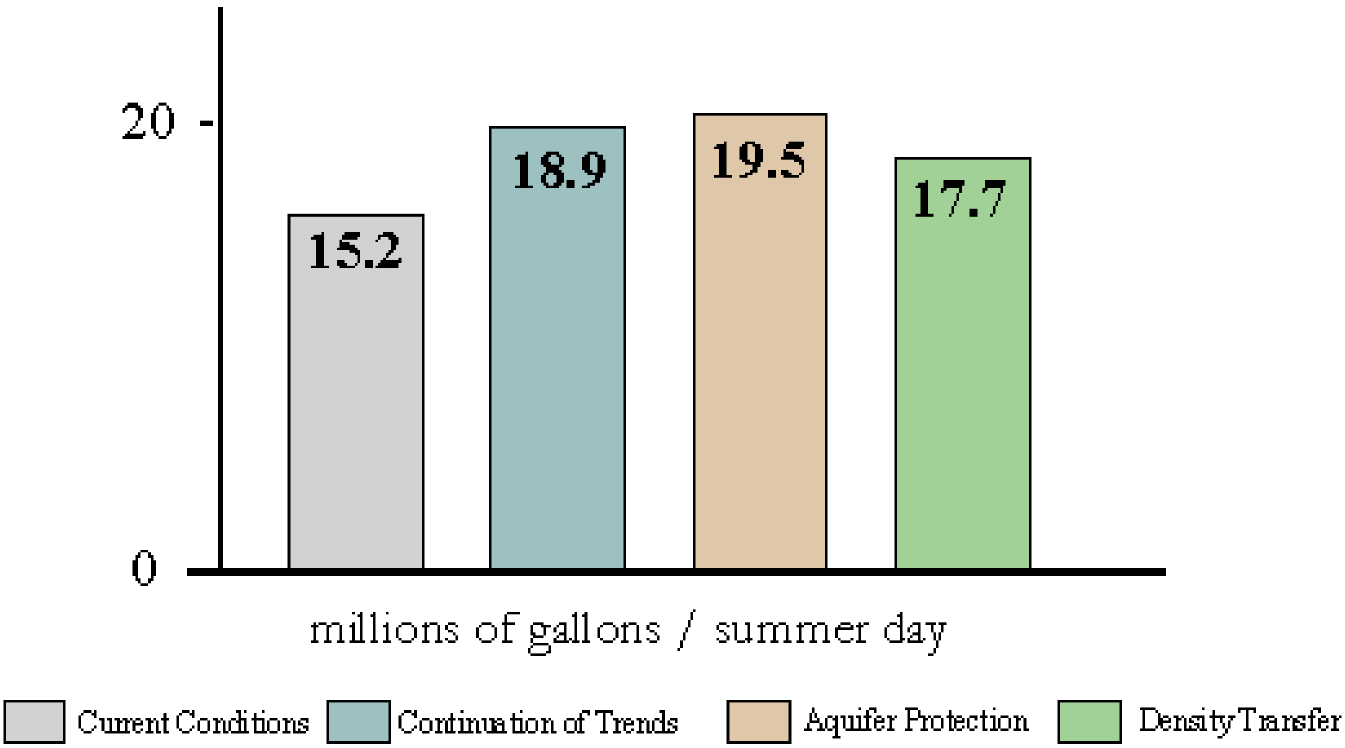

Figure 9 Quantity of Water Consumed

Results are similar for the three scenarios due to the identical increase of 1,331 residences in the study area. Still, there are implications to water consumption based on land use patterns. The large lot sizes (greater than five acres) of the aquifer protection scenario result in the greatest increase in water consumption over current conditions. Large lot sizes in the continuation of existing trends scenario yield the second largest increase in water consumed over current conditions. The density shift scenario also shows a significant increase in gallons per day consumed over current conditions, but relatively small lot sizes appear to minimize the impacts of water usage due to the increase in residences. The implication of the water use indicator is that irrigated lot size is a significant factor in determining overall water use for the community.

The best way to compare scenarios is by comparing the results from each indicator and determining which scenario leads to the largest number of desirable outcomes. In order to allow for such an overview, the following matrix (Figure 10) summarizes outcomes for each indicator. Green is used to identify the scenario with the most favorable results. Red depicts least favorable performance, and yellow indicates a mid-level. In some instances there were minimal differences between most and least favorable.

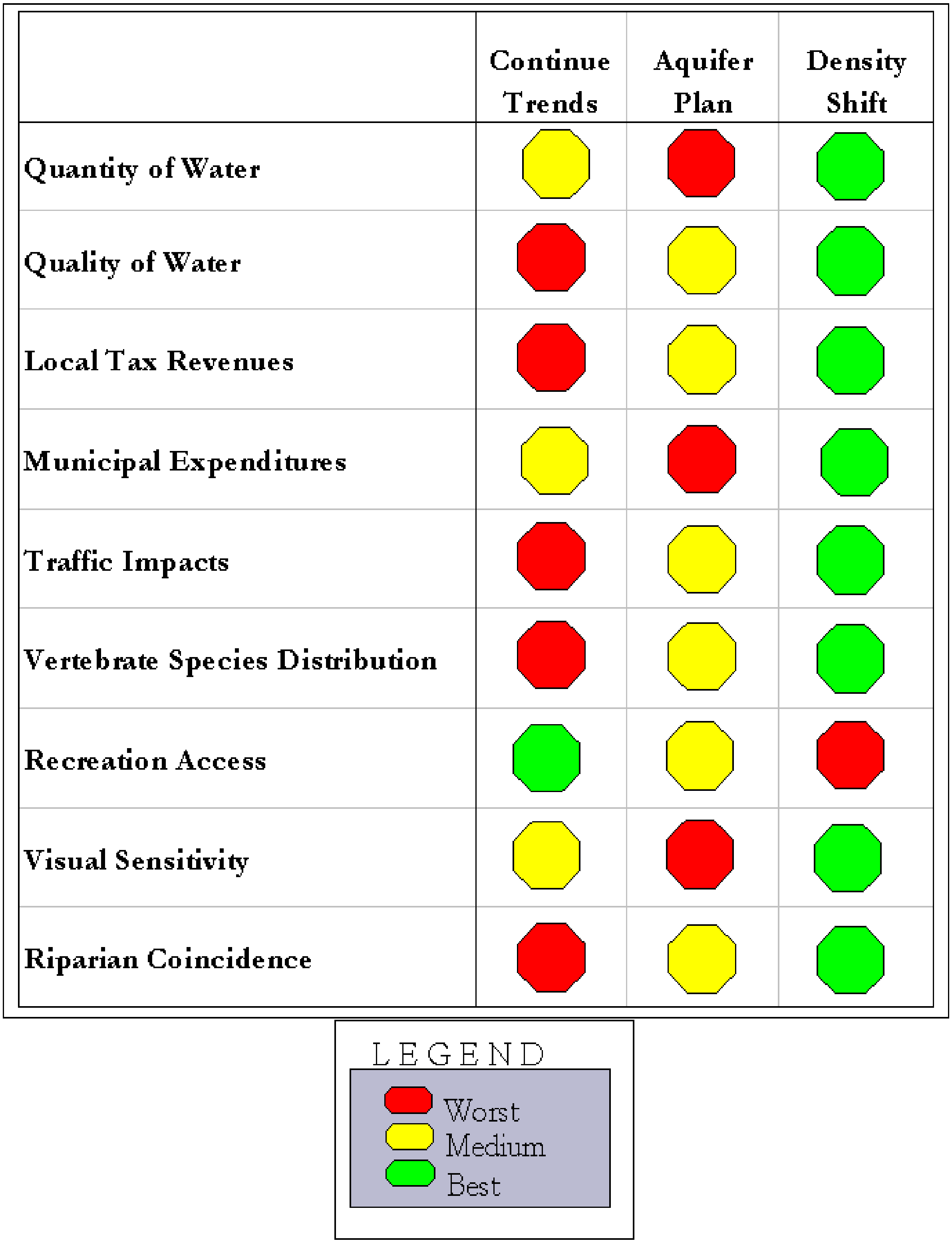

Figure 10 Indicator Summary Matrix

Conclusions

This project demonstrated the application of the Community Viz™ planning support system software in developing and evaluating alternative land use scenarios for implementation of a local aquifer protection plan. The scenarios were selected, in part, because they reflect significantly different approaches to land use planning and noticeably varied land use patterns. This analysis may be used to guide future land use in the city and county.

The project also provided valuable information which will help guide future Community Viz™ applicat in Wyoming. In terms of digital geospatial data requirements, we have learned that an accurate and complete digital parcel layer is of primary importance. Of near equal importance is a database linking information on property values, land use and zoning classifications, property tax rate information, and building type to the parcel layer. In order to make use of the visualization capabilities of the software, recommended a community obtain high resolution remotely-sensed digital imagery (e.g. digital orthophotographs or satellite imagery) as well as precise locations of features in a community (e.g. bu footprints) to assist in rendering three dimensional models of the built environment. Finally, the projec illustrates the need for a commitment of hardware, software and human resources in order to succes integrate decision support technologies into local planning processes.

[1] The Albany County Pilot Project is based on the June, 2002 draft of the Casper Aquifer Protection P

[2] In this instance, “Casper” refers to the name of a specific saturated, permeable geologic unit, not th of the city or county it serves.

Acknowledgments

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