Urban Development and Environmental Planning

Biodiversity and Landscape Planning

Alternative Futures for the Region of Camp Pendleton California U.S.A. Oak Grove Valley

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Abstract

The U.S. Environmental Protection Agency's (EPA Science Advisory Board, in its report Reducing Risk: Priorities and Strategies for Environmental Protection (U.S. EPA, 1990), identified the highest priority environmental risks to the United States, based primarily on geographic extent and irreversibility of effects. Habitat modification and loss of species diversity were ranked at the highest level of ecological risk. Habitat and species diversity are tightly coupled; species diversity at a regional level cannot be maintained without maintaining quality habitat. The Science Advisory Board expressed the view shared by many ecologists that natural habitats and their associated assemblages of plants and animals are under severe and widespread stress, primarily from the loss, alteration, and degradation of natural ecosystems resulting from human activities.

In recognition that research on the loss of biological diversity can be addressed effectively only through the cooperation of interested parties, the Biodiversity Research Consortium (the BRC) was formed to develop databases and analytical methods for assessing and managing risks to biodiversity. Current membership in the

consortium includes the U.S. Environmental Protection Agency, U.S.D.I. National Biological Survey, U.S.D.I. Geological Survey, U.S.D.I. Bureau of Land Management, U.S.D.A. Forest Service, U.S. Department of Defence, the Smithsonian Institution, and the Nature Conservancy. in addition, a number of academic institutions participate as research collaborators.

This study of the Camp Pendleton region is one of the pilot investigations supported by the BRC prior to its preparing a National Strategy for the maintenance of biodiversity.

A research program entitled "Alternative Futures for Camp Pendleton, California, in the Maintenance of the Biodiversity of its Context Region" was organized to explore how urban growth and change forecast and planned for the next 20-30 years in the rapidly developing area located between San Diego and Los Angeles, California would influence the biodiversity of that area. Of special concern is the role of the Camp Pendleton U.S. Marine Corps Training Base, a large public landholding between Los Angeles and San Diego, in the maintenance of that region's high biodiversity.

THE RESEARCH SETTING

The study was conducted by a team of researches from Harvard University Graduate School of Design, Utah State University Department of Landscape Architecture and Environmental Planning, Oregon State University, The Nature Conservancy and the U.S. Environmental Protection Agency with the full cooperation of the two relevant regional agencies-SANDAG (San Diego) and SCAG (Los Angeles)-and the U.S. Marine Corps., Camp Pendleton. The research is supported by the U.S. Environmental Protection Agency, the U.S. Forest Service and the multi agency Biodiversity Research Consortium.

The research team undertook the analysis 'of a 80 kilometers by 134 kilometers mile region that surrounds Camp Pendleton. Within this 10,720-square-kilometer rectangle, there are five major river drainage basins that directly affect Camp Pendleton: San Juan, San Mateo, San Onofre, Santa Margarita, and San Luis Rey. The research was organized at three geographic scales: The context-region of Camp Pendleton, defined as the area which includes the five watersheds; the property boundary of Camp Pendleton; and specific habitat zones within Camp Pendleton and the context region of known rare and endangered species which may be impacted by future change.

A larger context region of Camp Pendleton was examined because development-related land-use changes and determinants of hydrologic regimes that influence biodiversity occur over the larger area. Camp Pendleton is not an isolated parcel either structurally or functionally. For example, the rivers that flow through the camp and recharge its groundwater and maintain its wetlands all rise outside the camp boundaries. Likewise, urbanizing (or suburbanizing) land development takes place outside the camp's boundaries but influences land use patterns within the camp boundaries. Yet the camp and its property will continue to be a major component in any future attempts at managing landscape change toward the maintenance of biodiversity.

The study region has one of the most biologically diverse environments in the continental United States, supporting a variety of species and habitat types. This is partially due to the region's varied topography, climate and soils. The Mediterranean climate creates a semi-arid condition for potential vegetation, with warm, dry summers and mild winters. The year-around pleasant climate of the region also contributes to the area's attractiveness for development and use. The region's ecosystems include dry, hot, sparsely vegetated deserts, coniferous-dominated mountain areas, maritime-influenced chaparral and scrub communities, the coastal scrub dominated coastal areas, and coastal lagoons and estuaries. Each of these areas supports a unique assemblage of plant and animal species. There are roughly 1,700 plants, 80 mammals, 435 birds, 75 reptiles and amphibians, 125 butterflies and over 10,000 terrestrial and aquatic invertebrates in the region.

The region's population in 1970 was 1.3 million and has since doubled to 2.7 million. By 2010 the population is forecasted to grow to 3.8 million. This growth has had tremendous effects on the environment. In addition to destruction and loss of habitat and species, the region's remaining habitats have been fragmented, particularly in the coastal areas. Currently, over 200 plants and animals are listed or proposed to be listed by federal or state governments as endangered, threatened or rare. In addition, a number of plants and animals are of local concern due to declining populations. Some of the more commonly recognized species in the region which are endangered or threatened include the least Bell's vireo, the coastal cactus wren, and the California gnatcatcher.

There are several caveats to the work.

The investigators are conducting independent research and not providing consulting or planning services to any regional stakeholders, the Southern California Association of Governments (SCAG), the Sand Diego Association of Governments (SANDAG), or MCB Camp Pendleton.

The investigators have made assumptions based upon publicly available documents, without having met widely with private stakeholders or local government.

The research models are based on existing and publicly available data. The investigators cannot be held responsible for data errors or their implications.

Private property boundaries and local governmental jurisdictions are not being considered in the alternative futures except as they are identified in published regional plans.

The research has a limited scope with a selective focus on biodiversity and related aspects of environmental planning. The research findings, including the alternative future scenarios and their comparative evaluations, are not intended to be comprehensive analyses of the region.

In summary, there are several reasons for the research group to have selected the region of Camp Pendleton for study. First, it has some of the highest biodiversity in the United States, Second, it is experiencing dramatic growth and will have to manage increasing development pressures. Third, a considerable amount of information about the area has been compiled, but had not yet been synthesized across county boundaries for the regional management of biodiversity.

The research was organized to answer six questions of method following the framework for landscape planning outlined by Carl Steinitz (1990, 1993). Over the course of the study, each set of questions was asked three times; the first time to define the context and scope of the research, the second time to specify the methods of study, and the third time to carry the project forward to a set of conclusions.

There are six questions represented the usual order for defining the context of a landscape planning study. They are:

Ⅰ. How should the state of the landscape be described: in content, space, and time?

In essence, this requires defining a vocabulary and a syntax to identify those characteristics of a place relevant to a particular study. To describe the static and dynamic processes at work in this very large study area, a computer-based Geographic Information System, or GIS, was organized to contain spatially explicit data on the region. The information available for this area included elevation, soil type, annual rainfall, vegetation, hydrology, roads, land-use and public land ownership. With the GIS, it is possible to represent the state of the landscape with maps, charts, and diagrams that are derived from the data.

Ⅱ. How does the landscape operate? What are the functional and structural relationships among its elements?

Once the pertinent components of the landscape have been identified and defined, relationships between the parts can be established. These processes can be cultural, such as land management and protection status or visual preference; or physical, such as flooding or soil moisture; or biological, such as potential California gnatcatcher habitat. In most cases, these relationships can be modeled using the available data in the GIS.

Ⅲ. Is the current landscape working well?

The initial evaluation of the landscape is made by Operating the process models on the data that represents the baseline state of the study. The baseline for this study is taken to be sometime between 1990 and the present, the period when the various data were generated. The existing conditions are noted in the text by 1990+. The qualified "working well" question, of course, required the establishment of measures of judgment. For this study, some evaluations included watershed flood hydrograph and water discharge, soil moisture, risk of fire and of fire suppression, and visual preference. Biodiversity was evaluated three different ways: by the landscape ecological pattern, by models that assess potential habitat for several amphibian, reptile, bird, and mammal species, and by total species abundance of richness which is derived from vegetation communities. Although these three models of biodiversity are interrelated, each is based on a different premise and may present different implications for landscape planning and management.

IV. How might the landscape be altered - by what actions, where, and when?

At least two important types of change should be considered: those brought about by current trends and those caused by the implementation of purposeful change via actions such as plans, investments, and regulations. Future change for the region of Camp Pendleton is simulated via the complete implementation, or "build-out," of the area's current plans as summarized by the regional planning agencies, SCAG, and SANDAG, and by MCB Camp Pendleton.

In addition to this scenario, called Plans Build-Out, five alternative scenarios for the future urbanization of the study region reflect different development and conservation policies.

Alternative #1 illustrates the implications of the spread of extensive single family and rural residential growth with an assumed weakening or disregard of the regional plan, and with no additional conservation programs.

Alternative #2 also follows spread development, but it introduces a major conservation effort in the year 2010.

Alternative #3 proposes private conservation by encouraging large lot ownership adjacent to and within important habitat areas which are in turn protected by the landowners as a means to conserve biodiversity.

Alternative #4 employs a multi-centers approach by focusing on cluster development and new communities with extensive conservation efforts.

Alternative #5 concentrates growth in a single new city. All of the alternatives accommodate the projected population forecast for the year 2010, and were then extended to build-out.

V. What predictable differences might the changes cause?

Operating the process models on the change scenarios and comparing the results with the baseline evaluations yields impact assessments. This investigation of the Camp Pendleton region is based on the premise that the major stressors affecting biodiversity are urbanization-related activities. There are direct impacts on habitat caused by deforestation, grading, paving, ornamental landscape planting, and other human activities that alter or destroy plant communities. There are also indirect effects of development, such as modified hydrologic cycles and fire suppression in rural areas. While the indirect effects can remain unnoticed by the casual observer, their cumulative modification to the landscape can be as detrimental to biodiversity as the direct impacts. For this reason the research team is reporting contributing impacts, such as change in soil moisture, that are beyond those immediately associated with biodiversity studies.

VI. How should the landscape be changed?

Each of the impact assessments reveals one aspect of how the alternative scenarios are predicted to change the landscape. The alternative scenarios for the region of Camp Pendleton, presented here, and their projected impacts may be used by stakeholders of southern California, including MCB Camp Pendleton, to assess the desirability of the various policies which generated them. The criteria by which choices are assessed will vary among individuals and groups who hold different interests. Judging the importance of these is the responsibility of the people and jurisdictions that will be influenced by future development.

The research strategy is based on the hypothesis that the major stressors causing biodiversity change are urbanization-related development in the region and land use practices at Camp Pendleton. As human population increases and development spreads, habitat is lost from deforestation, grading, paving, construction, ornamental landscaping, associated land uses, and other human activities. There,are also indirect, secondary and cumulative influences on vegetation and thus on habitat and, ultimately, on biodiversity.

A major goal of the study was to determine how to accommodate regional growth and development without adversely affecting biodiversity or the hydrologic regime.

TECHNICAL IMPLEMENTATION

A computer-based Geographic Information System (GIS) was designed to contain digital data about the region, perform the analyses, and produce maps, charts, and other graphic and tabular results. A GIS is a type of database that allows descriptions of the landscape to be geographically referenced. Like many computer databases, a GIS can be searched for fact-based information, such as the amount of conservation land in the study area. Use of a GIS also permits analysis of the spatial relationships between elements in the landscape. For example, it is possible to query the locations of the conservation land in the study area. Further, models that use these spatially explicit data can be created to simulate natural processes. Changes to the landscape can also be modeled and assessed for potential impacts.

The data used for this project were acquired from several sources and have variation in spatial resolution and accuracy. Sources ranged from detailed observations made by wildlife biologists in the field of descriptions of roads and stream networks from the national data bases of the United States Geological Survey (USGS) and the Census Bureau. Additional data were provided to the research team by SANDAG, SCAG, MCB Camp Pendleton, the University of California at Santa Barbara, and others. While most source data were acquired in digital form, some data, such as the county level soils surveys prepared by the Natural Resources Conservation Service (formerly the Soils Conservation Service), were digitized from printed originals. All data were assembled, standardized to a common set of descriptive terms, and combined to produce the study's representation of the landscape.

In the GIS for this project, separate digital "layers," or maps, are used to represent the important aspects of the study area: topography, soils, vegetation, hydrology, roads, existing and planned land use, county and municipal boundaries, etc. Each separate layer is stored in "raster" form, which is a two dimensional array of "grid-cells," or "pixels." Each individual pixel represents a 30 meter x 30 meter area (approximately none-one hundredths of a hectare, or one-quarter of an acre). Thus, each data layer of the 80km x 135km study area is represented in the GIS as a matrix of approximately 4,000 cells east-west by 3,000 cells north-south, for a total of about 12 million cells. In addition, a number of linear features, such as roads, streams, county, municipal and other legal boundaries, are maintained as a linear or "vector" data base.

The analytical models that use the base data were implemented as computer program modules using the Arc/Info GRID analysis package (Environmental Systems research Institute, Redlands, California). Additional data re-classification and satellite date interpretation was performed in IMAGINE software (ERDAS, Atlanta, Georgia). Each model combines selected layers of the base data to analyze or predict some aspect of the structure or function of the regional landscape. Some models require as an input the results of other models. This "chaining" process can be seen, for example, in the cougar habitat model which is partly dependent upon mule deer habitat. The alternative future scenarios were developed in Map Factory GIS software (Think Space, Ontario, Canada). Each scenario was represented as a land cover map with the same land use classifications as the 1990+ baseline, thus making it possible to compare present and possible future conditions. Future change is studied at four scales: several restoration projects, a subdivision, a third order watershed, and the region as a whole. Regional change is simulated via six alternative projections of development to the year 2010 and to subsequent "build-out." The first scenario is abased upon the current local and regional plans as summarized by the Southern California Association of Governments, the San Diego Association of Governments, and those of Camp Pendleton. Five alternative scenarios provide a method to explore and compare the impacts of different land use and development policies relating to biodiversity. Alternative #1 illustrates what my be considered the dominant spread pattern of low-density growth. Alternative #2 also follows the spread pattern, but introduces a conservation strategy in the year 2010. Alternative #3 proposed private conservation of biodiversity by encouraging large-lot ownership adjacent to and encompassing important habitat areas. Alternative #4, focuses on multi-centers of development and new communities. Lastly, Alternative #5 concentrates growth in a single new city. All alternatives accommodate the population forecast for the region.

The soils models evaluate erodability and the agricultural productivity of the area's soils. The hydrology models predict the 100-year storm hydrographs for each of the rivers and their subwatersheds, flooding heights and water discharge, and resultant soil moisture. The fire models assess both the need for fire in maintaining vegetation habitats, and the risks of fire and fire suppression. The vegetation model assesses vegetation and provides a basis for species-habitat relationships.

ASSESSING BIODIVERSITY

Biodiversity is assessed in three ways: via landscape ecological pattern and function; via selected single species potential habitat models; and via species richness GAP analysis modeling.

The landscape ecological pattern model builds from the ongoing work of Richard Forman and Michel Godron, as presented in their 1986 book, Landscape Ecology, and elaborated in Forman's 1995 book, Land Mosaics. The focus of landscape ecology is the spatial relationships between structural and functional elements of the lands. Any type of landscape at any scale, whether natural or modified by human action, can be described as a mosaic: a background matrix and patches connected by corridors. This model provides a base for analysis and comparative evaluation, plus the potential for detecting general patterns and principles.

Qualifications to the generalized elements can provide evaluations of the landscape. Change in the landscape ecological pattern of a region can cause a change in the biodiversity of the area, and planning initiatives that maintain the landscape pattern my preserve biodiversity.

The single species potential habitat models map the possible home ranges for selected vertebrates based on food and nesting requirements, and on behavioral characteristics. While single species management has been criticized by wildlife biologists and planning professionals as being too narrowly focused, there are several reasons for integrating this type of modeling into a biodiversity study.

First, several species in the study area are on the federal lists of threatened and endangered species. The California gnatcatcher, least Bell's vireo, and arroyo toad are examples. Still other species are candidates for federal listing, or are listed as California Species of Special Concern. Consideration of those species is legally mandated. Some impact assessments, mitigation, or recovery management strategies clearly need to be species specific.

Second, one species, the California cougar, is in danger of regional extinction because development and roadways are split-ting the existing population into two increasingly isolated sub-populations. Without a habitat linkage, neither of these populations will be large enough to maintain genetic viability beyond the next 100 years. There are obvious species-specific planning, design, and management dimensions to this problem.

Third, some species are particularly susceptible to changes in the environment and, as such, are good indicators of environmental change associated with development. The least Bell's vireo, for example, is very sensitive to changes in hydrology, channel morphology, and riparian vegetation. In contrast, the brown-headed cowbird populations increase with suburban development.

The habitat information presented for each wildlife species has been formatted according to Standards for the Development of Habitat Suitability Index (HSI) Models of the U.S. Fish and Wildlife Service (1981). The HSI models are an outgrowth of the Habitat Evaluation Procedures (HEP)(USFWS, 1980). HEP is a widely used methodology for evaluating the various types of impacts on wildlife habitat and wildlife species associated with changes in water and land use. The single species models consisted of: California Cougar, Mule Deer, Arroyo Toad, Least Bell's Vireo, California Gnatcatcher, Coastal Cactus Wren, Orange Throated Whiptail Lizard, Cowbird, Gray Fox, Arroyo Chub, and Bluebird.

Biologists have long used knowledge of species; life history attributes to model animal ecology. One common method is to model habitat by linking known needs and use patterns with maps of existing vegetation, thereby identifying the spatial extent of important habitat features. This information can then be used in conservation and management (see Verner, et al., 1986). For California, a complete set of wildlife habitat relation (WHR) models has been developed that links all terrestrial vertebrates to specific habitat types (Mayer, et al., 1988). By mapping the abundance, or richness, of species associated with each habitat type as derived from these relation models, it is possible to understand better.the spatial implications of biodiversity in a region. The species richness approach does not focus on any particular species. Rather, it is an indicator of the properties of the set of all species associated with a pattern of vegetation. The study region is currently an area of high biodiversity.

CHANGE - ALTERNATIVE FUTURES COMPARED

Each of the alternatives has been assessed by each model for the impacts of changes between 1990+ and 2010, and between 1990+ and Build-Out. These are summarized the six alternatives:

Plans Build-Out

Spread

Spread with Conservation 2010

Private Conservation

Multi-Centers

New City

In the Plans Build-Out scenario, half the potentially productive agricultural soils listed by the NRCS or the State of California will be lost to development. The protection of the other half is not through any new conservation strategy, but rather through the stewardship for other reasons by the current owners and managers: the Metropolitan Water District, the Bureau of Land Management, the MCB Camp Pendleton.

All of the alternative scenarios do better than Plans Build-Out. The New City and both Spread alternatives urbanize considerable areas of prime agricultural soils. The Multi-Centers and Private Conservation proposals lose the least amounts.

The Plans Build-Out and Spread scenarios both cover considerable areas of permeable soils with impervious land uses or compacted soils. This will lead to more run-off and less retention and more severe flooding. Development in currently unprotected land in the eastern portion of the study area will change the runoff in the headwaters area, reducing soil moisture and altering the vegetation pattern in both the Multi-Centers and New City alternatives. The Private Conservation scenario spreads small disturbance widely so soil runoff will be increased, but not as severely as in the other alternatives.

In Plans Build-Out nearly 5000ha of upland soils will change from very dry to dry or mesic as more water runs off developed uphill land. Much of the change will occur within typically dry vegetation types. About 2% of the total area of chaparral will become wetter which may change the vegetation.

The Plans Build-Out, both Spread alternatives, and the New City late-stage (after 2010) alternative enable rural residential development which will place both houses and the native vegetation communities at risk and make fire management difficult. While the Multi-Centers alternative protects some large areas in the northern half of the study area, fragmented conservation land in the southern half will also prove difficult to manage for fire. The Private Conservation alternatives's strategy of clustering small numbers of houses at the edges of wide bands of conservation land affords a spatial distribution suitable for, fire management within developed areas.

Both the Plans Build-Out and Spread alternatives seriously impact the large natural areas in the eastern half of the study area. Even though one Spread alternative calls for conservation of available land after the year 2010, the landscape is expected to be so fragmented by that date that only the protection of small patches will be possible. The Multi-Centers, and to a slightly lesser extent the New City alternative, maintain smaller but contiguous patches of natural vegetation. The Private Conservation alternative, by privately protecting large natural areas and wide corridors at an early stage, best maintains the ecological pattern of the region. However, this alternative assumes that about 20% of the study area will fall within its policy proposals.

In general, the Private Conservation alternative best protects the single species potential habitats. In some cases, it expands potential habitats. The Spread alternatives and Plans Build-Out alter the patterns of habitat the most, it should be noted that several of the species will significantly expand their habitat because of the growth of rural residential development and its 'accompanying change to upland vegetation. Whether or not the great increase in cowbird habitat is good for biodiversity is questionable.

While suburbanization may only slightly change the total number of vertebrate species in the region, the habitat communities with the highest species richness will decrease significantly. The scenarios differ in the amount of that decrease, with the New City and Private Conservation proposals maintaining relatively more species richness than the others. All of the alternatives except Private Conservation decrease the number of species having at least 500 home range patches.

While species richness declines in all of the future scenarios, much is retained in the rural residential areas. This is especially true where small patches encompass species' home ranges. The definition of rural residential development posits an average of 25% conversion from native vegetation to structures, paving, and other land cover, and the retention of the remaining 75% of the natural vegetation. The analysis results are strongly dependent on strict adherence to this definition. Rural residential development that converts the remaining 75% to ornamentai gardens, avocado orchards, or horse pastures would not maintain the predicted levels of species richness.

OAK GROVE

Another major analysis concentrated on a third order watershed in the Santa Margarita River basin. The study area lies approximately 30 kilometers east of Camp Pendleton and is centered on the small rural community of Oak Grove.

The objectives of the Oak Grove Project were:

- To recommend planning strategies for the Oak Grove study site which may have applicability to the entire study region.
- To forecast future (2010) land use changes in the Oak Grove study area by creating several alternative growth scenarios.
- To compare and analyze the predicted impacts of each scenario on biodiversity, the hydrologic regime, and single species models.

The methodology and computer models utilized in the Oak Grove study extended techniques developed by Steinitz ('94) and Toth ('90). In addition, the models were designed to simulate the relationships between land use/hydrologic regime and biodiversity in order to evaluate and compare impacts from different future land use patterns. All of the models used inventory data from ArcInfo as inputs to programs that were executed using MapFactory.

The Habitat Evaluation Model incorporated ownership, slope, and land cover data in addition to individual species models for deer and cougar habitat. This information was combined to create a set of criteria applied to each scenario to evaluate the performance of development with respect to the protection of biodiversity. The model assumed a negative impact if development occurred within habitat areas.

The Runoff Evaluation Model is based on the Natural Resource Conservation Service Technical Release 55 (TR55) entitled, "Urban Hydrology for Small Watershed."

This model utilized land-cover, soils, and land use data. For each scenario, land use and/or land covers were assigned corresponding runoff curve numbers (RCNs) as determined by TR55. These BCNs were then aggregated into a composite RCN for each scenario. Each composite RCN was compared to the baseline RCN, which assumes only natural land cover. These results were then analyzed using TR55 to produce corresponding hydrographs for 25-year storms. These hydrographs show the impacts of development in the form of greater runoff with higher peaks.

The study team created nine different development scenarios for the Oak Grove study site, based on assumptions about regional population growth and development trends. Some of the Scenarios are 'business as usual" or "status quo," not considering beyond current land use ordinances, either habitat or runoff impacts. Others seek to further address these two issues through additional "conservation" restrictions on the location and nature of proposed development for Oak Grove Valley.

* Scenario A1 assumes a population increase of 1,500 residents by the year 2010, and attempts to settle these newcomers in a "Rural Residential" development density (one dwelling unit per five acres). A1 is based on current land use plans for unincorporated San Diego County, which generally prohibit development on slopes greater than 25% or within 30 meters of a stream bed.
* Scenario A2 makes the same assumptions as A1, but has further restrictions on development (80-meter "riparian buffer" and location decisions based on "Landscape Structure").
* Scenario A3 simply alters land use location decisions made in A2 by examining their impact on two species' habitat: 'Cougar and mule deer. If proposed development in Scenario A2 fell within either species' predicted habitat, then it was moved to areas that were not considered suitable habitat (areas currently agricultural in nature).
* Scenario B1 assumes the same population increase of 1,500 residents, but in addition to Rural Residential development, it includes some "Single Family" residential areas (four dwelling units per acre). Restrictions on development are identical to Scenario A1.
* Scenario B2 is similar to B1, but like A2, it places additional limits on

development with a 80-meter riparian buffer and "Landscape Structure."

* Scenario B3 behaves in the same manner as A3, taking B2 development that infringed upon predicted cougar or deer habitat and relocating it to non-habitat areas.
* Scenario C1 pushes population growth by the year 2010 to 5,000 new people, based on the possibility that a fairly large employer, perhaps a light industrial firm (+750 employees) would decide to locate its facilities with Oak Grove Valley. This Scenario generates not only the need for industrial space and new housing (a mix of Single Family and Rural Residential densities), but additional services required by such a large influx; commercial, parks, and "public institutions." The proportion or acreage of each land use was estimated based on a typical "multiplier effect" that such a "basic" industry might have on a local economy. The development restrictions for C1 are identical to Scenarios A1 and B1.
* Scenario C2, like the other "2" scenarios, incorporates additional restrictions via "Landscape Structure" and the 80-meter riparian buffer. It makes the same basic assumptions found in C1.
* Scenario C3 alters the development patterns found in C2 to avoid impact on species habitat, as A3 and B3 sought to do.

CONCLUSIONS

After analyzing the results of the evaluation models with respect to the objectives of the study, several conclusions can be drawn. The study demonstrates that if current San Diego County land use regulations are enforced, they do provide a certain degree of protection for biodiversity. Impacts on biodiversity through direct removal of habitat or an altered hydrologic regime appear to be minimized through steep slope restrictions, floodway buffers and public land protection. However, these results cannot be universally applied throughout the greater Camp Pendleton study area due to the unique characteristics of the Oak Grove site described below.

Runoff

- The runoff model demonstrated an insignificant change from development as compared to present conditions. This can be attributed to three factors:

1) The present land use/land covers, like agriculture, produce higher amounts of runoff than the proposed land uses.
2) The site is characterized by a large amount of publicly owned land (which presumably cannot be developed) and the overall steepness of the site, with the average slope being 22%
3) The scale of the collected GIS inventory data was intended primarily for a larger site, resulting in,data that was too course to allow the more detailed analysis needed to fully meet the study's objectives.

- The A3 rural residential scenario, at the densities we have suggested, appears to produce less runoff than existing agricultural and use. This is due in part to the nature of rural residential with its relatively low proportion of impervious surfaces (i.e. no sidewalks) and more on site mitigation of storm water runoff (i.e. no channelization).
- Scenarios C2 and C3, which accommodate over twice the population of the "A" and "B" scenarios, show an insignificant increase in runoff.

Habitat

- The habitat model was effective for determining the placement of development. This is evident in the final scenarios that show maximum habitat preservation. However, the model only showed direct impacts from development, and was unable to show the indirect impacts of an altered hydrological regime due to the insignificant runoff increase.
- In the "A" scenarios, while habitat can be preserved, other attributes not considered in this study, such as historical preservation and views, may be compromised. It is recommended that these attributes be considered in future studies.

- The "B" scenarios allow for greater habitat protection and additional open space preservation but may increase runoff due to different runoff management techniques for higher density development (i.e. stream channelization). Micro-mitigation such as on-site retention of storm water runoff can minimize any increase runoff due to development. More detailed analysis at a site or project level is necessary to determine more accurate hydrologic impacts.
- The "C" scenarios appear to meet runoff and habitat criteria, despite a much larger population. However, it does not take into account intensive water needs, sewage treatment, and the fire ecology regime. These issues require further study before any definitive recommendations can be made.