2/22/2019

Sent via email and FedEx (w/ references)

Placer County Community Development Resource Agency
Environmental Coordination Services
3091 County Center Drive, Suite 190
Auburn, CA 95603
cdraecs@placer.ca.gov

Re: Sunset Area Plan/Placer Ranch Specific Plan Draft Environmental Impact Report (State Clearinghouse No. 2016112012)

Dear Ms. Jacobsen,

These comments are submitted on behalf of the Center for Biological Diversity (the "Center") regarding the Sunset Area Plan and Placer Ranch Specific Plan (the "Project"). The Center has reviewed the Draft Environmental Impact Report ("DEIR") closely and is concerned by the numerous significant impacts the Project would have on sensitive wildlife and ecosystems in and around the Project area. The Project would destroy thousands of acres of vernal pools, directly harming numerous special-status species on what is one of the last intact areas of habitat in western Placer County. The California Environmental Quality Act ("CEQA") mandated environmental review is inadequate and fails to comply with the statute. The Center urges approval of the Project be denied, or at the very least substantial revisions to the DEIR to better analyze, mitigate or avoid the Project's significant environmental impacts.

The Center is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center has over 1.4 million members and online activists throughout California and the United States. The Center has worked for many years to protect imperiled plants and wildlife, open space, air and water quality, and overall quality of life for people in Northern California.

I. The DEIR's Alternatives Analysis Is Inadequate

The DEIR's analysis of Project alternatives is flawed and does not comply with the requirements of CEQA. First, the alternatives analysis uses an improper No-Project Alternative, which serves to understate the impacts of the proposed Project and fails to adequately inform decisionmakers and the public about the consequences of not approving the Project. Second, the alternatives analysis fails to include a reasonable range of alternatives and instead provides a

narrow range of alternatives that vary little from the proposed Project. Third, the DEIR fails to assess feasible alternatives that would significantly reduce the impacts of the Project without substantial evidence to justify its reasoning.

A. Assuming Buildout of the Sunset Industrial Area Plan as the No-Project Alternative is Improper

The DEIR confines and obscures its alternatives analysis by using a no project alternative that is only slightly less impactful than the other proposed alternatives. The DEIR's alternatives analysis assumes that if the proposed Project is not built, the area will be developed according to the 1997 Sunset Industrial Area Plan ("SIAP"). (DEIR at 6-9.) The CEQA Guidelines ("Guidelines") require analysis of a no project alternative to assess the existing site conditions as well as "what would be reasonably expected to occur in the foreseeable future if the project were not approved, based on current plans and consistent with available infrastructure and community services." (Guidelines § 15126.6(e)(2).) While the SIAP was indeed approved, the site remains 90% undeveloped 20 years after approval and the DEIR provides no evidence that the SIAP proposal has taken any further steps toward implementation. (DEIR at 3-5.) It is not reasonable to therefore to assume buildout of the SIAP is as "expected to occur in the foreseeable future" should the proposed Project not be approved. Any attempt to implement SIAP would require, at the very least, a subsequent environmental review, since the environmental conditions of the site, region and state have dramatically changed since the 1997 approval. (See Guidelines § 15162(a) [requiring subsequent review if the lead agency determines new information becomes available, or project impacts would occur that were not assessed during the initial review].) Indeed it appears more likely that should the Project not go forward, the area would remain in its largely undeveloped state unless another proposal and environmental review process is completed.

The DEIR also asserts that the no project alternative would be the environmentally superior alternative, despite producing greater impacts to biological resources as compared to the proposed Project. (DEIR at 6-28.) The DEIR then attempts to cast the proposed Project in an artificially positive light regarding its potential impacts so that the Project now appears to be only minimally more environmentally damaging. This approach is misleading to decision-makers and the public. Instead, the DEIR should be revised to present a no project alternative that more accurately depicts the existing undeveloped conditions of the SAP site, so that the impacts of the alternatives can be fully and adequately analyzed...

B. The DEIR Fails to Assess a Reasonable Range of Alternatives

The Project as proposed would result in numerous significant and unavoidable impacts, meaning a thorough alternatives analysis is absolutely necessary in fulfilling the DEIR's role of informing the public and decision-makers. Courts have consistently held that "[o]ne of [] an EIR's major functions … is to ensure that all reasonable alternatives to proposed projects are thoroughly assessed by the responsible official." (*Laurel Heights Improvement Assn. v. Regents of University of California* (1988) 47 Cal.3d 376, 400.) CEQA prohibits an agency from approving projects as proposed "if there are feasible alternatives or feasible mitigation measures which will avoid or substantially lessen the significant environmental effects of such projects." (Pub. Res. Code § 21002.) While the DEIR does not need to address "every conceivable

alternative," it should provide a reasonable range that allows the reader to understand the proposed Project's impacts and a range of feasible alternatives that might avoid project impacts. (Guidelines § 15126.6(a).) Under CEQA, "the public agency bears the burden of affirmatively demonstrating that, notwithstanding a project's impact on the environment, the agency's approval of the proposed project followed meaningful consideration of alternatives and mitigation measures." (*Mountain Lion Foundation v. Fish & Game Com*. (1997) 16 Cal.4th 105, 134.) The DEIR analyzes a narrow range of alternatives that do little to avoid Project impacts, falling short of a meaningful analysis. (DEIR at 6-8, 9, 28, see Table 6-7.) Despite the Project's significant impacts, the DEIR concedes that "none of the other alternatives [excluding the no project alternative] avoid or substantially reduce a significant impact of the Project." (DEIR at 6-28.) The DEIR also fails to provide substantial evidence to explain its rejection of the analyzed alternatives, nor is there a discussion of how the Project objectives would be met by each alternative. CEQA requires a more thorough and complete alternatives analysis.

C. The DEIR Failed to Analyze a Feasible Alternative that Would Significantly Lessen Project Impacts

The DEIR also fails to meet its CEQA alternative analysis mandate because it omitted consideration of a feasible alternative that would reduce and avoid significant Project impacts while meeting most of the objectives. The Citizen-Initiated Smart Growth Plan ("CISGP"), presented to the County by the Alliance for Environmental Leadership ("AEL"), is an example of the sort of alternative the CEQA process strives to illuminate. (Marsh, 2019). The DEIR should be revised to expand the scope of the alternatives analysis so that feasible alternatives, such as the CISGP, are made available so that the public and decision-makers are adequately informed, as directed by CEQA.

II. The DEIR Improperly Relies on Uncertain And Infeasible Mitigation Measures

The Project will have significant and unavoidable impacts to nearly every resource category that falls under the purview of CEQA. The Project's impacts are particularly large in number and magnitude when considering the biological resources present on the Project site. While the DEIR identifies significant impacts, it falls short when attempting to provide adequate mitigation. The rampant uncertainty and speculation of the DEIR's mitigation program gives the public and decision-makers no concrete understanding of how the immense impacts of the Project will be addressed. The inability of the DEIR to provide feasible mitigation demonstrates that the Project should not and cannot advance in its current form because the Project site is grossly inappropriate for a development of this type and scale.

A. The DEIR's Reliance on the Placer County Conservation Plan does not Constitute Feasible Mitigation

The mitigation of significant environmental impacts must be presented in a way that offers the public and decision-makers a sense of confidence that should the Project be approved, impacts will actually be mitigated to the maximum extent feasible. The DEIR fails to do this, as

its mitigation for biological resources relies on the draft Placer County Conservation Plan ("PCCP") to meet its permitting requirements under multiple federal and state laws. However, at the time of the DEIR's release, the PCCP is nothing more than a proposal. (DEIR at 4.4-28.) CEQA requires that mitigation measures that reduce or avoid Project impacts must be concrete ad not speculative. (*Preserve Wild Santee v. City of Santee* (2012) 210 Cal.4th 260, 281 [mitigation measures that are so undefined that their effectiveness is impossible to determine are legally inadequate].) The DEIR approach to base its mitigation on a draft plan, for which there is no guarantee, let alone indication, of approval, does not provide the certainty required under the Guidelines. (Guidelines § 15126.4.) The DEIR provides no assurances or substantial evidence that the PCCP will be approved. Instead the PCCP is discussed throughout the document in speculative terms such as "if the PCCP is approved by the state and federal agencies and is adopted and implemented in time to support development under the PRSP and Net SAP." (DEIR at 4.4-41.) Because the DEIR offers no support for the likely approval of the PCCP, it cannot rely on the plan to mitigate the Project's many significant impacts.

B. The Project Fails to Adequately Mitigate Significant Impacts to Special-Status Species and Protected Habitats

The DEIR fails to provide the level of mitigation that will be required for the issuance of permits that will be necessary for the Project to ultimately be approved. The Project site is home to endangered and special-status plants and wildlife, as well as multiple forms of high value habitat types. (DEIR at 4.4-11, 12.) The Project would require permits under many different statutes from multiple of state and federal agencies. (DEIR at 4.4-22-24.) Even if the Project could rely on the PCCP to meet its mitigation requirements there remain serious issues with the feasibility and capacity of the PCCP to fully mitigate the Project significant environmental impact.

For example, one of the permitting requirements the Project, via the PCCP or otherwise, will need to satisfy is the "no net loss of wetland habitat," as required by the United States Army Core of Engineers ("USACE"). (DEIR at 4.4-41.) However, the DEIR states that "existing credits may not be enough to fully cover the loss of wetland functions resulting from project implementation, and it is unknown if sufficient land would be available from willing sellers to fully mitigate the loss," which demonstrates the infeasibility of the proposed mitigation measures. (DEIR at 4.4-41.) The limitation of available land and credits would also apply in the event the PCCP is granted approval. Therefore, the DEIR appears to be admitting that there simply isn't enough land or mitigation credit available in the region to meet USACE standards of no net loss of wetland functions.

The DEIR's mitigation for impacts to federally listed vernal pool invertebrates is also insufficient to meet permitting standards. A large portion of the Project site falls within the Western Placer County core area as identified in the in the United States Fish and Wildlife Service ("USFWS") vernal pool recovery plan. (DEIR at 4.4-44.) The USFWS targets preservation of 85% within core recovery areas, yet the Project would achieve only 40%. (DEIR at 4.4-44.) The Project would remove over 5,000 acres of low density vernal pool complexes from the Project site. (DEIR at 4.4-48.) The DEIR, similarly to the uncertain language referenced above, cannot determine whether PCCP mitigation would reduce the significance of the vernal

pool removal, as the PCCP has not yet been approved. (DEIR at 4.4-48.) Should the PCCP be adopted and implemented in time to serve the Project, the mitigation would "not necessarily occur within the western Placer County core area because there is a limited amount of habitat present within the core area and a large proportion of it has already been developed or is planned for development." (DEIR at 4.4-48.) The DEIR acknowledges that mitigation in the absence of the PCCP would result in a lesser reduction in impacts than under the PCCP. (DEIR at 4.4-48.) This shows that even if the PCCP is adopted, it will do very little toward achieving the goals of the vernal pool recovery plan, and therefore it is difficult to see how USFWS would issue Endangered Species Act ("ESA") take permits under the PCCP for the Project's widespread destruction of vernal pool species such as the vernal pool fairy shrimp, and vernal pool tadpole shrimp.

C. The DEIR's Analysis of the Placer Ranch Specific Plan's Impacts and Mitigation is Insufficient

The analysis and mitigation of the PRSP's biological resources impacts does not meet the level of specificity required for a project-level assessment. The DEIR contains two levels of analysis, a programmatic level for the SAP, and a project level for the PRSP. (DEIR at 1-2.) While a programmatic EIR can provide more general assessments in its first tier of analysis, a project-level analysis must provide more detail regarding project impacts and proposed mitigation measures. (Guidelines § 15152.) The specificity of an EIR is determined by the nature of the project and the 'rule of reason.' (*Citizens for Sustainable Treasure Island v. City and County of San Francisco* (2014) 227 Cal.App.4th 1036, 1048.) The PRSP is a planned community, with specific land uses and the intensity thereof already established, therefore, it is reasonable that the DEIR assess the impacts and propose mitigation for those specific uses.

The DEIR provides separate impact assessments for the SAP and PRSP areas but applies the same general and deferred mitigation to each planning area. For example, Mitigation Measure 4.4-5a provides inadequately brief mitigation instructions for future development to avoid impacts to western pond turtles should the PCCP not be adopted. (DEIR at 4.4-59.) The mitigation requires surveys before earthmoving, and subsequent relocation if individual turtles are observed. (DEIR at 4.4-59.) There is no discussion of where the turtles will be relocated, nor are there performance standards that dictate the quality of relocation habitat or the turtle's survival post-relocation. Additionally, the measure only applies to construction activities within 200 feet of suitable aquatic habitat. (DEIR at 4.4-59.) Western pond turtles are known to utilize upland habitats up to 1,300 feet away from aquatic habitat. (Semlitsch and Bodie, 2003). The DEIR should be revised to include adequately detailed analysis of the impacts and mitigation measures for the PRSP, as well as providing accurate species-specific mitigation.

Given the vulnerability of the site's ecological resources and the DEIR's acknowledgment of regional development pressures, the scope and design of the Project should be seriously reconsidered.

III. The DEIR Fails to Adequately Analyze and Mitigate the Impacts of the Project on Biological Resources.

The Project site, in its currently undeveloped state, is home to numerous plant and animal species that rely on the area's unique ecological communities. The DEIR identifies 42 special-status fish and wildlife species that could occur on the site (DEIR at 4.4-15), and 10 special-status plant species that could occur on or near the Project site (DEIR at 4.4-12). Despite these findings, the DEIR fails to identify and assess the impacts to some of these species, while completely omitting discussion of other impacts. This inadequate and incomplete analysis violates CEQA's requirements that all environmental impacts from a project are fully disclosed and analyzed.

A. The DEIR's Analysis of Impacts to Western Spadefoot Toad is Insufficient.

The DEIR does not contain sufficient information to allow proper assessment of the Project's impacts to western spadefoot, which also undermines the efficacy of proposed mitigation. The DEIR acknowledges the impacts on western spadefoot in its discussion of vernal pool removal, as well briefly listing other potential indirect impacts due to Project development. (DEIR at 4.4-44, 45.) However, the discussion is superficial, and provides little detail about actual impacts because the location and population of western spadefoot in and around the Project site is unknown due to a lack of accurate surveying. Surveys for western spadefoot have not been conducted on the Project site since 2005. (DEIR at 4.4-45.) The DEIR defers surveys to future project proponents, when a qualified biologist must determine whether western spadefoot is present and take subsequent mitigation steps thereafter. (DEIR at 4.4-46.) Since western spadefoot is not covered under the PCCP, the DEIR should identify areas where western spadefoot is present, so that the scale of potential impacts and feasibility of mitigation, such as relocation, can be appropriately assessed by public and decisionmakers. Given the increasing development pressure on the area and the lack of suitable land for vernal pool restoration, a thorough analysis of potential impacts and suitable replacement habitat should be identified now, not at some later date.

In particular, surveys for western spadefoot should be conducted before the Project is considered for approval so that the extent of impacts can be accurately calculated before damaging land uses are locked in at the programmatic level. The DEIR runs through a list of potential indirect impacts to western spadefoot as a result of Project development, such as take related to traffic, landscaping and pesticide exposure. If left to a future project proponent, surveys and subsequent mitigation will be ineffective if habitat is on or near an area approved for residential or industrial uses that lead to take of western spadefoot.

Additionally, the DEIR fails to consider the impacts the night lighting on western spadefoot. Studies have shown that amphibians and reptiles can experience disrupted physiology, behavior and ecology when exposed to artificial light that interferes with natural lighting cycles. (Perry, 2008). As the Project proposes to urbanize the area, it will introduce numerous sources of artificial light. The DEIR must include updated survey information so that proper mitigation and planning can take place to minimize harm to western spadefoot.

B. The DEIR Fails to Identify and Assess Impacts to Vernal Pool Plant Species and Dependent Insect Species.

The specialized nature of vernal pool plant species require a specific range of habitat and resource conditions. The presence of a healthy population of pollinator insects is key to the survival of vernal pool plants; the loss of pollinators due to habitat fragmentation and upland habitat loss threatens the long-term viability of specialized vernal pool plant species. (USFWS, 2005). The DEIR identifies significant and unavoidable impacts to vernal pool plant species due to loss of vernal pool habitat but is silent on the impact the Project will have on the availability of pollinators in the area. Many pollinator species, such as solitary bees, specialize on flowering vernal pool taxa, such as *Downingia,* and do not disperse far from their food source. (Thorp, 1998). Since dwarf downingia is known to occur on the Project site, and is protected under CEQA (DEIR at 4.4-14), the DEIR must assess the impacts of the Project on the pollinator species upon which the plant depends.

The DEIR must also consider pollinator species in its mitigation measures intended to address the significant impacts to vernal pool plant species. As many vernal pool plant species rely on a narrow range of pollinator species, it is critical that a consideration of mitigation and/or restoration land include an assessment of habitat for pollinators. Additionally, mitigation for vernal pool and adjacent upland habitat destruction should include the removal and transport of resident pollinator species to the designated restoration site. (Thorp, 1998). It is critical that pollinator surveys be conducted for impacted vernal pool complex habitat, so that suitable off-site restoration areas can be identified. The suitability of such sites must consider available upland habitat for currently present pollinators, of the reestablishment of translocated pollinator species if no pollinators are present. The DEIR should be revised to include such analyses; any delay in these studies could result in mitigation opportunities becoming unavailable.

IV. Conclusion

Given the possibility that the Center will be required to pursue appropriate legal remedies in order to ensure enforcement of CEQA, we would like to remind the County of its duty to maintain and preserve all documents and communications that may constitute part of the "administrative record." As you may know, the administrative record encompasses any and all documents and communications which relate to any and all actions taken by the County with respect to the Project, and includes "pretty much everything that ever came near a proposed [project] or [] the agency's compliance with CEQA . . . ." (*County of Orange v. Superior Court* (2003) 113 Cal.App.4th 1, 8.) The administrative record further contains all correspondence, emails, and text messages sent to or received by the County's representatives or employees, which relate to the Project, including any correspondence, emails, and text messages sent between the County's representatives or employees and the project proponent's representatives or employees. Maintenance and preservation of the administrative record requires that, *inter alia*, the County (1) suspend all data destruction policies; and (2) preserve all relevant hardware unless an exact replica of each file is made.

Thank you for the opportunity to submit comments on the DEIR for the Sunset Area Plan/Placer Ranch Specific Plan. The DEIR highlights numerous significant and unavoidable environmental impacts, for which it fails to propose feasible mitigation. The Center strongly urges the County to reconsider such sweeping, intensive development on the Project site. Placer County should be protecting its rare and vulnerable ecological resources, instead of reviving a

decades-old development plan that would destroy countless acres of vernal pool, grassland and riparian habitat. In light of the foregoing analysis highlighting the DEIR's deficiencies and the unavoidable environmental impacts, the Project should not be approved in its current form.

Please add the Center to your notice list for all future updates to the Project and do not hesitate to contact the Center with any questions at the number or email listed below.

Sincerely,

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References
(Attached on CD)

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Citizen-Initiated Smart Growth Plan

Alliance for Environmental Leadership

Prepared by:

Genevieve Marsh
AGILE ARCHITECTURE

Phase 1

January 2019

Alliance for Environmental Leadership

AEL brings together existing like-minded organizations and citizens for a common cause: defending natural ecosystems and advocating for sustainable, inclusive communities in Placer and Nevada Counties.

Thank You

The collaborations of many organizations and individuals made this project possible. We need diversity of thought and resilience in this world to face new challenger. Thank you to our funders, organizers, citizen scientists, cheer leaders, planners and visionaries for enacting the change the they wish to see in the world.

Prepared By:
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Save Auburn Ravine Steelhead and Salmon
El Don Neighborhood Advisory Committee
Community Environmental Alliance
Auburn Area Democratic Club

Grants
Rose Foundation for Communities and the Environment
Sierra Foothill Audubon Society

Dear Community,

The Sunset Area (SA) is a highly dynamic site. The earth expands and contracts annually and forms vernal pools, the unique edge conditions are shared with different neighbors, and the acreage enables unique solutions for the regional job center. With so many dynamics, understanding and working with the site is critical and complex. In this day and age, we as planners and designers are becoming more scientific, collaborating and learning from consultants and incorporating research and data into the decision making process. The natural sciences, social theory, and economics, to name a few, are at our fingertips. The capability to simulate and analyze effects of change is also new. Now science supported design is expected.

Placer County has yet to explore the full range of possibilities for the SA within their own conceptual framework. The Sunset Area Plan (SAP) unfortunately considers three projects as an inseparable unit, while failing to consider better suited locations for the university or checking their design against their own objectives. The SA has long been established as a place reserved for industry and agriculture that suburban sprawl could not transgress. The impending donation of the university land by the Placer Ranch developer has been too shiny for a few politicians to resist, who personally value getting the donation at the expense of the health and wellbeing of thousands of families. To make this happen, jurisdictional lines have been moved and tax payers have funded the upfront planning work for the developer's design, to date at the cost of $5 million.

The Citizen-Initiated Smart Growth Plan (CISGP) seeks to diversify the conversation and right these wrongs. In this Phase 1 report, we have explored the region's collective vision, brought the site to life with the seasonal changes of the natural systems in the prairie, and worked diligently to respect the community and the land. The resulting zoning plan enhances the County's regional job center vision by providing comparable employment and business opportunity. It also sets straight the job-house balance, enables public transit, and improves quality of life and character of place. It embraces the natural features of the SA and enhances or protects them based on scientific review. It incorporates equity from the core, through quality locations for all housing choices, mixed use neighborhoods, and sustainable design standards that apply equally to blue and white collar working conditions. We have found that when we set out to grow smarter, many benefits arise from each element having various functions. For example, the higher density mixed use areas create walkable communities, have the ridership to support quality public transit, reduce household operating costs, and share public amenities across more people enabling them to be of higher quality.

The Phase 1 of the CISGP is intended to lead by example, to show rather than tell the public the thought process behind planning. It engages the reader in a critical discourse through literally illustrating the various considerations and by providing crucial excerpts of other documents within its own pages. It is designed as a useful tool for quickly getting up to speed on the SA, assisting well-informed commenting on the SAP DEIR, and bringing to the table a constructive conversation about what should be.

Phase 2 and 3 will continue to bring depth to this planning vision and layer in greater levels of refinement. As the citizen's plan, Phase 1 inevitably becomes a sounding board for further ideas, a welcome collaboration for the next phases to record.

With warm regards and a resilient heart,
Genevieve Marsh

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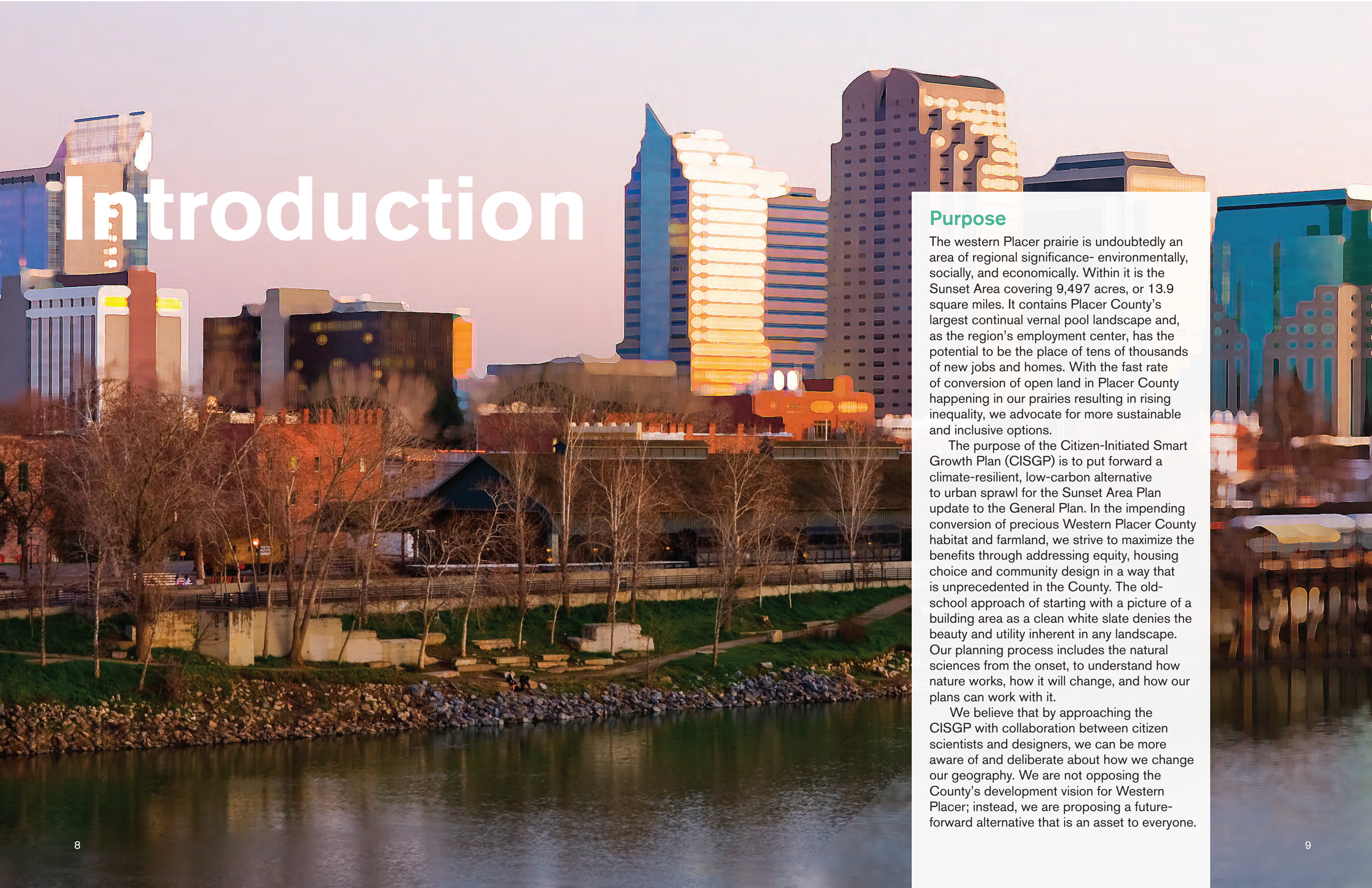
Acronyms

AEL	Alliance for Environmental Leadership
CISGP	Citizen Initiated Smart Growth Plan (The document you are reading)
SA	Sunset Area (the planning area)
SAP	Sunset Area Plan (Placer County's zoning and development guidelines plan for the site)
SIA	Sunset Industrial Area (name for the existing plan for the SA)
PR	Placer Ranch (Development within the SAP)
PRSP	Placer Ranch Specific Plan (De tailed development plan for a large part of the SA.)
PCCP	Placer County Conservation Plan (off-site mitigation that forms a Conservation belt in Placer County; currently in development.)
DEIR	Draft Environmental Impact Report (Evaluates the environmental impact of the SAP and PRSP.)
HDIMU	High Density Industrial Mixed Use
PP	Placer Parkway (Proposed express way between highway 95 and state route 99.)
BRT	Bus Rapid Transit
WRSL	Western Regional Sanitary Landfill (The landfill in the middle of the SA.)
GHG	Greenhouse Gas
FAR	Floor Area Ratio (Percentage of a parcel's area allowed to be made indoor floorspace. Used to establish density rules.)
HH	Household

Introduction



Purpose

The western Placer prairie is undoubtedly an area of regional significance- environmentally, socially, and economically. Within it is the Sunset Area covering 9,497 acres, or 13.9 square miles. It contains Placer County's largest continual vernal pool landscape and, as the region's employment center, has the potential to be the place of tens of thousands of new jobs and homes. With the fast rate of conversion of open land in Placer County happening in our prairies resulting in rising inequality, we advocate for more sustainable and inclusive options.

The purpose of the Citizen-Initiated Smart Growth Plan (CISGP) is to put forward a climate-resilient, low-carbon alternative to urban sprawl for the Sunset Area Plan update to the General Plan. In the impending conversion of precious Western Placer County habitat and farmland, we strive to maximize the benefits through addressing equity, housing choice and community design in a way that is unprecedented in the County. The old-school approach of starting with a picture of a building area as a clean white slate denies the beauty and utility inherent in any landscape. Our planning process includes the natural sciences from the onset, to understand how nature works, how it will change, and how our plans can work with it.

We believe that by approaching the CISGP with collaboration between citizen scientists and designers, we can be more aware of and deliberate about how we change our geography. We are not opposing the County's development vision for Western Placer; instead, we are proposing a future-forward alternative that is an asset to everyone.

Vision

Update the framework for the western Placer regional job center to establish an innovation ecosystem. Support high-quality employment, collaboration, distinct quality of place, and vibrant walkable communities.

Opportunities

Lead by Example
Set an example for smart growth development in Placer thought General Plan policy recommendations, the CISGP planning process, and specifications.

Demographics
Millennials will be the dominant generation in the workforce when the SA is project to be built out. Incorporate workforce demographic research to enhance area attractiveness.

Technological Advancement
With rapid changes to design, technology and business, include technology and trends already on the rise that will be the norm in Placer County in next two decades.

Large Undeveloped Parcels
Specify quality design and performance from the onset, instead of band-aid fixes later.

National Spotlight
Position Placer County as a leader nationally with synergistic employment ecosystem concept and CISGP planning process.

Regional Housing Balance
Balance the scale of Placer's affordable and achievable housing options so the ratios better reflect Placer County residents. Incorporate equity by design to make desirable living places for all income levels.

Kick Start Public Transit
Be a driver to start serious public transit in Placer County through designing in the density and infrastructure to support it.

Geodesign
Collaborate with the natural sciences from the beginning to create a plan that is climate resilient, while preserving the quality of life factors and basic needs nature provides.

Conservation
Use the Sunset Area as a pilot project for how to utilize the PCCP. Balance regional and local conservation.

Objectives

Diverse Opportunities for Industrial Innovation
Transition to a more high-employee density, labor-intensive mix of uses with an emphasis on goods and services focused on innovation and creativity. Make the area attractive for companies at all stages of business development. Broaden the range of development opportunities in the Sunset Area, by supporting small and large scale development and placing it symbiotically with neighborhoods and the university.

Mixed Use Compact Development
Develop mixed use compact development to provide a high quality of life through increasing social opportunities, reducing commute times, and encouraging walking, biking and transit use. Create the framework for the area to develop into a transit-oriented development.

Housing Choice
Support the provision of attractive and under represented housing types locally to accommodate employees of Sunset Area businesses and make a synergistic atmosphere. Integrate housing into mixed use areas to prevent housing islands.

High-Quality Design and Amenities
Utilize demand trends and changing markets to make wise projections about the design requirements of future occupants. Create a sense of place that incorporates the beauty of the prairie with an industrial-modern campus feel. Establish and maintain high-quality standards for sustainable design and construction.

Enhance Existing Assets
Promote infill and redevelopment that already have access to existing public sewer and water. Prepare for conversion of open space by design large-scale systems for managing water, energy, and waste to increase efficiency and environmental health. Make edges conditions compatible with neighboring jurisdictions.

Maintain Natural Resource Value
Balance regional and local conservation. Create zoning designations for open space and agricultural land that promote their multiple functions. Maximize conservation benefits by generating income for the PCCP and protecting it's territory in the SAP.

Retention of Unique Land Supply
Retain the large supply of large development sites in the Sunset Area by discouraging subdivisions that diminish long-term value and foreclose unique development opportunities. Preserve the viability of industrial and large-scale manufacturing operations.

Protection from Incompatible Uses
Protect existing and future development and populations from adverse impacts associated with incompatible uses. Maintain the landfill buffer zone.

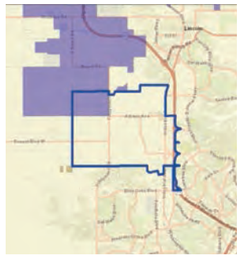
Education and Outreach
Share the benefits of compact mixed use development and the CISGP planning process with citizens, elected officials, and developers.

Monitoring
Establish an ongoing monitoring system to evaluate polices during development and determine if strategies are meeting objectives.

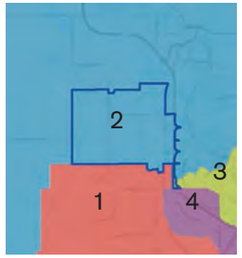
Today

A 2018 satellite view of the West Placer Region reveals suburban development spreading from highway 65 and interstate 80 into the farmlands of unincorporated Placer County. The towns of Roseville, Rocklin and Lincoln share boarders with the Sunset Area (outlined in white). In the below governance jurisdictions, the main authority is Robert Weygandt, District 2 Supervisor. Lincoln has a small area of influence in the North-west corner.

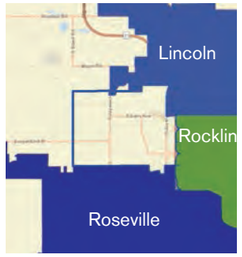
Municipal Advisory Council
Rural Lincoln MAC



Sphere of Influence
City of Lincoln



Board of Supervisors
District 2: Robert Weygandt



City Limits
None

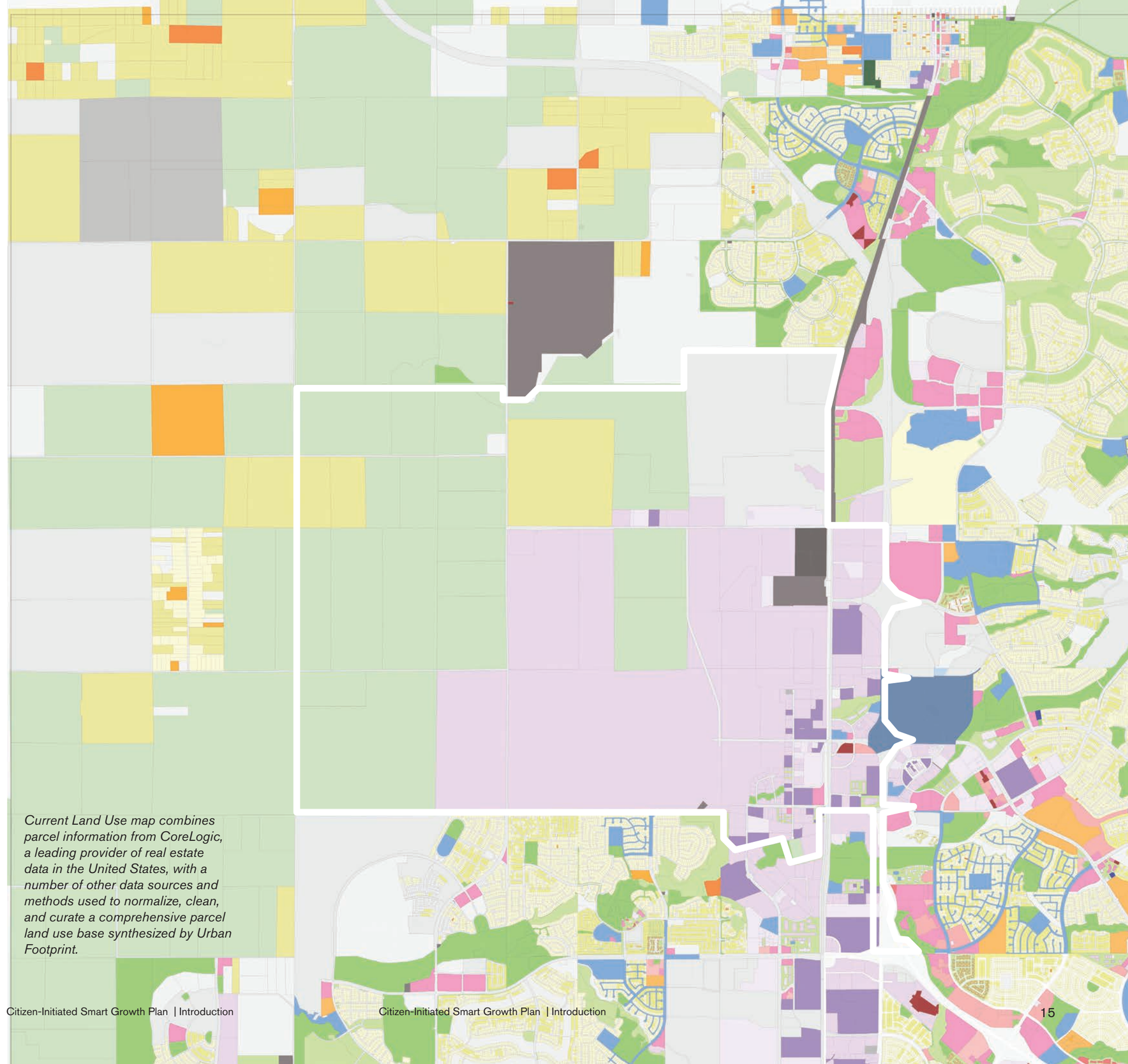
Current Land Use

This map shows the current parcel uses regardless of zoning. The extents include a two mile radius around the Sunset Area. Many parcels have yet to break ground, creating many greenfield parcels in existing development areas. These parcels are infill opportunities that could increase density. The current low density development in West Placer creates car dependence and discourages public transit expansion and walkable communities.

Zoning is highly segregated between residential areas and workplaces. Commercial is aggregated in large shopping areas accessible by car. Mixed use zoning is minimal and housing diversity is dominated by a spectrum of single family homes on various size lots.

Legend

- Garden Apartment
- Religious Center
- Residential Common Area
- Rural Employment
- Rural Ranchette Lot SF Detached
- Rural Residential Lot SF Detached
- Small Lot SF Detached
- Suburban Multifamily
- Suburban Townhome
- Town Civic Complex
- Urban High School
- Vacant
- Vacant Residential Lot
- Very Small Lot SF Detached
- Warehouse High
- Warehouse Low
- Hotel Low
- Industrial High
- Industrial Low
- Natural
- Water
- Blank Data
- Campus/College High
- Cemetery
- Commercial Recreation Facility
- Commercial Storage
- Communications Facility
- Daycare
- Duplex
- Estate Lot SF Detached
- Golf Course
- Hospital
- Large Format Standalone Commercial
- Large Lot SF Detached
- Low Intensity Strip Commercial
- Low-Rise Office
- Main Street Commercial Low
- Medium Intensity Strip Commercial
- Medium Lot SF Detached
- Military
- Mobile Home Park
- Office Park High
- Non-Urban Elementary School
- Non-Urban High School
- Non-Urban Middle School
- Office Park Low
- Open Space
- Park
- Parking Structure
- Parking Surface Lot



Current Land Use map combines parcel information from CoreLogic, a leading provider of real estate data in the United States, with a number of other data sources and methods used to normalize, clean, and curate a comprehensive parcel land use base synthesized by Urban Footprint.

Tomorrow

This map combines the future vision of relevant planning jurisdictions, excluding the SAP Update:

Placer County General Plan (current)
Placer County Conservation Plan (proposed)
City of Roseville General Plan 2035 (2010)
City of Lincoln General Plan (2012)
City of Rocklin Existing General Plan (2014)

Each map has a different time horizon and a level of detail, making this map best for general deductions.

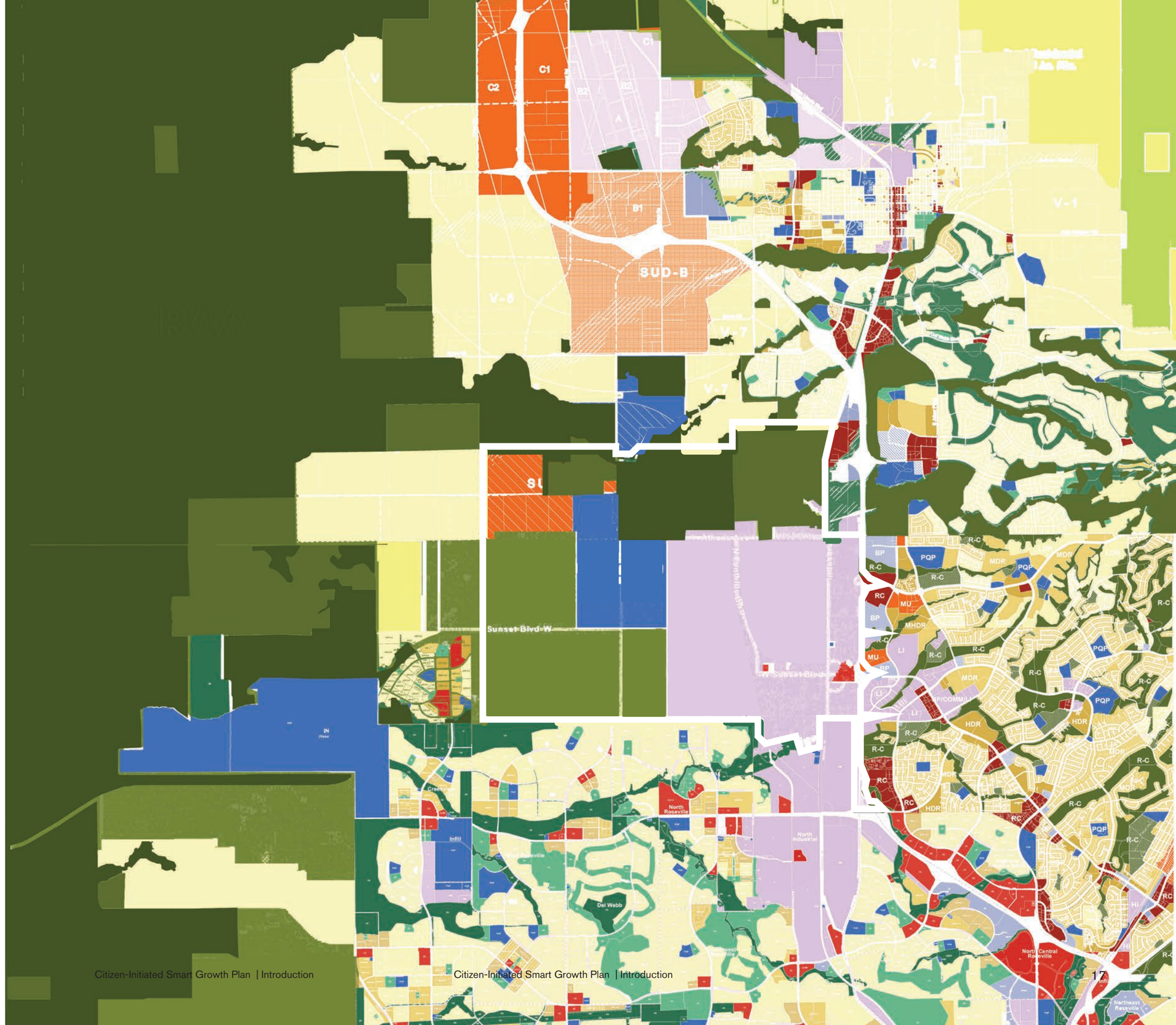
The dominant land use types are low density residential and conservation. These border each other where the farms buffer is gone.

Along highway 65, industrial zones blend across the borders of Lincoln, SA, and Roseville, creating a large industrial expanse. The north band of reserves act as a buffer that separates Lincoln's future residential areas from the landfill and preserve the landfill one mile buffer.

To the south, Roseville's residential area is built right up the landfill buffer. Roseville will expand development north along the western edge of the SA. A large regional water treatment plant will process runoff from the new developments.

Legend

- Agriculture/Timberland 10 Ac. Min.
- Agriculture/Timberland 20 Ac. Min.
- Agriculture/Timberland 40 Ac. Min.
- Agriculture/Timberland 80 Ac. Min.
- Conservation
- Reserve Acquisition Area
- Commercial
- Industiral
- Rural Residential
- Low Density Resiental (0.1-5 DU/acre)
- Medium Density Residential (5.1-7.0 DU/acre)
- High Density Residential (10.1+)
- Mixed-Use
- Open Space
- Professional Office
- Public
- Recreation
- Resort/Recreation



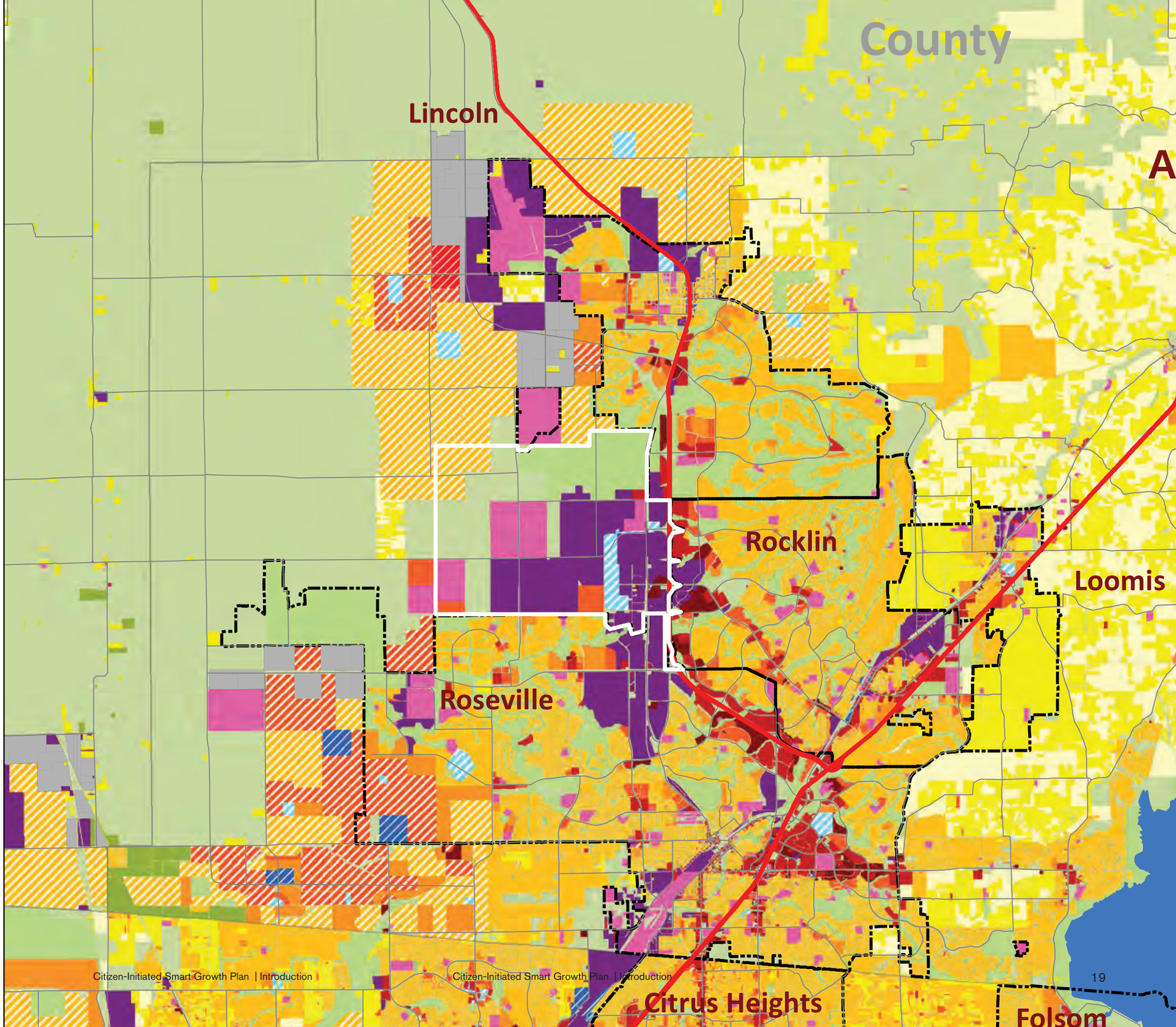
SACOG Regional Blueprint

This regional blueprint is a smart growth vision for the greater Sacramento area adopted by the Sacramento Area Council of Governments Board of Directors in 2004. The spirit of the Blueprint is to integrate land use and transportation planning to curb sprawl, cut down on vehicle emission and congestion in order to improve the quality of life for residents of the Greater Sacramento Region. It accomplishes this by implementing smart growth principles that encourage a variety of housing options closer to employment, shopping, and entertainment hubs, which gives options for people to walk, bike, or take public transportation to work and play.

For the SA, it encourages industrial in the south-east with a low density mixed use zone. A large amount of the site remains open space and residential encroaches from the north and south. Since 2004, SACOG has tracked development in relation to the blueprint and created preferred build out scenarios. Single family small lot residential has been building out to capacity at an unanticipatedly fast rate.

Legend

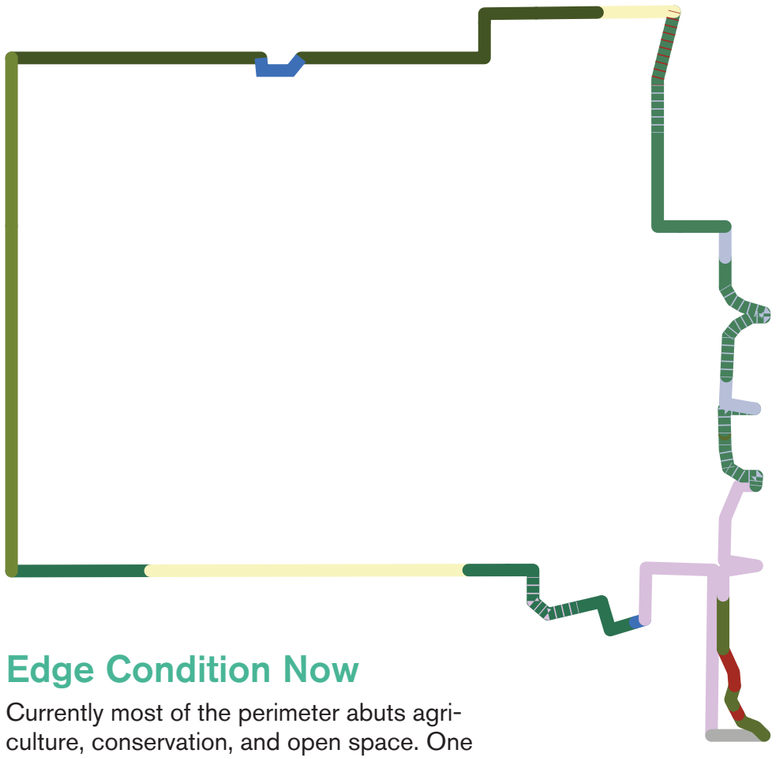
- Retail
- Office
- Industrial
- Public
- Rural Residential
- Single Family Large Lot
- Single Family Small Lot
- Attached Residential
- Agriculture
- Forest
- Open Space
- Parks
- Water
- Future Growth Area
- Vacant Rural Residential
- Medium Density Mixed Residential
- High Density Mixed Residential
- Low Density MU Center/Corridor
- Medium Density MU Center/Corridor
- High Density MU Center/Corridor
- Mixed Use Employment Focus



Citizen-Initiated Smart Growth Plan | Introduction

Comparison

As the Sunset Area touches three city jurisdictions, the edge condition must be considered so uses can appropriately blend across boarders.

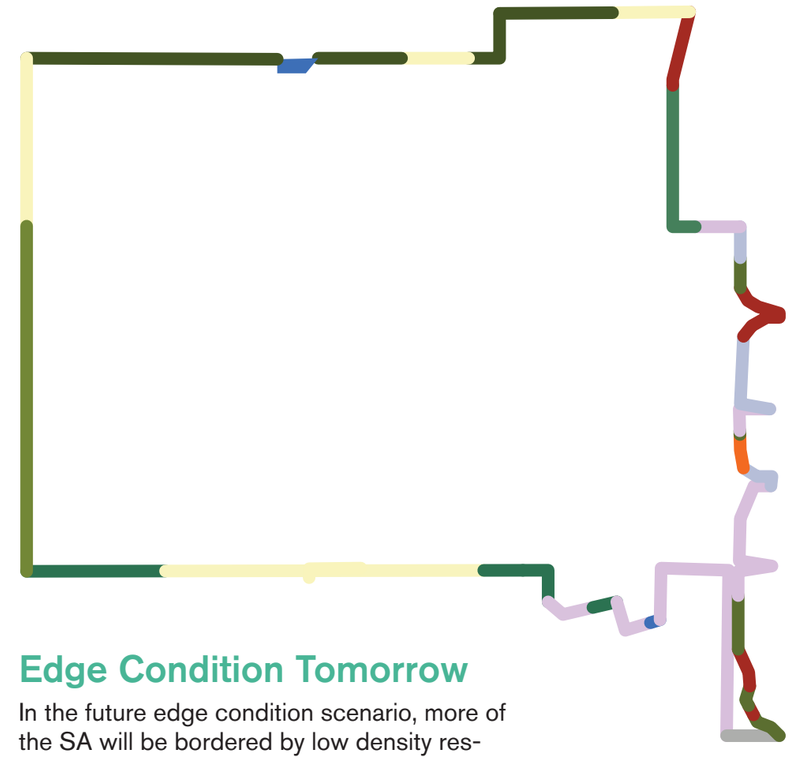


Edge Condition Now

Currently most of the perimeter abuts agriculture, conservation, and open space. One of Roseville's low density residential areas is built out along the south border. Roseville has the least amount of available growth along the edge, confined to a small industrial area.

Rocklin to the east has yet to build out the properties along highway 65, leaving approximately half their border in an open space condition. This edge is interspersed with a few small conservation areas along streams.

Lincoln's edge is dominated by agriculture use, except for their wastewater treatment plant. A residential community abuts the north east corner. The western boarder, which meets the Placer County General Plan, is currently entirely large agricultural land uses.



Edge Condition Tomorrow

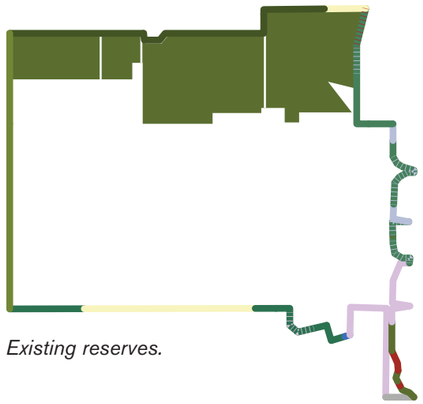
In the future edge condition scenario, more of the SA will be bordered by low density residential. Lincoln will expand their residential villages across the north border and down the western edge.

Roseville will have built out their light industrial area along the southeast corner and expand north along the western edge. Rocklin will have populated the edge of hwy 65 with a mix of professional office, commercial and industrial uses, in a similar approach to Roseville's stretch of highway 65.

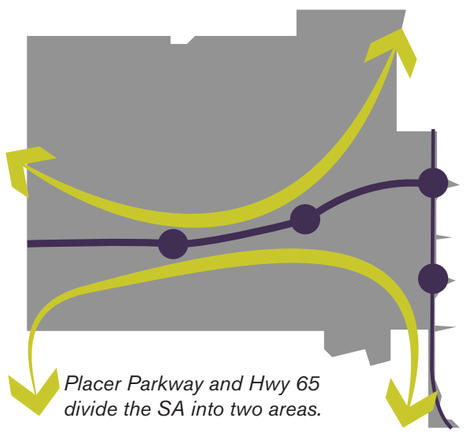
The PCCP establishes an urban growth boundary one mile west of the SA and reinforces the existing reserves in the north SA by including them in it's habitat corridor network.

Constraints

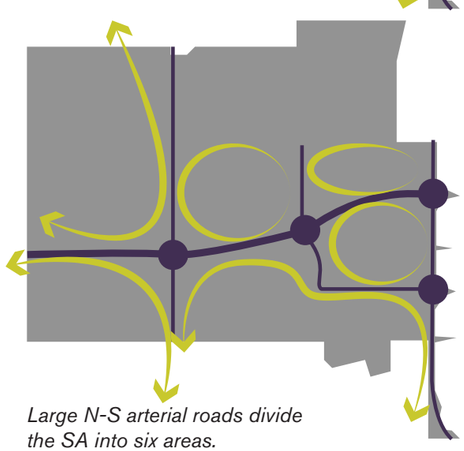
Project constraints identity natural and man-made borders that shape distinct senses of place, and in some cases act as barriers.



Existing reserves.



Placer Parkway and Hwy 65 divide the SA into two areas.



Large N-S arterial roads divide the SA into six areas.

Existing Conservation

The four conservation areas along the north edge of the site separate the SA from Lincoln. These reserves are mitigation banks and three of them are anticipated to be in the PCCP. Recreation and through traffic is not aloud.

As a result, uses along the northern half of the SA will remain isolated from Lincoln. The sensitive habitat of the conservation areas will require safeguards to prevent contaminated by development along its edge.

Major Roadways

While major roadways provide high capacity regional access to an area, their great width and few crossings create community edges. These can be limiting barriers to pedestrians and cyclists. For drivers, they foster a psychological response of a change of place.
As a result, Placer Parkway will create a strong divide amidst the north SA and the south. It's width and few crossings will discourage dissemination across the line. As a result, community nodes that seek to span the parkway, will likely be unsuccessful. Instead, design self sufficient districts.

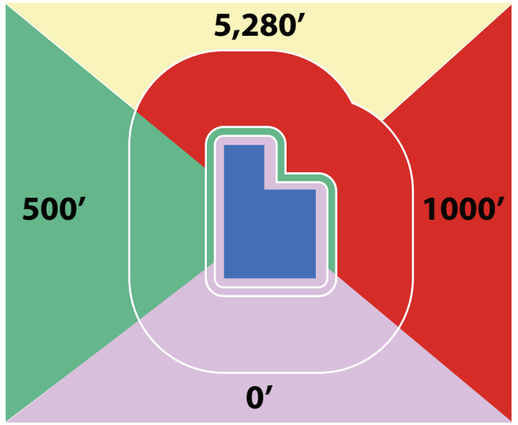
Connectivity

Highway 65 and Placer Parkway will be the main access points in and out of the SA. In terms of local road access, Lincoln has the most connected roads into the SA. They approach the north of the site from west, north and east. These roads reach out to far spread areas of Lincoln and unincorporated Placer County.

Roseville currently has two entry roads on the south border, with groundwork constructed for potentially five more. Seven of their eight possible roads approach from the south and connect the residential developments to interstate 80 further south.

Rocklin currently has one access point with one other possible. Rocklin is divided from the SA by highway 65 and overpasses are the only means of entry. This limits local diffusion from one side to the other as a result of poor pedestrian and public transit access.

Considered collectively, the south edge and Roseville has the most potential for local community continuity. The east edge will mostly serve highway 65. The north edge condition of far spaced access points will make the SIA more of a destination to people in Lincoln and unincorporated Placer County. The west edge will primarily be entered through Placer Parkway with low volume local access.



Landfill buffer zoning constraints.

Western Regional Sanitary Landfill Buffers

The landfill buffer zone includes most of SA, including the majority of PR. This is a major constraint, as it effects allowable land uses. It protects both the future operation of WRSL and the health and comfort of people. The CISGP will respect the buffer and not put residences or schools in within the buffer zone. Placer Ranch seeks a variance to the buffer to put 5,827 of homes, an elementary school, a middle school, and a university within the mile buffer.

General Plan on Landfills

4.G.11. When considering land use changes in the vicinity of a landfill operation, the County shall consider the landfill as the dominant land use in the area. In order to protect these facilities from incompatible encroachment, new residential land uses shall be separated from the property lines of active and future landfill sites by a buffer of one mile. Such buffers do not apply to closed landfills or solid waste transfer stations. Other uses will be required to provide buffers as described in Table 1-5. The intent of this policy is to prohibit the creation of new parcels for residential use within one mile of the landfill; not to prohibit construction of a residence on an existing legal building site within this area.

4.G.6. The County shall ensure that landfills and transfer stations are buffered from incompatible development.

1.B.4. The County shall ensure that residential land uses are separated and buffered from such major facilities as landfills, airports, and sewage treatment plants.

TABLE 1-5

MINIMUM PUBLIC FACILITY BUFFER ZONE WIDTH

Type of Public Facility	Minimum Buffer Zone Width (feet) by Land Use Designation			
	Residential	Commercial	Industrial	Recreation
Airport [1]	2,000	1,000 [2]	0	0 - 500 [3]
Sewage treatment plant	1,000	1,000	0 - 500 [4]	1,000
Solid waste transfer station	500	0	0	500
Solid waste disposal site	5,280 [5]	1,000	0	500

[1] *See also comprehensive land use plans (CLUPs) for airports.*

[2] *Buffer required for non-airport related commercial uses only.*

[3] *No separation necessary for expansive, low-population outdoor recreation facilities such as golf courses; 500 feet for places of public assembly, outside of aircraft overflight areas.*

[4] *No separation necessary for warehousing uses with a low employee-per-square foot ratio; 500 feet required for manufacturing facilities and business parks.*

[5] *Policy 4.G.11 protects landfill facilities from future residential encroachment by requiring a residential buffer of one mile measured from the property line of an active or future landfill site.*

All Together

These constraints shape the objectives in the following ways:

Diverse Opportunities for Industrial Innovation: Industrial uses are aloud on all areas of the site except for the conservation zone. The constraints naturally form different areas for various industrial intensities, the lest intense being in the free choice area and the most intense being around the landfill.

Mixed Use Compact Development: Mixed use is only possible in the free choice areas. The largest of the free choice areas has the most potential to be a mixed use community.

Housing Choice: Housing is only aloud in the free choice area and should be incorporated within mixed use communities. As such, housing will be concentrated in the largest free choice area.

Enhance Existing Assets: Enhance the landfill, conservation area, and the existing building stock.

Maintain Natural Resource Value: Potential for intense industrial uses line the conservation area. Safeguards must be put in place to prevent contamination.

Retention of Unique Land Supply: Large industrial parcels should be preserved within the landfill buffer zone, while subdivision should be allowed in the mix use zone.

Protection from Incompatible Uses: Distinct areas gradually transition from intense industrial uses to residential in the south and south east.

Access

Different types of zoning have different access needs and modes of transportation. The off ramps from Hwy 65 and Placer Parkway correspond with three different locations in relation to the buffer zone. Two for the free choice area, one for the commercial/industrial zone, and the other for the landfill/industrial zone.

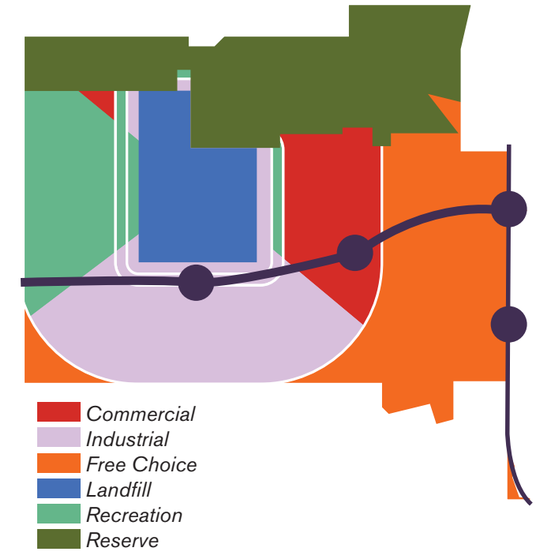


Diagram showing constraints overlaid.

Smart Growth Plan

Superstructure of the Sunset Area Economic Ecosystem

Growing smarter means encouraging development on vacant or underused land, redeveloping derelict properties, rehabilitate industrial "brownfield" sites, and adapting and reusing our old and historic structures. Doing so not only strengthens our existing communities, but also helps us to care for our natural environment and preserve it for future generations.

The location of a project within a region is critical because even projects designed to be compact and walkable can have unwanted impacts on transportation systems and natural areas if they are dependent on overburdened roads, or are disconnected from the transit system, or require unnecessary destruction of irreplaceable farms or forests.

This section lays out the CISGP zoning plan and how the different districts work together to achieve the project objectives. Topics include:

- 21st Century Industry
- Zoning Designations
- Exclusive Comparison
- Comparison in Context

CISGP Zoning

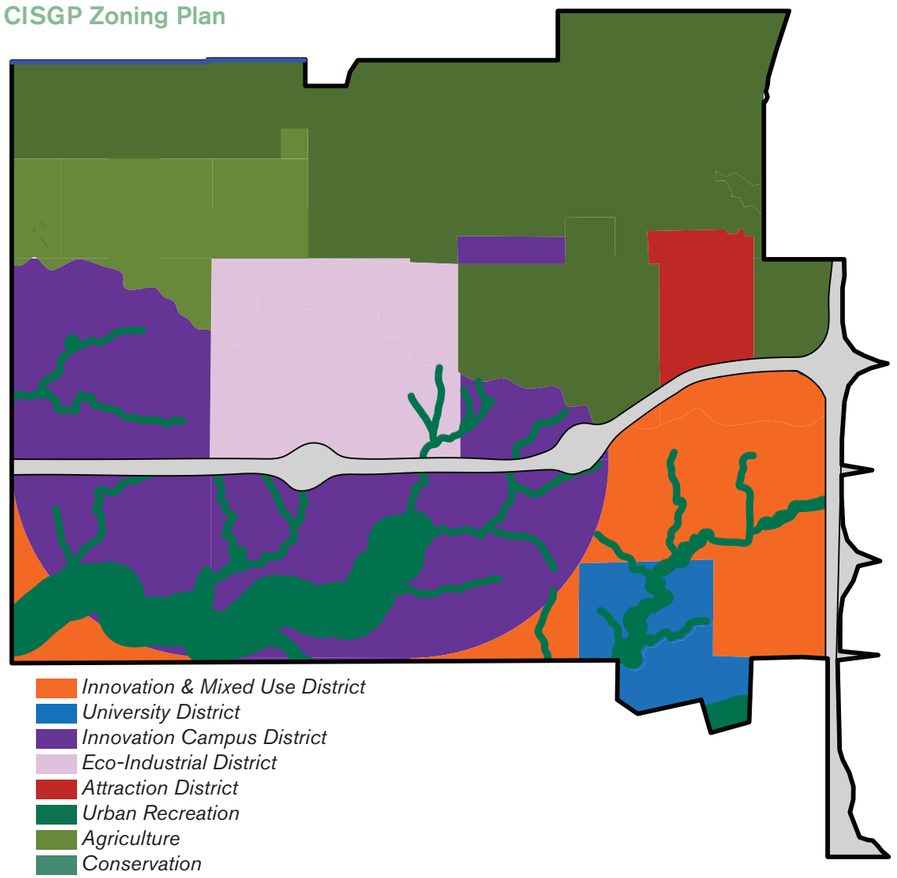
The CISGP includes eight different zoning types and four sub-types. Three of the zoning types layout the spectrum of industrial use from innovation and mixed use to eco-industrial at the landfill. Industrial is the most flexible zoning for an innovation ecosystem because it allows for the fill product development cycle. From office work to prototyping, to manufacturing and warehousing, to shipping, industrial zoning accommodates it all. As a result, businesses can scale in place.

A university district and an attraction district form unique areas within the larger whole. Natural areas are given three different designations to accommodate various uses: Urban Recreation, agriculture, and conservation. The Innovation and Mixed-Use district includes four sub-zones: Town Center, High Density Industrial Mixed Use, Office and R&D, and Office Industrial.

21st Century Industry

Industrial facilities are important in the global marketplace and impact every facet of our daily lives. Virtually everything you touch and use all day was manufactured, stored and transported before it came to you. Industrial facilities enable all of this to happen and are a significant economic driver. Manufacturing contributes $2.1 trillion to the U.S.'s GDP. It employs 12.33 million manufacturing workers and supports an 18.5 million jobs- about one in six private-sector jobs (National Association of Manufacturers).

CISGP Zoning Plan



Exon Mobil Corporate Campus in Spring, TX, designed by Gensler and PDR and built by Harvey Construction, covers 385-acres and opened in 2015. Image from PDR , https://workdesign.com/2016/05/new-corporate-campus/

The CISGP includes three different zoning types related to industrial use: light industry in the innovation and mixed use zone, large industrial campuses in the industrial zone, and an eco-industrial zone that is symbiotic with the landfill. The design of facilities in these zones has evolved over time and the SA zoning policies must reflect that. This excerpt written by Drew Patton summarizes the sector's state today:[1]

"Decades ago, the sprawling suburban campus was the corporate office solution — think classic campuses like Connecticut General outside of Hartford and the Texaco campus in Rye, N.Y. Today, a new corporate real estate model, influenced by the combined history of corporate campuses and leased office space, has emerged to better meet the needs of global corporations and their changing workforce. As companies centralize their employees, we are seeing a renewed commitment to real estate ownership and investment in campuses. If a company employs 50, 100, or even 200 employees, leasing space in a landlord-owned building will likely provide the most economical, flexible solution. However, companies that are looking to centralize thousands of employees and make a 20- 30- 40- 50-year real estate investment will make different decisions about property location and ownership.

"Suburban campuses appeal to corporations for three key reasons. First, the abundance of affordable land in suburban locations allows them to buy it up, develop some of it, and reserve the rest for future needs. Second, suburban campuses provide easy access to

1 Patton, Drew. "The New Corporate Campus." Work Design Magazine, 24 May 2016, workdesign.com/2016/05/new-corporate-campus/.

Method Manufacturing Facility: The South Side Soapbox in Chicago, Illinois. Image from: Patsy Mcenroe Photography, 2015. http://www.mcdonoughpartners.com/projects/method-home/

nearby, affordable housing for employees. This proximity enables companies to locate the workplace closer to employees' homes, a priority that has existed for over 50 years. Finally, developing a campus in a suburban location provides a company with the ability to significantly impact the development of surrounding infrastructure, resulting in a competitive advantage.

"There are three realms of work that a well-designed campus amplifies: the urban vibe, the collegiate atmosphere, and the walk in the woods. The urban vibe can be understood as the energy and the urgency of working in an urban setting in close proximity to colleagues. A lot of people have to get their work done today or in the next 10 minutes. A sense of urgency is achieved with density; even if you can see the trees and the skyline or walk outside, you are located nearby your peers. The urban vibe is the highest impact realm of work for researchers and companies with long-term goals in mind.

"The second realm is the collegiate atmosphere: a walkable, pedestrian-friendly campus. Today's leading corporate campuses have their employees park their cars outside the campus. The campus is pedestrian-oriented — inside or outside, elevated or on the ground, and builds the sense of a college. The collegiate atmosphere is also achieved using scale: 90 feet across from building to building, with buildings six and seven stories tall so that employees can identify the person they see across the way. Visibility is key to the collegiate scale — all views are short enough that you can actually identify someone walking toward you.

"The third realm is the walk in the woods: truly, woods to walk in, a soccer field, or a swimming pool. Outdoor spaces nurture the authentic roots of a company and support the people."

Innovation & Mixed Use District

The Innovation & Mixed Use District is the heart of the overarching employment center concept in the SA, hosting a live-work campus style community for employees and entrepreneurs at companies at various stages of the business life cycle. It is symbiotically located next to the Innovation Campus District and the University District to encourage idea dissemination and fast pedestrian access. It has four sub-zonings: Town Center, High Density Industrial Mixed Use, Office and R&D, and Office Industrial.

The Urban Recreation network is the focal point and primary pedestrian thoroughfare providing opportunities for a spectrum of outdoor uses from urban lawn to riparian walks and programmable edges. It provides the 'walk in the woods' design requirement.

At the time of build-out, millennials (already aged 22-39) will be the largest generation in the workforce. This is the demographic that will need to be attracted to locate their businesses in the Sunset Area and who will need to like the area enough to work for companies based there. The other demographic are the boomers, who are looking for downsizing options with high quality social life. They are less interested in the acquiring possessions and are more interested in seeking experiences.

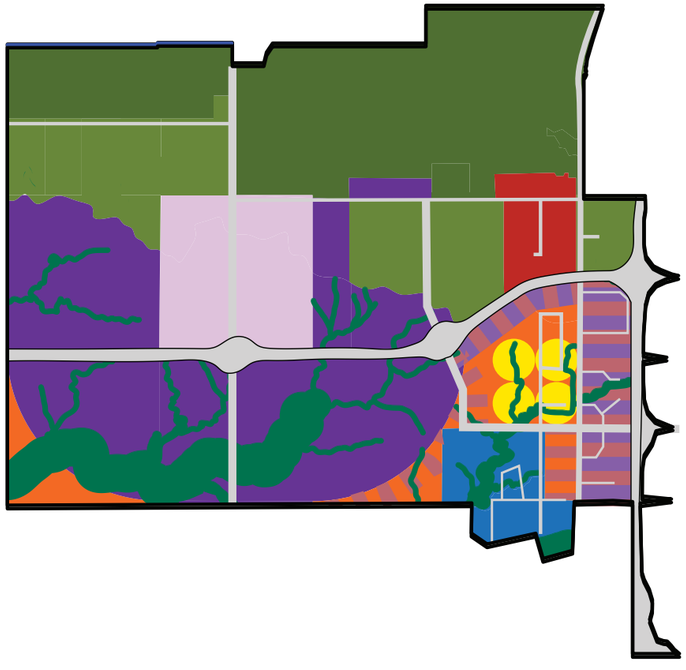
Town Centers

Adjacent to the Urban Recreation network are quarter-mile mixed-use town centers. A quarter mile is the distance people are willing to walk to access amenities and transit stops. It is also the radius of pre-automobile towns. Town centers include shops, restaurants, professional offices, dwellings and other community amenities in a high density mix. This layout prioritizes access instead of space per person, a highly desirable trait for two significant and dominant demographics.

The town center is the ideal zone for schools and public facilities that service the local community. It ensures that all residents in the eastern Innovation and Mixed Use District can access the establishments within a 15 minute walk, as the crow flies.

Detailed Zoning Diagram

Innovation & Mixed Use District:
- *Town Centers*
- *High Density Industrial Mixed Use*
- *Office and R&D*
- *Office Industrial*
- *University District*
- *Innovation Campus District*
- *Eco-Industrial District*
- *Attraction District*
- *Urban Recreation*
- *Agriculture*
- *Conservation*



Industrial Modern Facility. Image from: KTC-External Elevation by PGDesigns.co.uk, http://www.flickr.com …pgdesignscouk/8116108980/

High Density Industrial Mixed Use

Surrounding the town centers light industrial uses enter the mix. The high density industrial mixed use district (HDIMU) has high employment-density industrial with office and residential mixed in. It is composed of low-rise office buildings, high density office parks and warehouses. Housing options include mid-rise residential, standard and suburban multifamily podiums, and some suburban townhomes.

Office and R&D

Surrounding the HDIMU is the Office and R&D area. A higher percentage of industry enters the use mix. It is composed of low density office parks, warehouses, low and medium intensity commercial strips. Housing includes standard multifamily podiums.

Office Industrial

Along the perimeter of the Innovation Mixed Use District the Office Industrial designation lines the highways. It is the farthest away from the town center and houses the industrial uses with that employ less people per square foot. It includes office parks, high density industrial, warehouses, and medium intensity commercial strips.

The district has large lots for industrial uses, such as light manufacturing, research and development labs, and warehouses that support large established businesses. It also has smaller lots and a variety of existing building sizes for smaller companies seeking adaptive reuse or new construction.

When multiple building types coexist within a neighborhood, physical and social mono cultures are avoided and the neighborhood can naturally evolve in use, which decreases the likelihood of demolition.

The Edison at Gordon Square multifamily podium apartments create a modern-industrial look with zigzagging roof lines,colorful facades, the retaining the water tower. Image from: NRP Group, https://www.multifamilyexecutive.com/design-development/class-a-cleveland-mid-rise-eschews-high-density-hits-several-price-points_o

Buildings Types: Light Industry

Consists of manufacturing buildings, warehouses and distribution centers. Manufacturing buildings are industrial facilities that house machines and tools to produce goods for use or sale. Business activities in manufacturing buildings may range from handicraft to high tech. Today, most manufacturing facilities are involved in industrial production through which raw materials are transformed into finished goods on a large scale. Warehouses and distribution centers are buildings that store goods, manufactured products, merchandise, raw materials, or personal belongings, such as self-storage centers.

Building Types: Residential

The various residential options permitted in this zone are compatible with the high density design and community-experience centric approach. Acceptable residential building type include mid-rise residential apartments/condos/lofts, garden apartments, multifamily podiums with commercial below, cohousing, suburban multifamily, live-work, urban townhomes and suburban townhomes.

To guide the formation of the Innovation and Mixed Use District community, individual projects within the district should be located so that 50% of its dwelling units are within a quarter mile walking distance of the number of supporting uses. Projects with no dwelling uses should be positioned within quarter mile of dwelling units. Sufficient supporting uses must be in place by the time of 50% occupancy of total building floor area (exclusive of portions of parking structures devoted to parking).

Innovation Campus District

The Innovation Campus District is for large industrial campuses looking to invest in new facilities. These businesses will likely have more than 200 employees and will be looking to invest in long term use of the site. To encourage this, sustainable design is required to be certified through a highly rated national building rating standard program. With direct access to Placer Parkway, these major employers will have easy access to the regional road network. Campuses may to have supporting commercial uses that provide amenities to work life as well as retail showrooms for their products. Located within the landfill odor zone, the Innovation Campus District does not include town centers, residential, or public education facilities. As industrial campuses tend to be insular, the Urban Recreation network gives an overarching organizational feature and sense of place, while connecting the campuses with a common space and pedestrian commuter corridor.

Industrial Campuses

Manufacturers often operate at a large scale with multiple processes taking place across several buildings, with shared infrastructure and policies. Industrial campuses are large areas or collections of buildings that participate in common manufacturing activities, and include manufacturing buildings and warehouses.

Scale

Manufacturing and industrial facilities operate on a vastly different scale than homes, office buildings or even large campuses, like universities. When talking about industrial facilities, we should compare them to small cities. All buildings on an industrial campus are connected by a complex network of utility infrastructure. Hundreds or thousands of employees move between office buildings and plants as they perform their daily activities. Because the buildings, the people and the processes are all interconnected, any single building on an industrial campus as a critical component of a larger whole. For manufacturers, efficiency equals a healthy business unit. Saving energy and water produce major cost-savings on the industrial campus scale.

Sustainable Design

Industrial campuses must be designed to standards of LEED, Living Building Challenge, WELL Building Standard, BOMA 360, NZEB, or other highly rated national building rating standard programs. Currently California has 200 LEED-certified factories.

These certifications create healthier, more productive places, reduced stress on the environment, and savings for owners and occupants stemming from increased building value, higher lease rates and lower utility costs. At the scale of industrial campuses, they put a triple bottom line into action, benefiting people, planet and profit. For example, a leading manufacturer saw 33 percent savings on energy costs after making changes to a building's baseline design in pursuit of LEED Gold certification. Ozzie Gonzalez of CH2M, says, "When we consider an entire campus project for LEED, we can gain enormous benefits in predictability, streamlining processes, cost savings, standardization, successful implementation and continuous improvement. For me, nowhere is the impact bigger or more meaningful than at the level of the manufacturers who produce the products we use every day, around the world."
Benefits of requiring certification include:

Workers: Green buildings positively impact occupant health, safety, well-being and overall experience. Blue collar and white collar workers alike, regardless of location, can expect the same quality standard.

Higher Value Construction Jobs: Industrial facilities can be the cornerstone business for entire towns, cities and metro areas, providing not only direct employment but a ripple effect of commerce throughout the region (NAM). USGBC's recent Green Building Economic Impact Study found that across industries, green construction is poised to create more

Modern ceramic plant campus facade. Image from: https://depositphotos.com/stock-footage/ceramics-plant.html

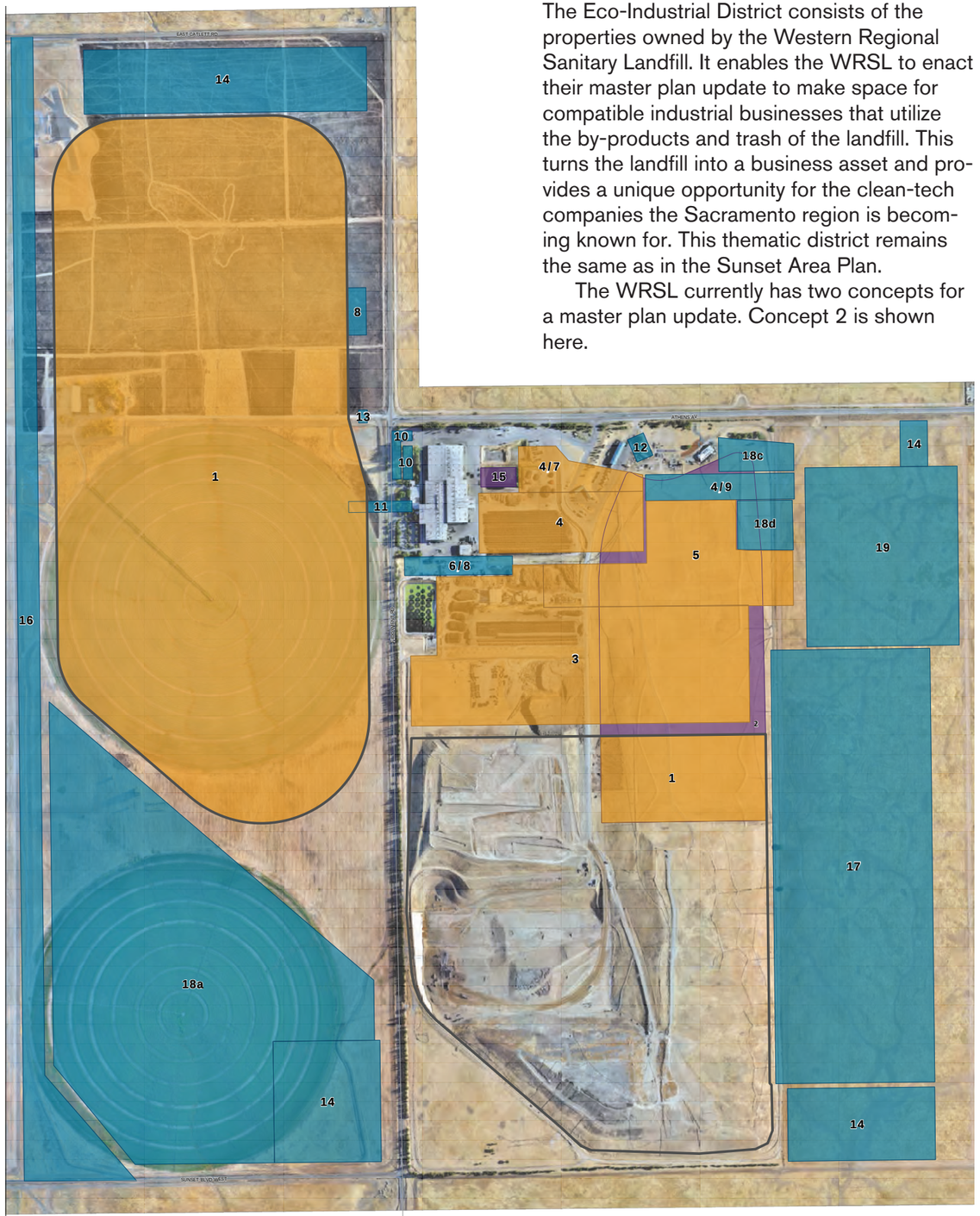
than 3.3 million US jobs and $190.3 billion in labor earnings through the end of 2018. The growth of green jobs in manufacturing is expected to continue at a strong pace. USGBC's recent Green Building Economic Impact Study found that across industries, green construction is poised to create more than 3.3 million U.S. jobs and $190.3 billion in labor earnings through the end of 2018.

Community Health: Green buildings help ensure manufacturers are good stewards for their communities. Sustainable manufacturing facilities protect local residents and workers, promoting a healthy environment and economy.

Eco-Industrial District

The Eco-Industrial District consists of the properties owned by the Western Regional Sanitary Landfill. It enables the WRSL to enact their master plan update to make space for compatible industrial businesses that utilize the by-products and trash of the landfill. This turns the landfill into a business asset and provides a unique opportunity for the clean-tech companies the Sacramento region is becoming known for. This thematic district remains the same as in the Sunset Area Plan.

The WRSL currently has two concepts for a master plan update. Concept 2 is shown here.



CONCEPT 2

WPWMA, Placer County, California

Legend
- Overall Landfill Footprint
- Existing Feature To Be Removed
- Critical Element
- Non-Critical Element

Concept Elements:
1. Landfill Operations
2. Waste Relocation
3. Composting Operations
4. Public Tip/HHW/Buyback/Reuse
5. Construction & Demolition
6. Corporation Yard
7. Household Hazardous Waste
8. Maintenance
9. Recovered Materials Storage
10. Administration & Parking
11. Overpass/Underpass/Waste Conveyance
12. Entrance
13. Entrance
14. Storm Water Pond
15. Storm Water Pond Removal
16. Potential Fiddyment Realignment Easement
17. Complementary Manufacturing
18. Other Alternative Uses

18a. Other Commercial/Industrial Uses
18b. University Research and Development Center
18c. Landfill Gas to Compressed Natural Gas
18d. Alternatives Technologies Pilot Study Area
19. Biological Reserve Area

Attraction District

The Attraction District enables super-regional entertainment venues and supporting uses that are compatible with the Thunder Valley Casino. It is the same as in the SAP Entertainment and Mixed-Use District, but the Regional Shopping Center and Cornerstone District have been removed.

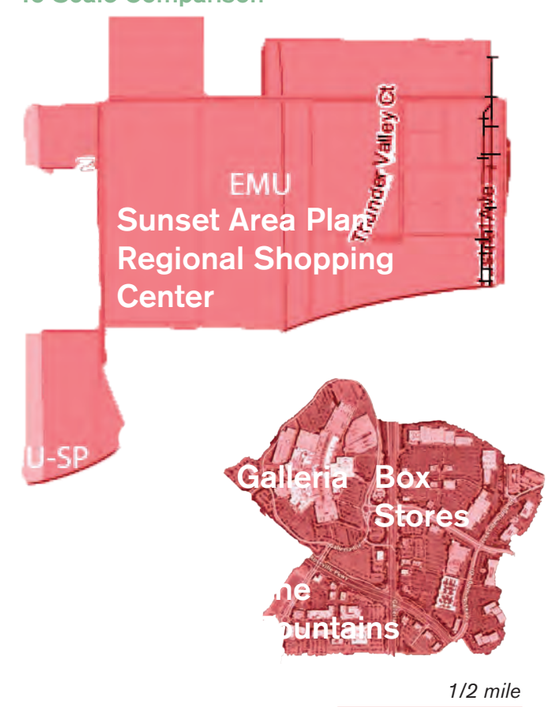
How big is retail in the Sunset Area Plan?

A comparison with the one of Roseville's shopping districts puts it in perspective. The Westfield Galleria Mall is approximately 90 acres. The Galleria plus the Fountains and the big box stores east-side of Galleria Blvd is approximately 260 acres.

The Sunset Area Plan Draft includes a regional shopping center that is 517 acres-that's twice as big!

By removing this component of the SAP, the CISGP maintains retail revenue for Lincoln, Roseville and Rocklin.

To Scale Comparison



CSU Chico's new arts & humanities building is 91,000 sf and LEED certified. Image from Otto Construction, https://ottoconstruction.com/portfolio-items/csu-chico-arts-humanities-building/

University District

The university furthers the objective of creating a major job center in the community, by creating a pipeline for students to find jobs and employers to engage in research. The CISGP moves the university slightly to the east out of the dump buffer zone, where half of it's district is vacant and the other half has buildings and infrastructure. Adaptive reuse will help the university get established with less infrastructure and utility expansion cost, mitigation fees, and environmental impact.

The site has various edge conditions that work well with a university's many faces, and incorporates the most scenic stream courses. By nestling the university amidst the Innovation and Mixed Use District, Roseville's industrial business area, and the Neighborhoods to the south, it's community catchment area expands and it becomes more of a community asset, for those on the outside and the inside.

What are the university mitigation costs in the Sunset Area Plan?

The SAP university land is donated by the developer and landowner of Placer Ranch, Eli Broad. The university site is a subdivision of a larger parcel with the an assessed market value of approximately $20 million. All 300 acres are a vernal pool complex. Mitigated through the PCCP, the total land conversion and special habitat fees are upwards of $40 million.

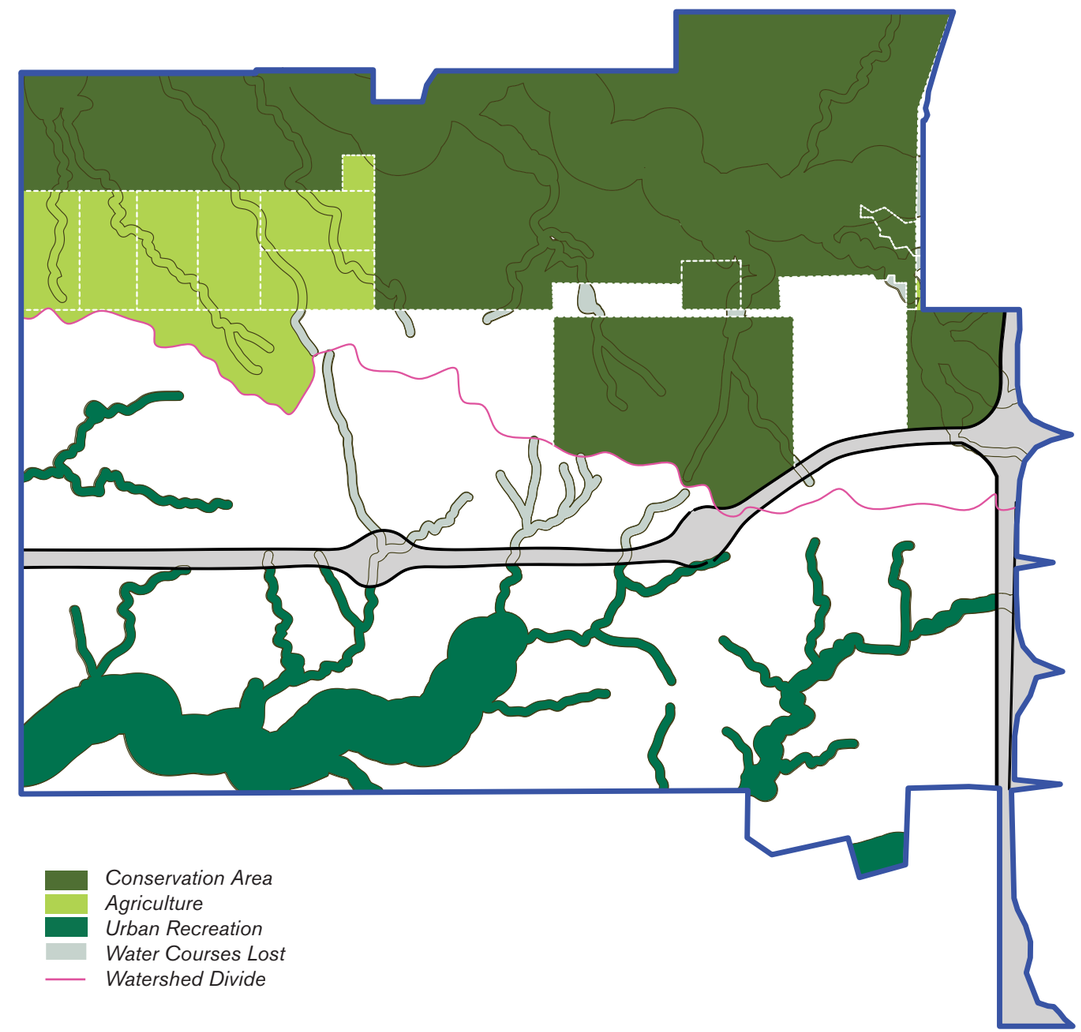
Agriculture

The SAP's urban reserve district will remain agricultural uses, for future consideration of it as part of the conservation network or another use. This district is ecologically significant and the rest of the SA should be built out first. The agriculture designation protects the catchment areas of the Auburn Ravine watershed that supports the conservation zone and maintains extensive vernal pool complexes.

Conservation

This district includes existing reserves and mitigation banks that will be in the PCCP, or are immediately adjacent to the PCCP and provide increased habitat value and migration corridor.

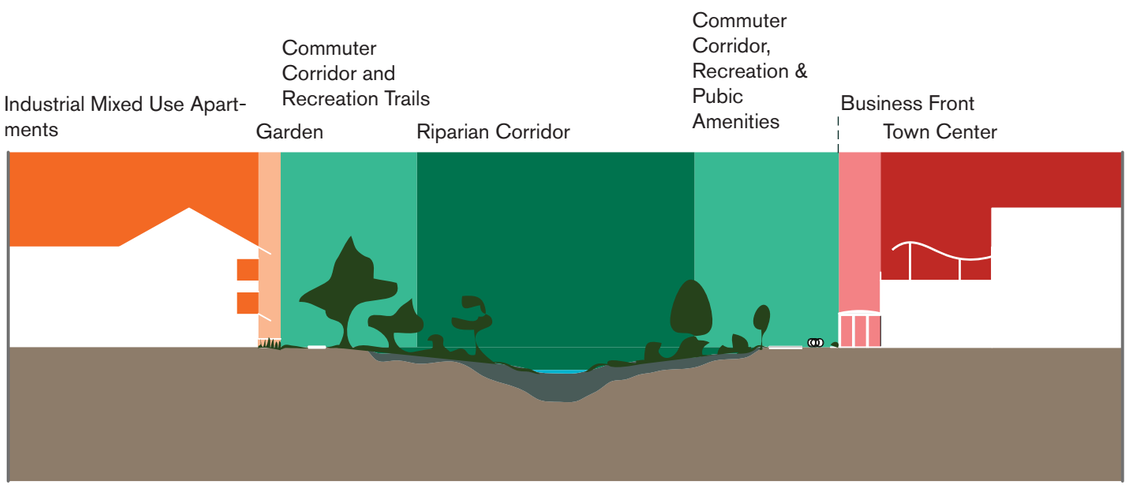
To learn more about how the open space designations have been determined, see the natural systems section.



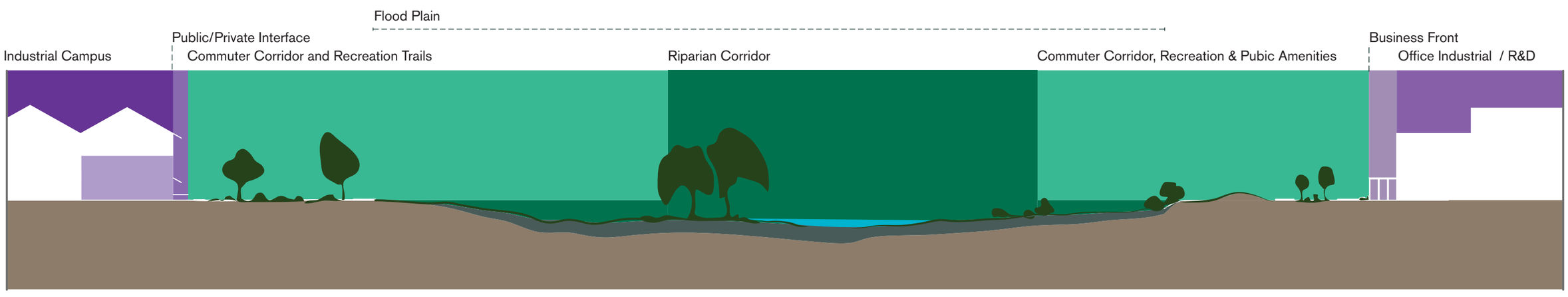
Urban Recreation District

The Urban Recreation District outlines the headwater catchment channels across the plan area. It is a core component of the walkable community design, and contributes many features to the plan in character and function. Long winding natural corridors are a defining and popular feature of the West Placer area and give a feel of the countryside throughout the seasons amidst developments. As part natural area and part park, the corridor edges incorporate a variety of public amenities, such as workout equipment, nature education signage, and gathering spaces. Building edges along the corridor will have front-facing facade designs, to create a riverfront feel, with shops, restaurants, garden apartments and business entrances opening onto this pedestrian thoroughfare. It is meant to be a daily part of life and work in the community, the long green-ways connecting various zonings with recreational and commuter walking and bike paths.

Conceptual Cross Section of Urban Recreation District for Level 1 Streams



Conceptual Cross Section of Urban Recreation District with Wide Setback



Example of amenities along the Urban Recreation district include bike and pedestrian paths, cafes, sitting spots, and plazas.

Urban Recreation preserves the natural hydrology of the site and maintains the headwater flow for two streams. It has little habitat conservation value because reserves of such area and perimeter-area ratio are unlikely to protect species from edge impacts. Instead, the Urban Recreation becomes the greenway through community and an enhanced riparian corridor for native birds that are compatible with humans.

Zoning Place Types Table

This table indicates the buildings mix in each district. Comparing across columns reveals similar and unique uses.

	Place Type	Secondary Mixed Use	District: Innovation Campus	Eco-industrial	Agriculture	Attraction	Conservation	Innovation and Mixed Use: HDIMU	Office and R&D	Office Industrial	Town Center	University
Office	low-rise office							x			x	
	office park high							x		x		
	office park low								x			
	low-rise mixed use	COM/RES									x	
Industrial	industiral high		x					x	x	x		
	office industrial											
	industrial low		x									
	SIA ind eco			x								
	warehouse high		x					x	x	x		
	warehouse low		x					x	x	x		
Commercial	low intensity commerical strip								x	x		
	large format standalone commercial		x									
	urban convention center					x						
	hotel high					x						
	hotel low					x					x	
	commercial recreation facility					x						
	main street commerical / mu low	RES									x	
	main street commercial / mu high	RES									x	
	medium intensity strip commerical					x			x	x		
	town mixed use	OFF/RES										
Residential	mid-rise residential							x				x
	garden appartment											
	Small lot SF detached											
	standard podium miltifamily	COM						x	x		x	x
	suburban multifamily							x				
	urban podium multifamily	COM									x	x
	urban town home/ live-work	OFF									x	
	suburban townhome							x			x	
Other	parking structure								x			x
	campus/college high	COM/OFF										x
	hospital										x	x
	urban elementary school										x	
	urban high school										x	
	urban middle school										x	
Open Space	agriculture		x		x							
	urban recreatoin								x		x	
	conservation						x					

Zoning Densities

	District				Innovation and Mixed Use					
	Innovation Campus	Eco-industrial	Agriculture	Attraction	Conservation	HDIMU	Office and R&D	Office Industrial	Town Center	University
Employment Breakdown										
Employment density gross emp/ac	22.14	41.2	0	149.63	0	36.8	43.02	22.97	71.31	24.95
retail	9.5%	0.0%	0.0%	81.8%	0.0%	15.5%	6.1%	5.7%	30.8%	29.4%
industrial	88.0%	89.3%	0.0%	0.0%	0.0%	16.7%	14.6%	54.2%	0.0%	0.0%
office	2.6%	10.7%	0.0%	1.0%	0.0%	67.8%	79.3%	40.1%	62.6%	10.5%
public	0.0%	0.0%	0.0%	18.2%	0.0%	0.0%	0.0%	0.0%	6.5%	60.1%
Residential Breakdown										
Residential Density (gross) du/ac	0	0	0	0	0	59	0	0	24	77
Population Density pop/ac	0	0	0	0	0	100	0	0	42	131
Building Scale										
FAR	0.52	0.75	0	2	0.01	2.33	0.53	0.5	1.65	2.4
Average Number of Floors	1.5	8*	0	8.5	2	4.7	2.4		3.4	5.2

*height of equiptment allowed

The Zoning Densities Table breaks down what each zone contributes to employment and residencies. The higher the density, the more the jobs or residents the zone supports per acre.

Primary wage earner jobs are most likely to be office and industrial jobs. Minimum wage jobs typically include retail and hospitality.

Residential exists in three zones, the High Density Industrial Mixed Use, the Town Center, and the University District.

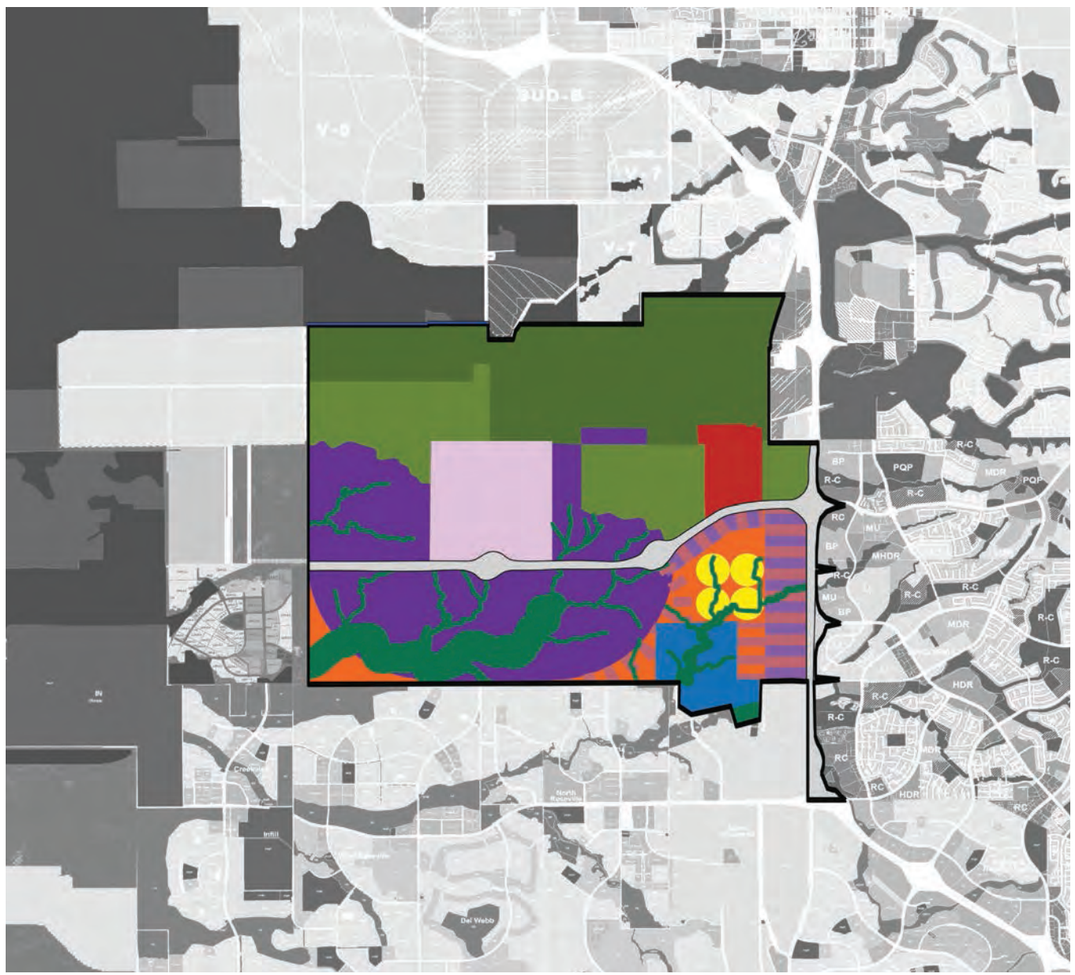
The Innovation and Mixed Use District has building heights of two to five stores. To its east, the Innovation Campus District has an average height of 1.5 stories. The tallest buildings are in the Attraction District, with 8.5 stories, primarily for hotels. The Eco-Industrial district also has a high number of floors, per the SAP designation.

Exclusive Comparison

Sunset Area Only

The following analysis includes only the Sunset Area and no surrounding context. It evaluates at the zoning level only, excluding CISGP reduction measures such as public transit and walking trails that would reduce impacts further. Because of this it is a fair comparison with the SAP and also represents a worst case scenario. The SAP numbers are the combined totals from the December 2018 SAP Draft and December 2018 PR Draft.

Scope of Analysis Map



Exclusive Comparison: Emissions Report

The Emissions Report calculates emissions from building operations, passenger vehicle transportation and water use. It uses an average from the energy mix of the California grid to determine the emission associated with electricity use, as reported by the U.S. Environmental Protection Agency (EPA) Emissions & Generation Resource Integrated Database (eGRID). In the calculation of the energy use and GHG emissions from water use, it includes the conveyance, treatment, and distribution of water and wastewater. The energy associated with the end uses of water, such as the cost of heating water, are rather included in building energy use.

In addition, the Emissions module currently applies a single water energy use rate to both indoor and outdoor water uses. The Total Building Energy GHG Emissions estimates displays the total greenhouse gas emissions due to building energy. The Total Water Energy GHG Emissions estimates the emissions produced by the energy used for all stages of water use except for end use. It includes source, conveyance, treatment, distribution, and wastewater treatment. This includes residential and commercial indoor and outdoor water use purposes. The GHG Emissions Per Household chart displays the GHG emissions attributed to the energy consumed per household.

When striving for reductions, the CISGP strives to decrease emissions per capita rather than displace the effect.

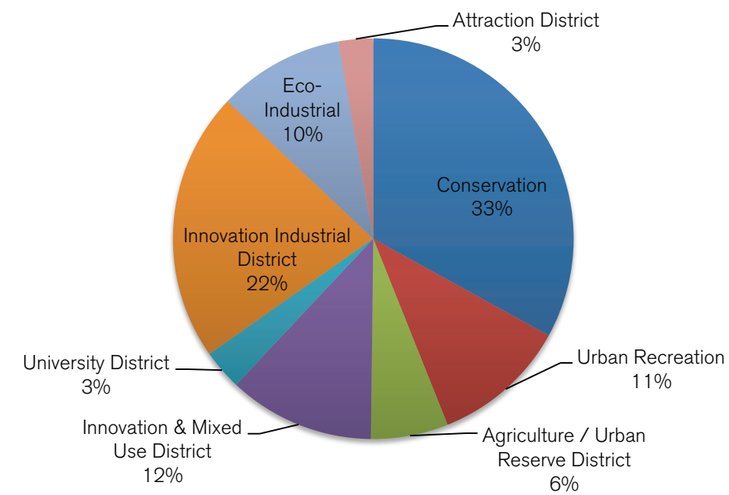
	Existing Conditions	CISGP	SAP	
Total GHG Emissions by Source, metric tons / year				
Annual passenger vehicle emissions without public transit)	5,311	414,922	340,399	
Annual building energy emissions	74,406	1,753,708	1,686,302	
Annual water-energy emissions	328	7,462	9,235	
Total	80,045	2,176,091	2,035,936	
GHG Emissions Per Household by Source, metric tons / household / year				
Annual passenger vehicle emissions per household (without public transit)	758.69	8.90	40.46	-79%
Annual building energy emissions per household	11.88	5.13	8.35	-39%
Annual water-energy emissions per household	20.83	0.04	0.13	-66%
Total	791.40	14.07	48.94	
Pollutant Emissions by Pollutant Type, metric tons / year				
Annual NOx emissions	12.36	966	792.10	
Annual PM10 emissions	0.28	22	17.83	
Annual PM2.5 emissions	0.25	19	15.81	
Annual SOx emissions	0.12	9	7.64	
Annual CO emissions	99.95	7,809	6,406.11	
Annual ROG/VOC emissions	9.40	734	602.55	
Total	122.35	9,559	7,842.04	

Exclusive Comparison: Land Consumption Report

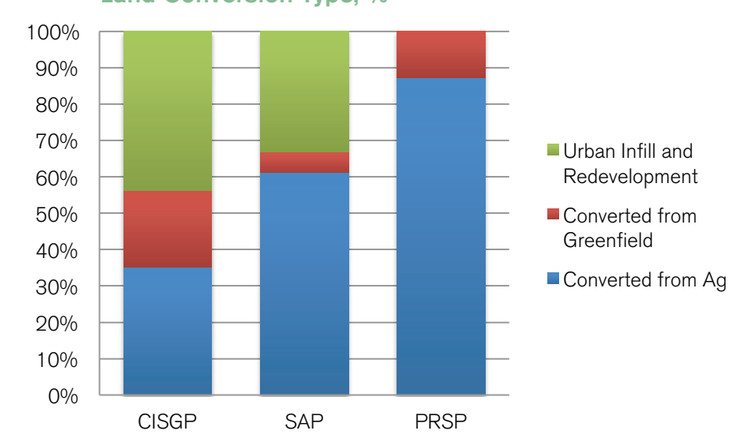
CISGP	Acres	Converted from Ag	Converted from Greenfield	Urban Infill & Redevelopment
Conservation	2,564	220	102	0
Urban Recreation	849	704	130	15
Agriculture / Urban Reserve District	484	0	0	0
Innovation & Mixed Use District	918	0	469	449
University District	252	0	137	115
Innovation Industrial District	1,691	1,058	0	633
Eco-Industrial	790	305	155	330
Attraction District	217	0	49	168
Totals				
Development Area	3,868	1,363	811	1,694
Reserved Development Area	494	0	0	0
Natural Area	3,413	924	232	15
Total per Conversion Type		2,287	1,044	1,709
SAP				
General Commercial	34	0	27	7
Entertainment Mixed-Use	517	265	33	218
Business Park	147	0	137	10
Innovation Center	1,245	1,204	0	41
Eco-Industrial	927	613	0	314
Light Industrial	750	0	214	536
Public Facility	6	n/a	n/a	n/a
Preserve/Mitigation Reserve	1,943	0	0	12
Urban Reserve	320	0	0	0
Totals				
Development Area	3,627	2,082	197	1,127
Reserved Development Area	320	0	0	0
Natural Area	1,943	0	0	12
Total per Conversion Type		2,082	197	1,139
PRSP				
Residential	801	713	88	0
General Commercial	23	23	0	0
Commercial Mixed Use	49	49	0	0
Campus Business Park	335	229	106	0
University	301	301	0	0
Public Facilities	33	33	0	0
Parks + Open Space	335	310	24	0
Totals				
Development Area	1,542	1,347	195	0
Reserved Development Area	0	0	0	0
Natural Area	335	310	24	0
Total per Conversion Type		1,658	219	0

	Converted from Ag from Ag	Converted from Greenfield Greenfield	Urban Infill & Redevelopment t
CISGP	35%	21%	44%
SAP	57%	5%	31%
PRSP	87%	13%	0%

CISGP Land Use, acres

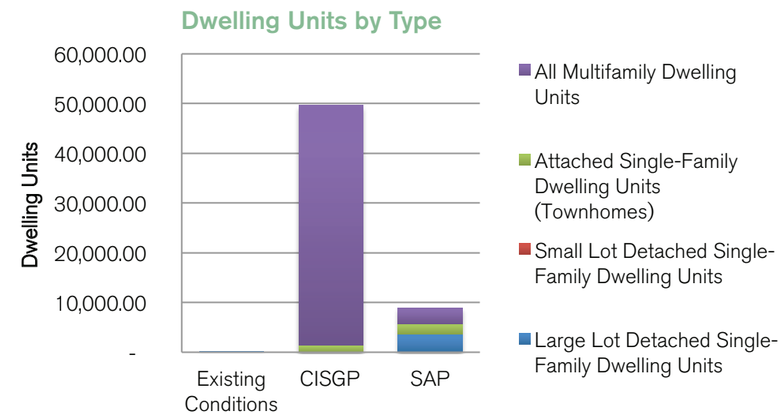


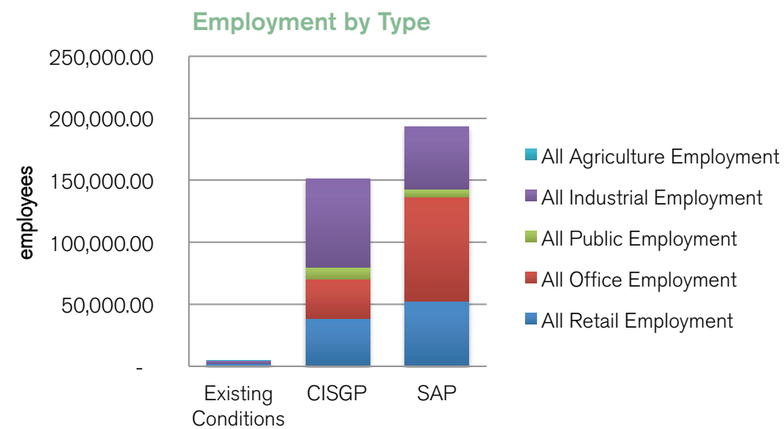
Land Conversion Type, %



Exclusive Comparison: Summery Stats Report

	Existing Conditions	CISGP	SAP
Population	19.00	84,080.49	17,367.32
Dwelling Units	9.00	49,613.62	8,950.27
Households (Occupied Dwelling Units)	7.00	46,636.80	8,412.80
Employment	4,480.00	151,462.63	192,879.40
Job-Housing Balance			
Jobs per Single Dwelling Unit	497.78	3.05	21.55
Dwelling Units by Type, dwelling units			
Large Lot Detached Single-Family Dwelling Units	9.00	0.06	3,578.03
Small Lot Detached Single-Family Dwelling Units	-	-	2.93
Attached Single-Family Dwelling Units (Townhomes)	-	1,427.85	2,145.29
All Multifamily Dwelling Units	-	48,185.71	3,224.02
Total	9.00	49,613.62	8,950.27
Employment by Type, employees			
All Retail Employment	1,910.00	38,458.52	52,681.68
All Office Employment	505.00	31,646.43	84,035.42
All Public Employment	64.00	9,724.01	5,934.90
All Industrial Employment	1,993.00	71,633.68	50,227.41
All Agriculture Employment	8.00	-	-
Total	4,480.00	151,462.63	192,879.40
Building Square Feet - Residential, (millions)			
Small Lot Detached Single-Family Building Area	0.00	0.00	0.01
Large Lot Detached Single-Family Building Area	0.01	0.00	12.43
Attached Single-Family Building Area	0.00	2.31	3.55
Multifamily Building Area	0.00	40.88	3.30
Total	0.01	43.20	19.29
Building Square Feet - Retail,, (millions)			
Retail Services Building Area	0.34	3.47	5.79
Restaurants Building Area	0.02	2.38	2.49
Arts & Entertainment Building Area	1.98	2.92	2.41
Accommodation Building Area	0.06	10.66	15.02
Other Retail Building Area	0.12	3.14	4.74
Total	2.51	22.56	30.46





	Existing Conditions	CISGP	SAP
Building Square Feet - Office, (millions)			
Office Services Building Area	0.36	8.29	18.75
Medical Services Area	0.02	1.00	7.29
Total	0.37	9.29	26.05
Building Square Feet - Public Services, (millions)			
Education Building Area	0.30	2.48	3.24
Total	0.30	0.00	3.24
Building Square Feet - Industrial, (millions)			
Transportation/Warehouses Building Area	0.32	36.76	20.16

Exclusive Comparison: Accessibility - Walk Report

The Walk Report evaluates the land use distribution for its potential as walkable community. The given time frames are the durations people are willing to walk to get to various amenities. Walk times greater than these are likely to discourage walking and encourage car dependence. Distances are measured as the crow flies and thus percentages indicate the portion of the population that has the potential for these walk times. Actual percentages are expected to be lower as a result of walking path layout.

	Existing Conditions	CISGP	SAP
Parks			
Percent of Residents within 10 min.	0%	100%	72%
Schools			
Percent of Residents within 15 min	0%	89%	17%
Hospitals			
Percent of Residents within 15 min.	0%	89%	23%
Transit Stops			
Percent of Residents within 5 min.	0%	n/a	89%
Percent of Residents living in minimum required density of 9 du/ac to support Bus Rapid Transit	0%	100%	12%
Percent of Non-Residential Uses with the minimum FAR of 1.0 required to support Bus Rapid Transit	0	45%	0%
Restaurants			
Percent of Residents within 10 min.	0%	100%	30%
Work Commute			
Percent of Residents within 15 minute walking distance of a job site	n/a	100%	9%
Percent of Job sites within 15 minute walking distance for a residence	n/a	61%	38%

Exclusive Comparison: Household Cost Report

The Household Cost Report estimates annual household costs associated with passenger vehicle transportation, residential energy use, and water use. Analyzed together, these represent dimensions of housing affordability as it relates to location efficiency and housing type. The same energy efficiencies have been applied to all scenarios. The transportation costs *assume no public transit* to reflect the cost savings inherent in the zoning layout alone.

	Existing Conditions	CISGP	SAP
Total Residential Costs, Dollars / year (millions)			
Annual residential water costs	0.78	10.91	5.71
Annual residential building energy costs	0.02	51.48	15.11
Annual passenger vehicle costs	0.17	311.79	82.25
Average Household Costs, Dollars / year			
Annual residential building energy costs per HH	2,552.27	1,103.75	1,795.60
Annual passenger vehicle costs per HH	24,783.94	6,685.58	9,776.56
Total	27,336.21	7,789.34	11,572.16
Average Household Transportation Costs by Type, Dollars / year			
Auto fuel costs per HH	4,966.61	1,339.77	1,959.19
Ownership and maintenance costs per HH	19,817.33	5,345.82	7,817.38
Total	24,783.94	6,685.58	9,776.56

Exclusive Comparison: Water Use Report

The Water Use Report calculates residential and commercial water demands for all buildings in each scenario. Water demand profiles vary by scenarios vary due to their building program, the location of new growth, and policy-based assumptions about improvements in water efficiency over time. The costs and GHG emissions associated with water demand, in turn, vary according to policy-based price and emissions rate assumptions.

Indoor and outdoor water use for residential and commercial buildings are modeled separately. Indoor water use is estimated on a per-capita and per-employee basis, while outdoor water use is estimated by irrigated area at the parcel scale. For both, baseline rates are adjusted to account for efficiency and conservation policies into the future.

	Existing Conditions	CISGP	SAP
Total Water Use, gallons / year (millions)			
Total Residential Indoor Water Use	0.38	1381.02	311.31
Total Residential Outdoor Water Use	100.22	28.07	426.08
Total Commercial Indoor Water Use	119.56	3275.32	4657.83
Total Commercial Outdoor Water Use	6.11	203.43	977.28
Total	226.27	4887.85	6372.51
Total Indoor Use, gallons / year (millions)			
Total Residential Indoor Water Use	0.38	1381.02	311.31
Total Commercial Indoor Water Use	119.56	3275.32	4657.83
Total	119.94	4656.35	4969.14
Total Outdoor Use, gallons / year (millions)			
Total Residential Outdoor Water Use	100.22	28.07	426.08
Total Commercial Outdoor Water Use	6.11	203.43	977.28
Total	106.33	231.50	1403.37
Total Residential Use, gallons / year (millions)			
Total Residential Indoor Water Use	0.38	1381.02	311.31
Total Residential Outdoor Water Use	100.22	28.07	426.08
Total	100.61	1409.09	737.39
Total Commercial Use, gallons / year (millions)			
Total Commercial Indoor Water Use	119.56	3275.32	4657.83
Total Commercial Outdoor Water Use	6.11	203.43	977.28
Total	125.67	3478.75	5635.12
Per Capita Residential Use, gallons / person / year			
Residential Water Use per Capita	5,295,040	16,759	42,459
Per Household Residential Use, gallons / household / year			
Residential Indoor Water Use per Household	54,489	29,612	37,005
Residential Outdoor Water Use per Household	14,317,761	602	50,647
Total	14,372,251	30,214	87,651

Exclusive Comparison: Energy Use Report

The Energy Use Report totals building energy use for all new and existing residential and commercial buildings. Building program, the location of new growth, and policy-based assumptions for improvements in energy efficiency all effect energy consumption. Costs and GHG emissions associated with energy use, in turn, vary according to policy-based price and emissions rate assumptions.

This report determines energy use with three types of variables: building characteristics, climate zone, and efficiency factors. Baseline per-residential unit or per-commercial square foot factors are derived from survey data by building characteristics and climate zone. Reductions are then applied to the resulting baseline estimates to reflect the implementation of energy efficiency and conservation policies into the future across all scenarios.

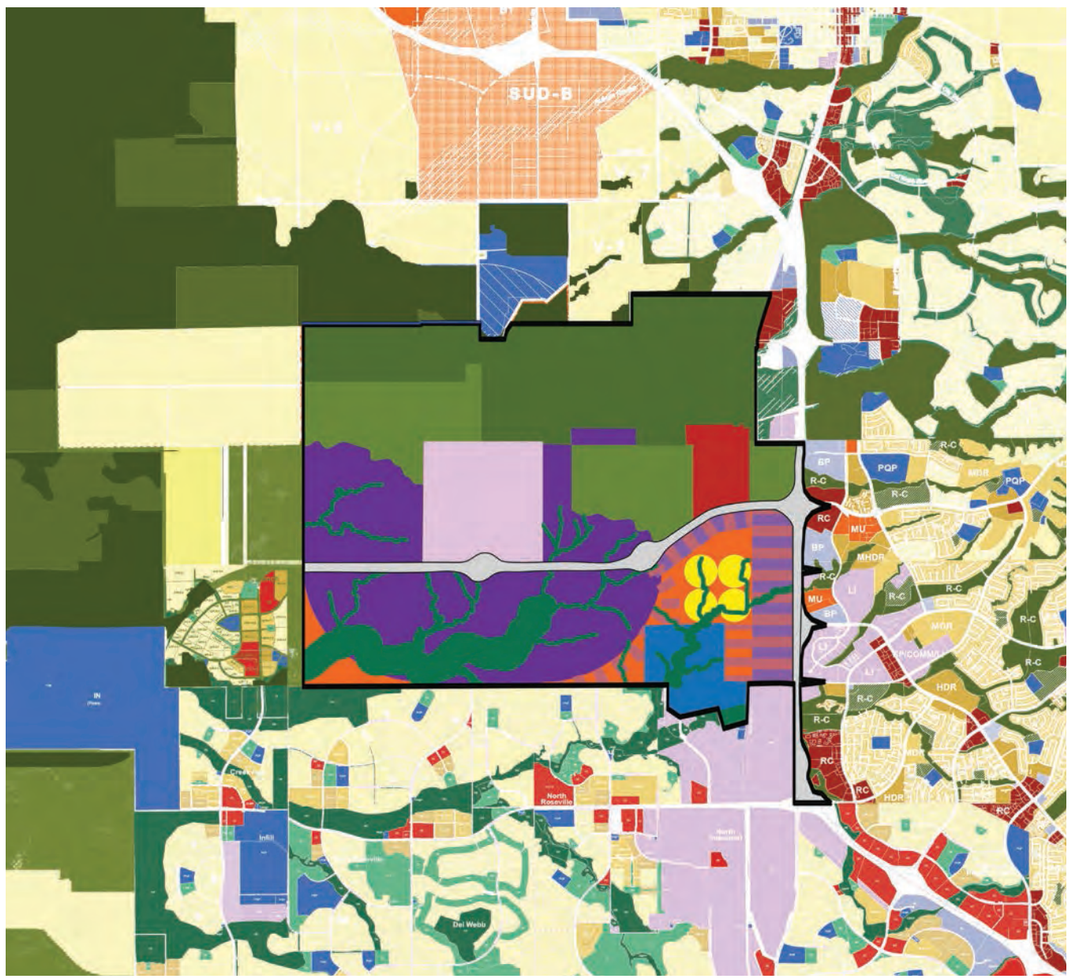
	Existing Conditions	CISGP	SAP
Total Annual Electricity Use, Kilowatt hours / year (millions)			
Residential Electricity Use	0.07	217.95	64.01
Commercial Electricity Use	85.99	1575.10	1531.93
Total	86.07	1793.05	1595.93
Total Annual Gas Use, Therms / year (millions)			
Residential Gas Use	0.01	14.78	4.33
Commercial Gas Use	2.08	66.53	91.41
Total	2.08	81.31	95.74
Per Household Energy Use, Kilowatt hours / household / year			
Residential Energy Use per Household	32,748	13,959	22,691
Total Household Energy Costs, Dollars / year (millions)			
Annual residential building energy costs	0.02	51.48	15.11
Total Building Energy GHG Emissions, metric tons / year (millions)			
Annual building energy emissions	0.07	1.75	1.69

Comparison in Context

Sunset and Surrounds

The following analysis includes a two mile area around the perimeter of the Sunset Area in order to identify effects on the greater community. In West Placer the two mile radius is equal to a 15 minute drive or 30 minute bike ride. The following analysis also utilizes the Future Vision of the Tomorrow Map from the Introduction section as the base line. SAP refers to the combined December 2018 SAP Draft and the December 2018 PR Draft. The Nature Conservancy's evaluation modules have been used for the conservation analysis.

Scope of Analysis Map

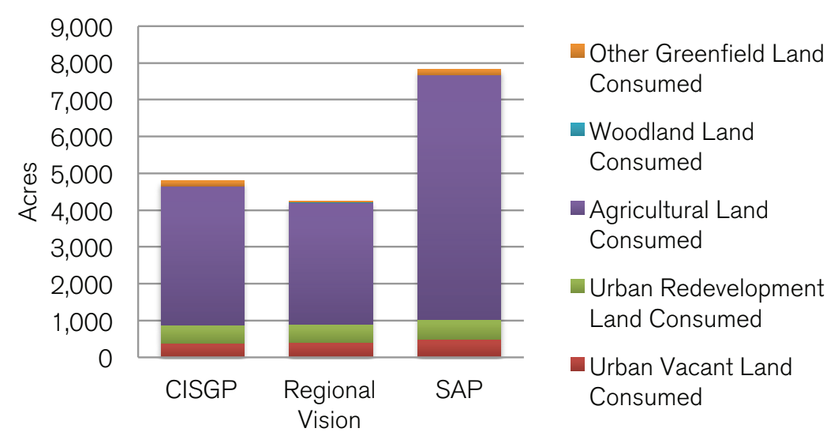


Comparison in Context: Land Consumption Report

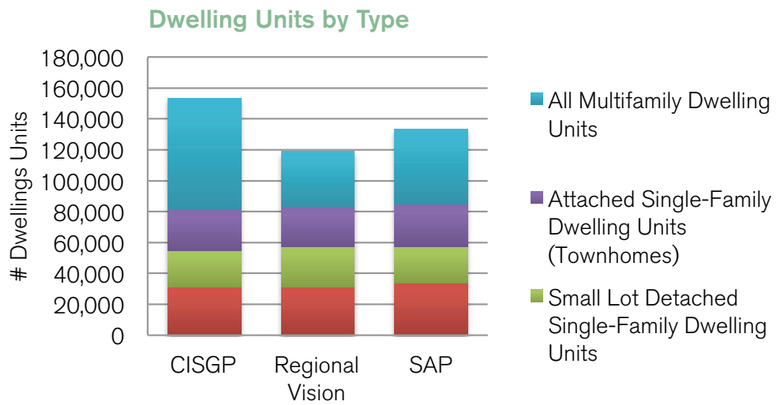
The land consumption report analyzes three scenarios within the Sunset Area.

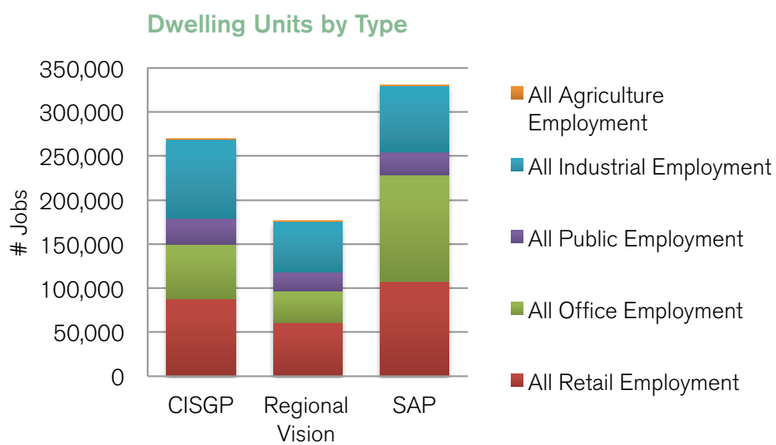
	CISGP	Regional Vision	SAP
Total Land Consumed, acres			
Urban Vacant Land Consumed	390	411	488
Urban Redevelopment Land Consumed	488	485	547
Agricultural Land Consumed	3,781	3,317	6,632
Woodland Land Consumed	1	1	1
Other Greenfield Land Consumed	139	36	162
Total	4,799	4,250	7,830

Total Land Consumed



Comparison in Context: Summary Stats Report



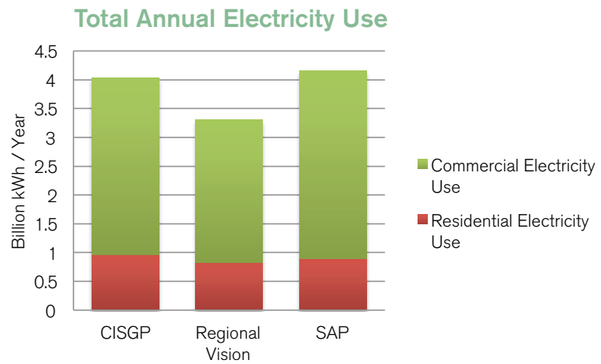


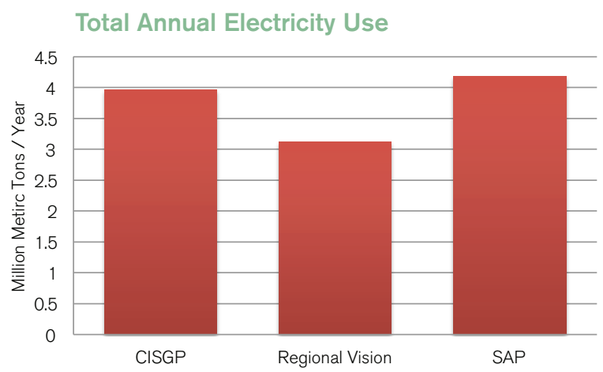
	CISGP	Regional Vision	SAP
Population, people	297,993	240,455	265,864
Dwelling Units	153,422	118,845	133,503
Households (Occupied Dwelling Units)	144,017	111,516	125,294
Employment, employees	268,968	175,536	329,695
Dwelling Units by Type, dwelling units			
Large Lot Detached Single-Family Dwelling Units	31,111	31,418	33,823
Small Lot Detached Single-Family Dwelling Units	23,681	25,964	23,684
Attached Single-Family Dwelling Units (Townhomes)	26,662	25,919	27,170
All Multifamily Dwelling Units	71,968	35,544	48,826
Total	153,422	118,845	133,503
Employment by Type, employees			
All Retail Employment	87,582	61,117	107,492
All Office Employment	62,223	36,064	120,846
All Public Employment	29,832	20,768	25,963
All Industrial Employment	89,329	57,577	75,392
All Agriculture Employment	2	10	2
Total	268,968	175,536	329,695
Building Square Feet - Residential, square feet			
Small Lot Detached Single-Family Building Area	50,359,817	55,738,248	50,365,961
Large Lot Detached Single-Family Building Area	91,043,334	92,197,006	100,446,046
Attached Single-Family Building Area	41,250,530	40,037,399	42,141,440
Multifamily Building Area	60,938,803	29,766,364	41,244,826
Total	243,592,484	217,739,018	234,198,274
Building Square Feet - Retail, square feet			
Retail Services Building Area	19,384,192	18,730,979	22,409,531
Restaurants Building Area	7,648,671	6,393,287	8,478,888
Arts & Entertainment Building Area	6,094,726	6,599,077	6,313,594
Accommodation Building Area	13,684,750	3,343,446	18,086,416
Other Retail Building Area	11,380,631	9,535,536	13,589,239
Total	58,192,971	44,602,325	68,877,669
Building Square Feet - Office, square feet			
Office Services Building Area	17,495,891	10,697,544	29,511,293
Medical Services Building Area	2,183,259	1,316,097	8,720,006
Total	19,679,150	12,013,641	38,231,299
Building Square Feet - Education, square feet	19,735,422	17,099,814	16,144,038
Building Square Feet - Industrial, square feet			
Transportation/Warehouses Building Area	48,542,304	46,169,951	36,633,680
Wholesale Building Area	24,168,468	17,408,886	16,008,677
Total	72,710,772	63,578,837	52,642,357

Comparison in Context: Energy Use Report

The Energy Use Report models building energy use for all new and existing residential and commercial buildings. Scenarios vary in their building energy use profiles due to their building program, the location of new growth, and policy-based assumptions for improvements in energy efficiency. Costs and GHG emissions associated with energy use, in turn, vary according to policy-based price and emissions rate assumptions.

Within the model, energy use is determined by three types of variables: building characteristics, climate zone, and efficiency factors. Building characteristics and climate zone determine what baseline per-residential unit or per-commercial square foot factors (derived from survey data) are used to calculate energy use. Reductions are then applied to the resulting baseline estimates to reflect the implementation of energy efficiency and conservation policies into the future.

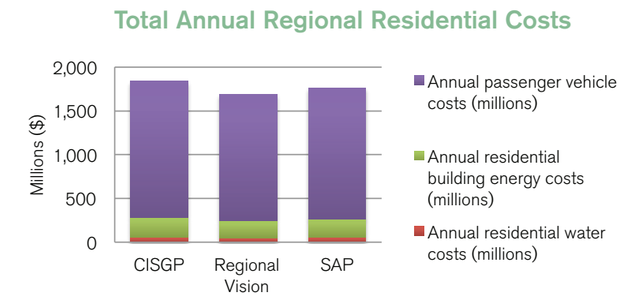


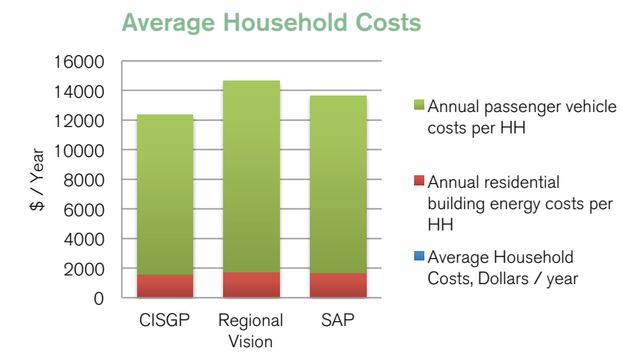


	CISGP	Regional Vision	SAP
Total Annual Electricity Use, Kilowatt hours / year (billions)			
Residential Electricity Use	0.97	0.82	0.90
Commercial Electricity Use	3.07	2.48	3.25
Total	4.04	3.30	4.15
Total Annual Gas Use, Therms / year (millions)			
Residential Gas Use	66.69	57.12	61.98
Commercial Gas Use	119.21	72.52	150.02
Total	185.89	129.64	212.00
Per Household Energy Use, Kilowatt hours / household / year			
Residential Energy Use per Household	20,286	22,403	21,662
Total Building Energy GHG Emissions, metric tons / year (millions)			
Annual building energy emissions	3.97	3.12	4.19

Comparison in Context: Household Cost Report

The Household Cost Report evaluates how much residents will pay on average for basic services. The results show that transportation is the largest expense providing cost saving measures to transit would benefit residents the most.





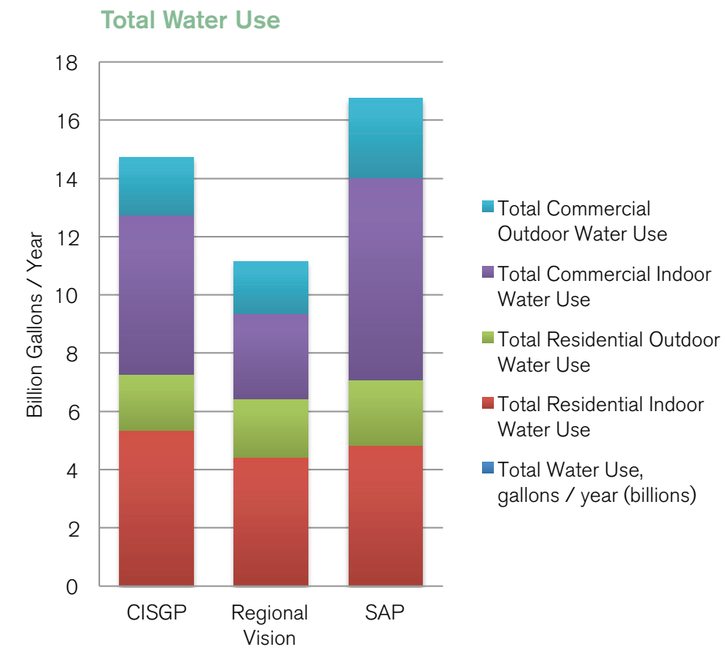
	CISGP	Regional Vision	SAP
Total Annual Regional Residential Costs			
Annual residential water costs (millions)	56.35	49.75	54.92
Annual residential building energy costs (millions)	229.67	196.03	213.25
Annual passenger vehicle costs (millions)	1,553.34	1,438.86	1,496.52
Total	1,839.36	1,684.63	1,764.69
Average Household Costs, Dollars / year			
Annual residential building energy costs per HH	1,595	1,758	1,702
Annual passenger vehicle costs per HH	10,786	12,903	11,944
Total	12,381	14,661	13,646
Average Household Transportation Costs by Type, Dollars / year			
Auto fuel costs per HH	2,161	2,586	2,394
Ownership and maintenance costs per HH	8,624	10,317	9,551
Total	10,786	12,903	11,944

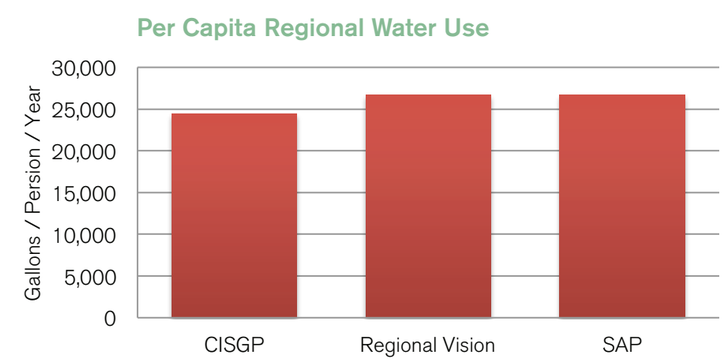
Comparison in Context: Water Use Report

The Water Use Report models residential and commercial water demands for all buildings in the base year and for future scenarios. Scenarios vary in their water demand profiles due to their building program, the location of new growth, and policy-based assumptions about improvements in water efficiency over time. The costs and GHG (Greenhouse Gas) emissions associated with water demand, in turn, vary according to policy-based price and emissions rate assumptions.

Indoor and outdoor water use for residential and commercial buildings are modeled separately. Indoor water use is estimated on a per-capita and per-employee basis, while outdoor water use is estimated by irrigated area at the parcel scale. Indoor and outdoor water use are first calculated according to baseline rates and then adjusted to account for the application of efficiency and conservation policies into the future.

	CISGP	Regional Vision	SAP
Total Water Use, gallons / year (billions)			
Total Residential Indoor Water Use	5.35	4.42	4.84
Total Residential Outdoor Water Use	1.93	2.00	2.25
Total Commercial Indoor Water Use	5.47	2.93	6.93
Total Commercial Outdoor Water Use	1.97	1.79	2.73
Total	14.72	11.15	16.75
Total Indoor Use, gallons / year (billions)			
Total Residential Indoor Water Use	5.35	4.42	4.84
Total Commercial Indoor Water Use	5.47	2.93	6.93
Total	10.82	7.36	11.77
Total Outdoor Use, gallons / year (billions)			
Total Residential Outdoor Water Use	1.93	2.00	2.25
Total Commercial Outdoor Water Use	1.97	1.79	2.73
Total	3.90	3.79	4.98
Total Residential Use, gallons / year (billions)			
Total Residential Indoor Water Use	5.35	4.42	4.84
Total Residential Outdoor Water Use	1.93	2.00	2.25
Total	7.28	6.42	7.09
Total Commercial Use, gallons / year (billions)			
Total Commercial Indoor Water Use	5.47	2.93	6.93
Total Commercial Outdoor Water Use	1.97	1.79	2.73
Total	7.45	4.72	9.65
Per Capita Residential Use, gallons / person / year			
Residential Water Use per Capita	24,420	26,718	26,678
Per Household Residential Use, gallons / household / year			
Residential Indoor Water Use per Household	37,139	39,657	38,635
Residential Outdoor Water Use per Household	13,390	17,953	17,974
Total	50,529	57,610	56,609



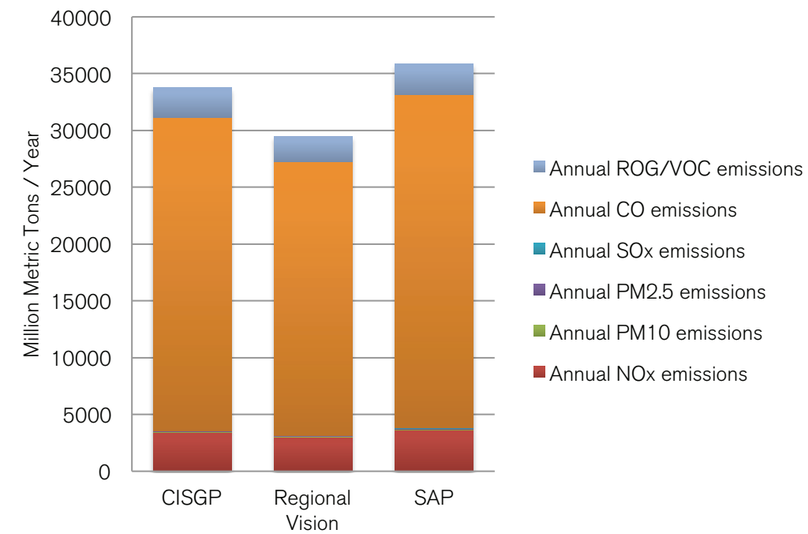


Comparison in Context: Transportation Report

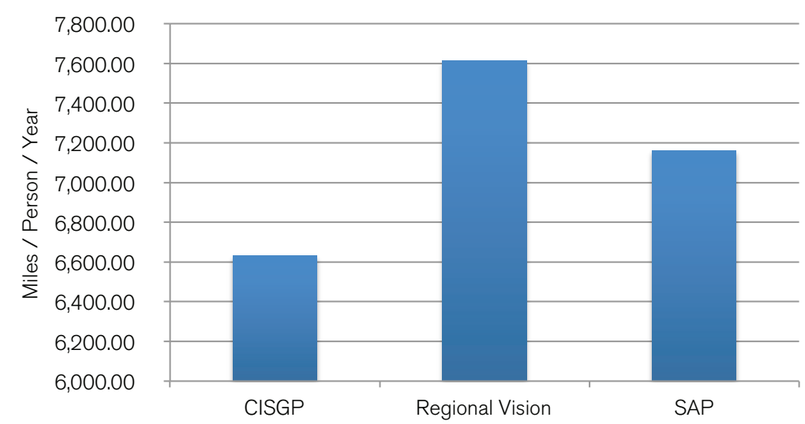
The Transportation Report incorporates a comprehensive "sketch" travel model that interacts with regional travel network data to produce estimates of vehicle miles traveled (VMT) for land use and transportation scenarios. In turn, the VMT estimates are used to calculate transportation-related costs, greenhouse gas (GHG) emissions, and pollutant emissions. It assumes that public transit remains the same and no new public transit is added to the Sunset Area. In this way it identifies the worst case scenario. *Excludes CISGP Public Transit.*

	CISGP	Regional Vision	SAP
Total Annual VMT, miles / year (billions)	2.60	2.30	2.70
Average Annual VMT per Capita	6,631.11	7,612.63	7,161.21
Average Annual VMT per Household	13,718.27	16,413.08	15,193.82
Total Transport Pollutant Emissions, metric tons / year			
Annual NOx emissions	3,408.82	2,978.54	3,623.96
Annual PM10 emissions	76.73	67.05	81.58
Annual PM2.5 emissions	68.04	59.45	72.33
Annual SOx emissions	32.89	28.74	34.96
Annual CO emissions	27,568.81	24,088.95	29,308.74
Annual ROG/VOC emissions	2,593.09	2,265.78	2,756.75
Total	33,748.39	29,488.51	35,878.32
Total Transport GHG Emissions, metric tons / year (millions)			
Annual passenger vehicle emissions	1.46	1.28	1.56
Total Transportation Costs, Dollars / year (billions)			
Annual passenger vehicle costs	1.55	1.44	1.50
Average Household Transportation Costs by Type, Dollars / year			
Auto fuel costs per HH	2,161.45	2,585.66	2,393.55
Ownership and maintenance costs per HH	8,624.41	10,317.07	9,550.54
Total	10,785.85	12,902.73	11,944.10

Total Transportation Pollutant Emissions



Average Annual VMT per Capita



Comparison in Context: Emissions Report

The Emissions Report accounts for the Greenhouse gas (GHG) emissions from transport, water, and energy utilities.

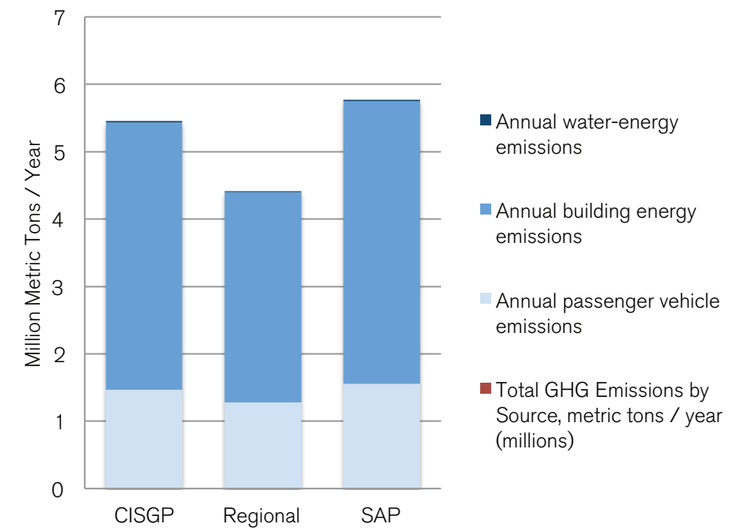
GHG emissions from transportation include carbon dioxide equivalent (CO2e) emissions from both upstream and downstream components of the energy life cycle. Upstream emissions (also known as well-to-tank, or WTT emissions) include those associated with the production of energy, from material extraction to processing and transport. For electricity, this includes power plant emissions. Downstream emissions (tank-to-wheel, or TTW emissions) are those that occur upon energy use. For liquid fuels, this includes the emissions that occur upon fuel combustion. The emissions associated with electric and other alternative or "zero emission" vehicle use are primarily upstream.

Greenhouse gas (GHG) emissions associated with building energy use are determined from California average GHG emission rates for electricity generation and natural gas combustion.

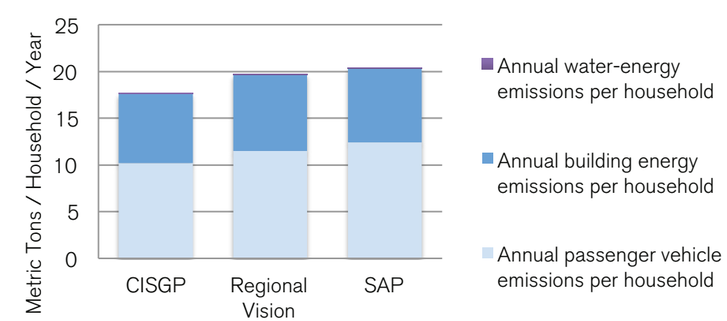
Water-related energy use and greenhouse gas (GHG) emissions refer to those resulting from two main water-related energy use categories. System Uses include the transport and treatment of residential water consumed. End Uses include all uses of water that occur within homes (e.g., water heating).
The Emissions Report calculates energy use and emissions for water system uses only, since these can be considered as a discrete component of a GHG emissions inventory (along with transportation-related and building energy emissions). Water end-use emissions are counted as part of building energy emissions.

	CISGP	Regional Vision	SAP
Total GHG Emissions by Source, metric tons / year (millions)			
Annual passenger vehicle emissions	1.46	1.28	1.56
Annual building energy emissions	3.97	3.12	4.19
Annual water-energy emissions	0.02	0.02	0.02
Total	5.45	4.42	5.77
GHG Emissions Per Household by Source, metric tons / household / year			
Annual passenger vehicle emissions per household	10.17	11.48	12.43
Annual building energy emissions per household	7.42	8.18	7.92
Annual water-energy emissions per household	0.07	0.08	0.08
Total	17.67	19.74	20.43
Transportation Pollutant Emissions by Pollutant Type, metric tons / year			
Annual NOx emissions	3,409	2,979	3,624
Annual PM10 emissions	77	67	82
Annual PM2.5 emissions	68	59	72
Annual SOx emissions	33	29	35
Annual CO emissions	27,569	24,089	29,309
Annual ROG/VOC emissions	2,593	2,266	2,757
Total	33,748	29,489	35,878

Total GHG Emissions by Source



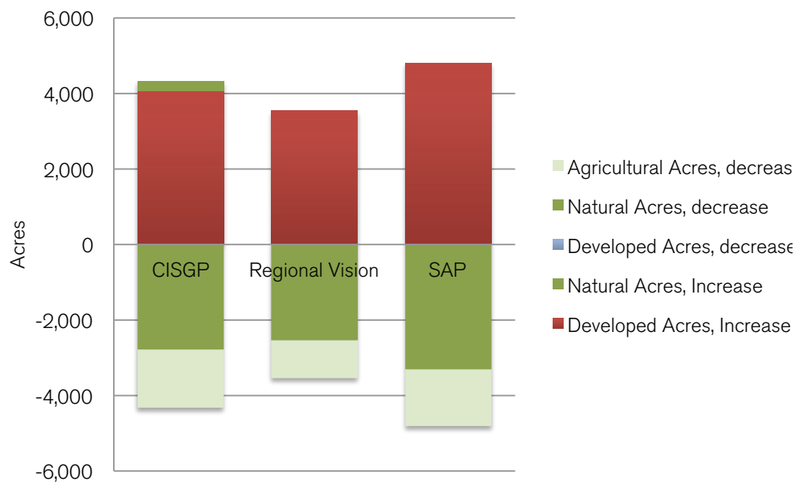
Total GHG Emissions per Household by Source



Comparison in Context: Conservation - General Report

The General Conservation Report gives a high-level understanding of the land cover changes.

Change in Landcover Types

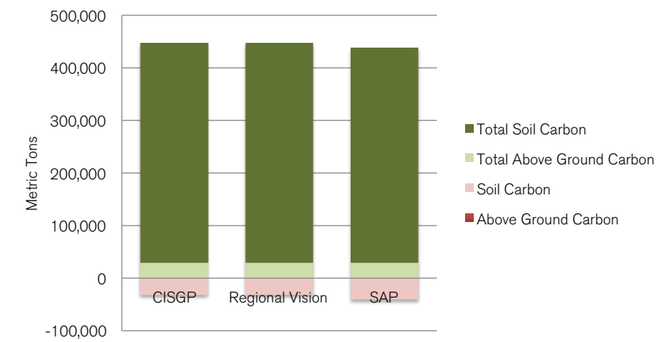


	CISGP	Regional Vision	SAP
Total Increase in Acreage of Land Cover Types, acres			
Developed Acres, Increase	4,082	3,542	4,809
Natural Acres, Increase	246	0	0
Total	4,328	3,542	4,809
Total Decrease in Acreage of Land Cover Types, acres			
Developed Acres, decrease	-22	0	0
Natural Acres, decrease	-2,755	-2,543	-3,303
Agricultural Acres, decrease	-1,551	-999	-1,506
Total	-4,328	-3,542	-4,809
Net Change in Acreage of Land Cover Types, acres			
Developed Acres	4,060	3,542	4,809
Natural Acres	-2,509	-2,543	-3,303
Agricultral Acres	-1,551	-999	-1,506

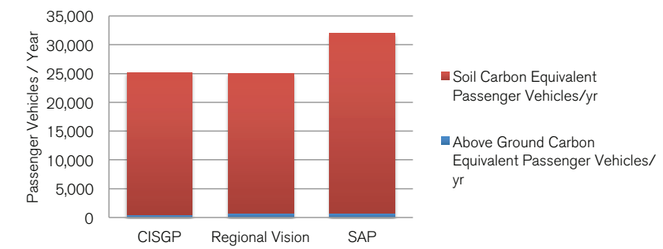
Comparison in Context: Conservation - Carbon Report

The terrestrial carbon storage analysis is focused on measurement of the stock change of carbon (C) in natural vegetation and soil. This change is associated with various land use changes and land management actions. The model is used to analyze the impact of land use change on above-ground carbon stock in grassland, shrubland, forested ecosystems, and below-ground carbon stock in all environments. Above-ground carbon includes carbon stocks in live natural vegetation; soil carbon includes carbon stocks that are up to 30 cm below the surface of the soil.

Net Change and Total Carbon Stock



Net Change in Carbon Stock Measured as Equivalent Passenger Vehicles Driven per Year



	CISGP	Regional Vision	SAP
Net Change in Carbon Stock, metric tons			
Above Ground Carbon	-654	-962	-973
Soil Carbon	-31,456	-30,809	-39,743
Total	-32,110	-31,771	-40,715
Total Carbon Stock, metric tons			
Total Above Ground Carbon	29,370	29,063	29,052
Total Soil Carbon	417,957	418,604	409,670
Total	447,328	447,666	438,722
Net Change in Carbon Stock measured as equivalent passenger vehicles driven per year, passenger vehicles/yr			
Above Ground Carbon Equivalent Passenger Vehicles/yr	514	755	763
Soil Carbon Equivalent Passenger Vehicles/yr	24,693	24,185	31,198
Total	25,207	24,941	31,962

Comparison in Context: Conservation - Water Report

The water theme is based on impacts related to four aquatic subthemes: Watershed Integrity, Water Demand (Agricultural and Urban), Groundwater Recharge Potential, and Priority Resource Areas.

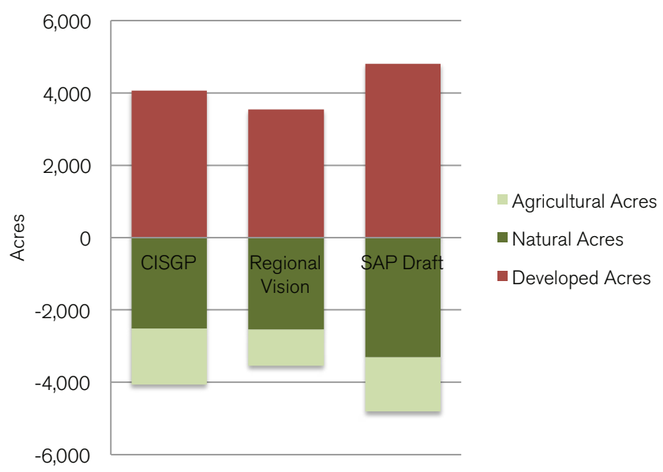
Watershed Integrity has been used by several agencies as an indicator of the "health" of water-related ecosystem processes, functions, and services. Natural land cover within the catchment supports water quality by decreasing the potential for non-point source pollution from runoff. Natural lands proximal to riparian areas are important for filtering out sediment, particles, nitrogen, phosphorous, and other pollutants. The natural land cover in riparian buffers supports natural flow, sediment, and water temperature regimes, and it maintains natural levels of nutrient and organic matter input to streams.

Water Demand (Agricultural and Urban) changes with associated land use. When agricultural lands expand into natural lands, agricultural water demand in that area may increase. Alternatively, urban lands expanding into agricultural lands can reduce agricultural water demand and increase regional urban water demand. Demand can also change when lands are converted from one agricultural type to another.

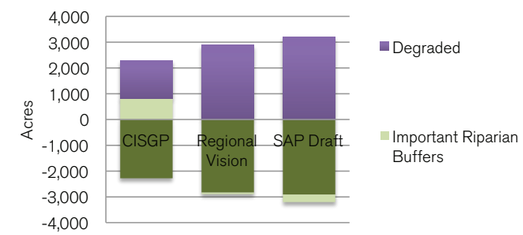
Groundwater Recharge Potential also changes when land cover changes. When natural, agricultural, or developed open space land cover becomes low-, medium-, or high-density urban, the groundwater recharge potential in that area will be reduced. Alternatively, when low-, medium-, or high-density development is returned to natural, agricultural, or developed open space, recharge potential will be restored. The model is used to measure the net change in volume of potential groundwater recharge. The model does not quantify the relationship between groundwater recharge, actual evapotranspiration (AET), and runoff; nor does it quantify the shift in that relationship that was caused by changes in land use and land management.

Priority Resource Areas include wetlands, floodplains, active river areas, and drinking water source watersheds. The change in acreage by type in water resource priority areas provides the spatial extent of land cover change in those areas.

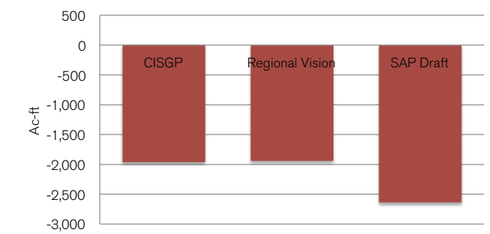
Change in Land Use within Drinking Water Source Watersheds



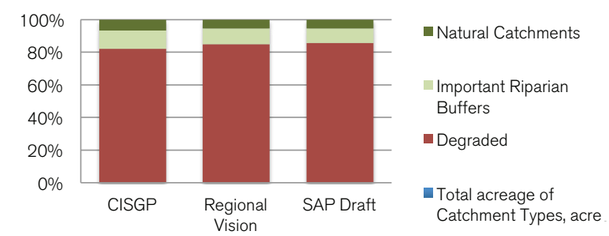
Change in Acreage by Watershed Integrity Class



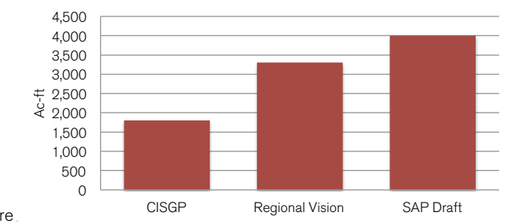
Net Change in Groundwater Recharge Potential



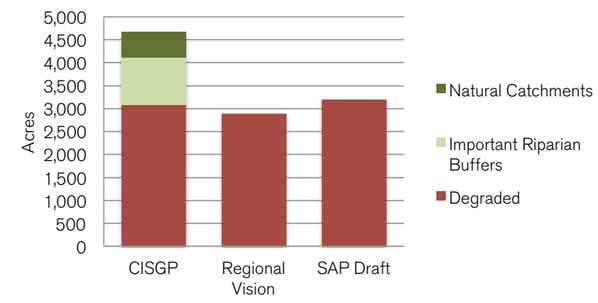
Total Acreage of Catchment Types



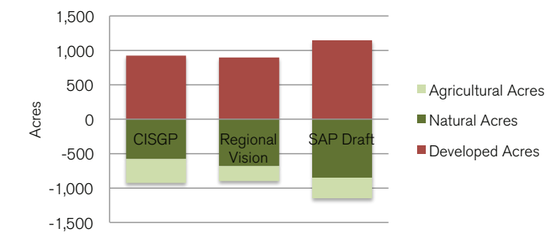
Net Change in Total Water Demand, Ag Loss to Urban Gain



Increase in Catchment Types



Change in Land Use within Active River Area



	CISGP	Regional Vision	SAP
Land Use			
Net Change in Land Use within Wetlands (Developed/ Natural/ Ag), acres			
Developed Acres	20	18	25
Natural Acres	-20	-12	-25
Agricultural Acres	0	-6	0
Total	0	0	0
Net Change in Land Use within Drinking Water Source Watersheds (Developed/ Natural/ Ag), acres			
Developed Acres	4,060	3,542	4,809
Natural Acres	-2,509	-2,543	-3,303
Agricultural Acres	-1,551	-999	-1,506
Total	0	0	0
Net Change in Land Use within Active River Area (Developed/ Natural/ Ag), acres			
Developed Acres	924	898	1,148
Natural Acres	-576	-684	-848
Agricultural Acres	-349	-214	-300
Total	0	0	0
Change in Acreage by Watershed Integrity Class (Natural / Riparian/ Degraded), acres			
Natural Catchments	-2,283	-2,839	-2,908
Important Riparian Buffers	801	-54	-295
Degraded	1,482	2,893	3,203
Total	0	0	0
Net Change in Groundwater Recharge Potential, ac-ft			
Volume Impacted	-1,961	-1,940	-2,637
Catchments			
Change in Acreage of Catchment Types, acres			
Degraded	1,482	2,893	3,203
Important Riparian Buffers	801	-54	-295
Natural Catchments	-2,283	-2,839	-2,908
Total	0	0	0
Total acreage of Catchment Types, acres			
Degraded	39,940	41,351	41,661
Important Riparian Buffers	5,484	4,629	4,388

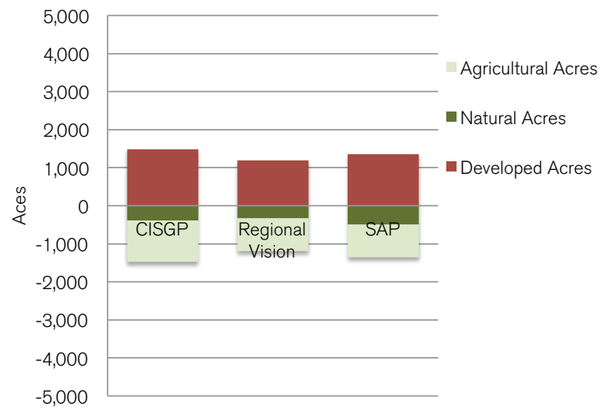
	CISGP	Regional Vision	SAP
Natural Catchments	3,217	2,661	2,592
Total	48,641	48,641	48,641
Increase in Catchment Types, acres			
Degraded	3,080	2,893	3,203
Important Riparian Buffers	1,042	0	0
Natural Catchments	556	0	0
Total	4,678	2,893	3,203
Decrease in Catchment Types, acres			
Degraded	-1,598	0	0
Important Riparian Buffers	-241	-54	-295
Natural Catchments	-2,839	-2,839	-2,908
Total	-4,678	-2,893	-3,203
Demand			
Total Agricultural Water Demand, ac-ft			
Cropland	14,216	16,179	13,942
Deciduous Orchard	233	234	234
Dryland Grain Crops	200	211	267
Evergreen Orchard	26	26	26
Irrigated Grain Crops	469	469	469
Irrigated Hayfield	4,782	4,325	5,070
Irrigated Row and Field Crops	125	125	125
Rice	16,365	16,365	16,365
Vineyard	1	1	1
Total	36,417	37,934	36,500
Net Change in Agricultural Water Demand, ac-ft			
Cropland	-3,445	-1,482	-3,719
Deciduous Orchard	-1		
Dryland Grain Crops	-115	-104	-48
Irrigated Grain Crops	-1	-1	0
Irrigated Hayfield	-1,251	-1,708	-962
Total	-4,812	-3,295	-4,729
Net Change in Urban Water Demand, ac-ft			
Urban Water Demand	6,619	6,595	8,735
Net Change in Total Water Demand (Urban + Agricultural), ac-ft			
Total (Ag+Urban) Water Demand	1,807	3,300	4,006

Comparison in Context: Conservation - Habitat Report

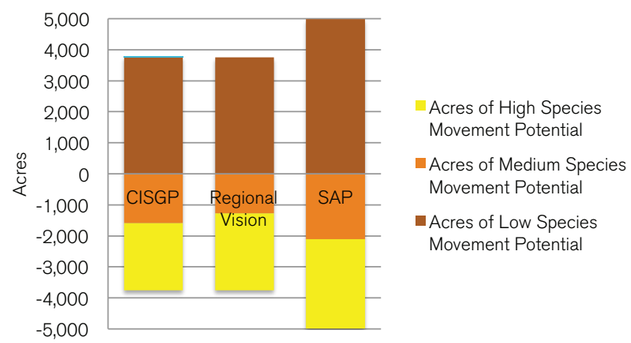
The terrestrial habitat analyses integrates habitat conservation values into a decision-making framework to reveal the impact and benefits of land use change decisions on habitats and associated biodiversity. The metrics specific to terrestrial habitat conservation reveal how land use in an area contributes to habitat value for terrestrial vertebrates, species movement potential, and conservation priority areas.

The Habitat Report focus on the landscape's capacity to facilitate or inhibit species' movement and the suitability of an area's land use for supporting terrestrial vertebrates. Movement potential is evaluated under the assumptions that natural landscapes generally facilitate movement and converted landscapes generally inhibit movement. The terrestrial habitat models also evaluate the acreage affected by proposed land use change that intersects with predefined habitat conservation priorities.

Net Change in Land Use within Essential Connectivity Areas



Net Change in Species Movement Potential

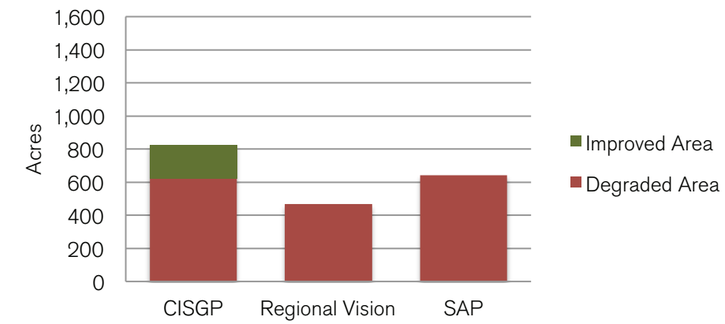


Connectivity	CISGP	Regional Vision	SAP
Net Change in Land Use within Essential Connectivity Areas (Developed/Natural/Ag), acres			
Developed Acres	1,477	1,195	1,353
Natural Acres	-382	-323	-489
Agricultural Acres	-1,095	-872	-864
Total	0	0	0
Net Change in Acres of High, Medium and Low Species Movement Potential, acres			
Acres of Low Species Movement Potential	3,756	3,750	4,981
Acres of Medium Species Movement Potential	-1,588	-1,269	-2,112
Acres of High Species Movement Potential	-2,168	-2,481	-2,869
Total	0	0	0

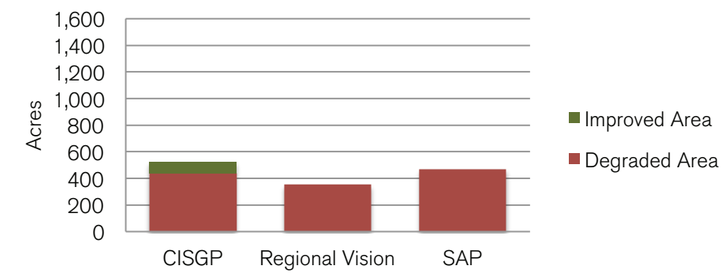
Habitat Degraded and Improved	CISGP	Regional Vision	SAP
Amphibians, acres			
Degraded Area	195	146	204
Improved Area	39	0	0
Total	234	146	204
Birds, acres			
Degraded Area	1,389	1,040	1,430
Improved Area	446	0	0
Total	1,835	1,040	1,430
Mammals, acres			
Degraded Area	864	667	897
Improved Area	228	0	0
Total	1,092	667	897
Reptiles, acres			
Degraded Area	638	460	640
Improved Area	132	0	0
Total	769	460	640
Threatened and Endangered Species, acres			
Degraded Area	621	468	642
Improved Area	202	0	0
Total	823	468	642
Species Vulnerable to Climate Change (except Birds), acres			
Degraded Area	439	353	469
Improved Area	84	0	0
Total	523	353	469
Birds Vulnerable to Climate Change, acres			
Degraded Area	1,141	859	1,195
Improved Area	419	0	0
Total	1,560	859	1,195
Bald Eagle, acres			
Bald Eagle Degraded	3,753	3,033	4,533
Bald Eagle Improved	2,067	0	0
Total	5,820	3,033	4,533
Swainson's Hawk, acres			
Swainson's Hawk Degraded	5,634	3,711	5,005
Swainson's Hawk Improved	721	0	0
Total	6,354	3,711	5,005

	CISGP	Regional Vision	SAP
Sandhill Crane, acres			
Sandhill Crane Degraded	4,079	3,539	4,806
Sandhill Crane Improved	2,068	0	0
Total	6,147	3,539	4,806
Loggerhead Shrike, acres			
Loggerhead Shrike Degraded	6,243	3,814	5,052
Loggerhead Shrike Improved	8	0	0
Total	6,252	3,814	5,052
California Towhee, acres			
California Towhee Degraded	273	279	250
California Towhee Improved	489	0	0
Total	762	279	250
Savannah Sparrow, acres			
Savannah Sparrow Degraded	4,081	3,541	4,809
Savannah Sparrow Improved	2,076	0	0
Total	6,157	3,541	4,809
California Vole, acres			
California Vole Degraded	6,041	3,815	5,052
California Vole Improved	286	0	0
Total	6,328	3,815	5,052
Red Fox, acres			
Red Fox Degraded	4,314	3,542	4,809
Red Fox Improved	1,844	0	0
Total	6,157	3,542	4,809
Common Gartersnake, acres			
Common Gartersnake Degraded	4,082	3,542	4,809
Common Gartersnake Improved	2,076	0	0
Total	6,157	3,542	4,809
Giant Gartersnake, acres			
Giant Gartersnake Degraded	3,742	3,030	4,530
Giant Gartersnake Improved	2,076	0	0
Total	5,818	3,030	4,530

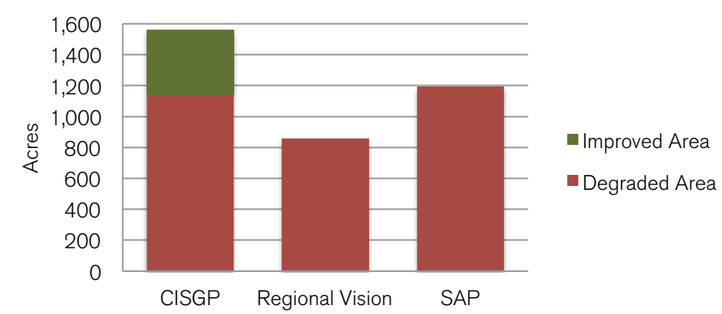
Habitat for Threatened and Endangered Species



Habitat for Species Vulnerable to Climate Change (except Birds)



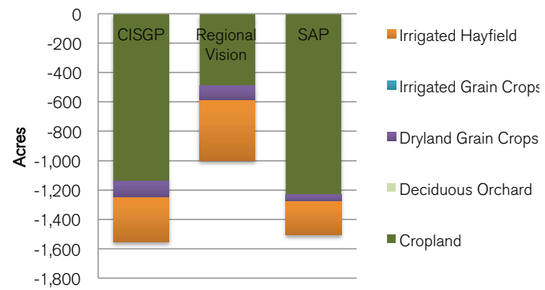
Habitat for Birds Vulnerable to Climate Change



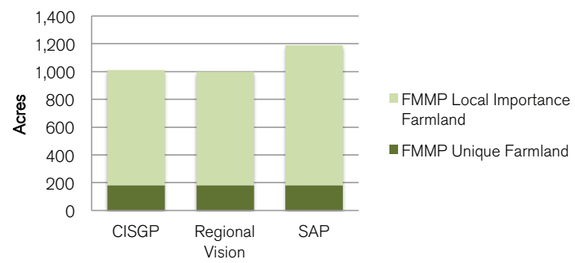
Comparison in Context: Conservation - Agriculture Report

The Agriculture Report focuses on the conversion of land to and from agricultural and non-agricultural uses. Broadly, metrics are classified into three groups—agricultural capacity, agricultural acreage, and agricultural production. Agricultural capacity calculates the impact of development in areas considered important for agriculture. Agricultural acreage calculates the change in acreage of agricultural land by agricultural type through expansion of agricultural land on urban or natural lands, and consumption of agricultural land by urban lands. Agricultural production represents how the above changes affect the monetary value of crop production in the region studied. When agricultural lands expand into natural lands, local agricultural production may increase. On the other hand, the expansion of urban lands into agricultural lands can reduce agricultural production. Production value also changes when agricultural lands are converted from one agricultural type to another.

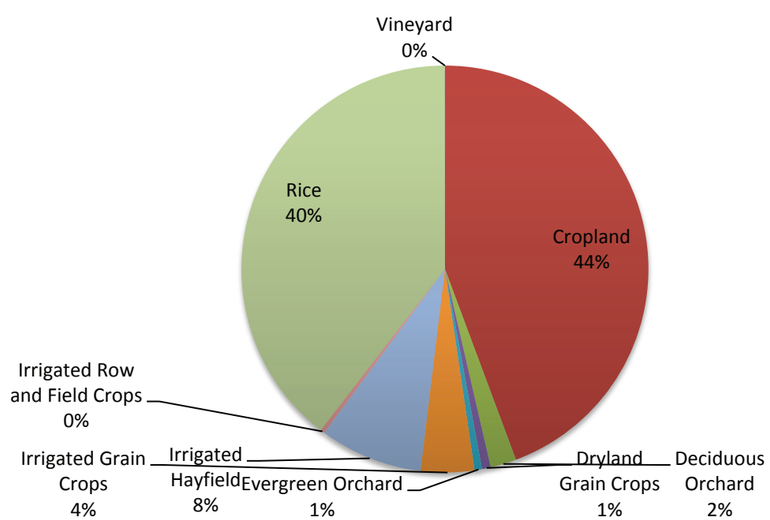
Net Change in Crop Class



Development on Cultivated Crop Lands



Total Production Value of CISGP and 2 Mile Surrounds



	CISGP	Regional Vision	SAP
Total Production Value, $			
Cropland	5,801,390	6,602,443	5,689,698
Deciduous Orchard	269,251	270,077	270,077
Dryland Grain Crops	91,541	96,478	122,295
Evergreen Orchard	77,356	77,356	77,356
Irrigated Grain Crops	556,103	556,103	556,556
Irrigated Hayfield	1,070,924	968,531	1,135,549
Irrigated Row and Field Crops	46,504	46,504	46,504
Rice	5,172,583	5,172,583	5,172,583
Vineyard	1,590	1,590	1,590
Total	13,087,242	13,791,665	13,072,207
Net Change in Production Value, $			
Cropland	-1,405,890	-604,837	-1,517,582
Deciduous Orchard	-826	0	0
Dryland Grain Crops	-52,559	-47,622	-21,805
Irrigated Grain Crops	-905	-905	-452
Irrigated Hayfield	-280,110	-382,503	-215,486
Total	-1,740,291	-1,035,867	-1,755,326
Total Acreage by Crop Class, acres			
Cropland	4,701	5,351	4,611
Deciduous Orchard	73	73	73
Dryland Grain Crops	198	209	264
Evergreen Orchard	8	8	8
Irrigated Grain Crops	273	273	274
Irrigated Hayfield	1,135	1,027	1,204
Irrigated Row and Field Crops	48	48	48
Rice	2,945	2,945	2,945
Vineyard	0	0	0
Total	9,381	9,933	9,426
Net Changes in Acreage by Crop Class, acres			
Cropland	-1,139	-490	-1,230
Deciduous Orchard	0	0	0
Dryland Grain Crops	-114	-103	-47
Irrigated Grain Crops	0	0	0
Irrigated Hayfield	-297	-405	-228
Total	-1,551	-999	-1,506
Development on Cultivated Crop Lands, acres			
FMMP Unique Farmland	181	181	181
FMMP Local Importance Farmland	830	818	1,008
Total	1,010	999	1,189

Natural Systems

Why include natural systems?

Studying the natural systems reveal what is possible, useful, and beautiful about the West Placer Prairie. It shows us the interconnectivity of how the earth works and provides us with models to evaluate the effects of proposed changes. All changes create ripple effects and the systems approach helps us to think about where the ripples are going, and where they coincide.

In this section we connect the lines between various natural sciences to get a holistic picture of the site. The following analysis contributed to our decision making in the CISGP. Read on to learn more about:

Cycle of Change

Watersheds

Water Dynamics

Soil Dynamics

Species Displacement & Migration

Cycles of Change

Dry Season

Summer

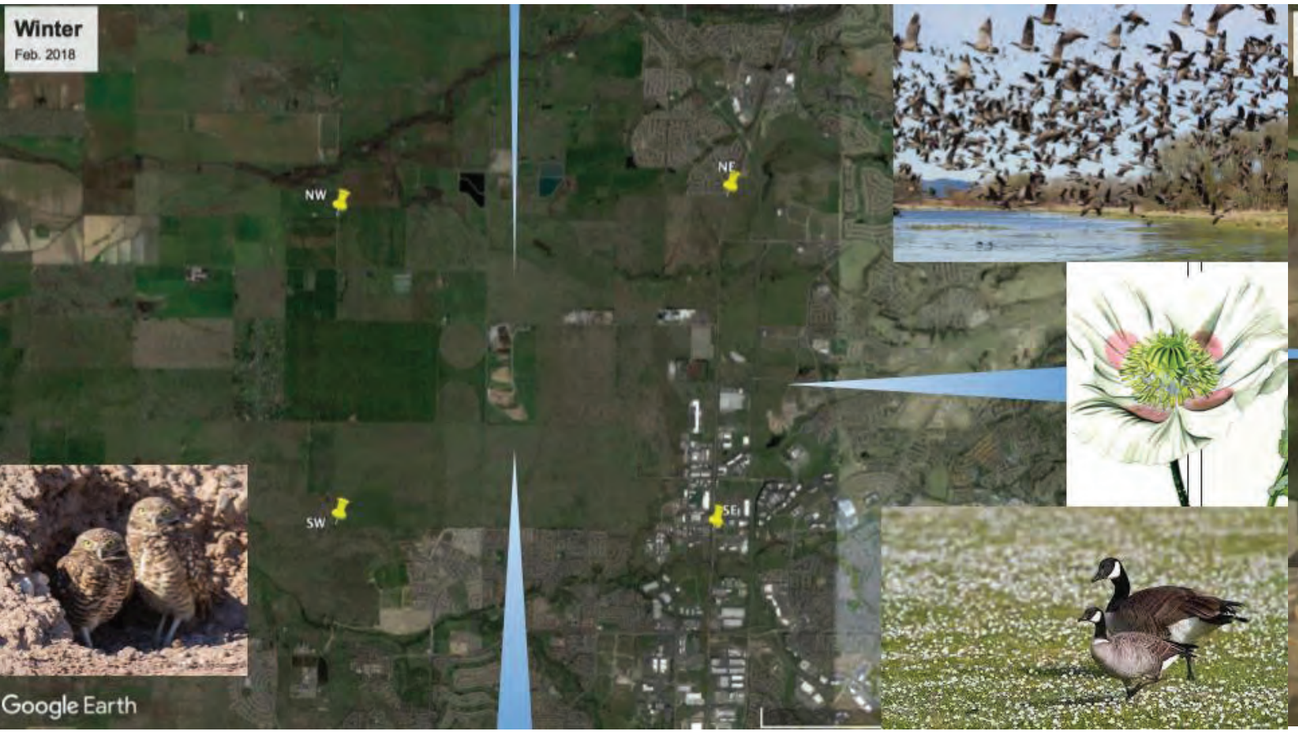
Summers are hot, arid, and very bright. Like every summer, there are few trees and little shade, no rain, and no cloud cover. The grass, mostly native, dances in a light southwesterly breeze. With so much sun the prairie grasses grow quickly and dry them out. Some farmers irrigate.

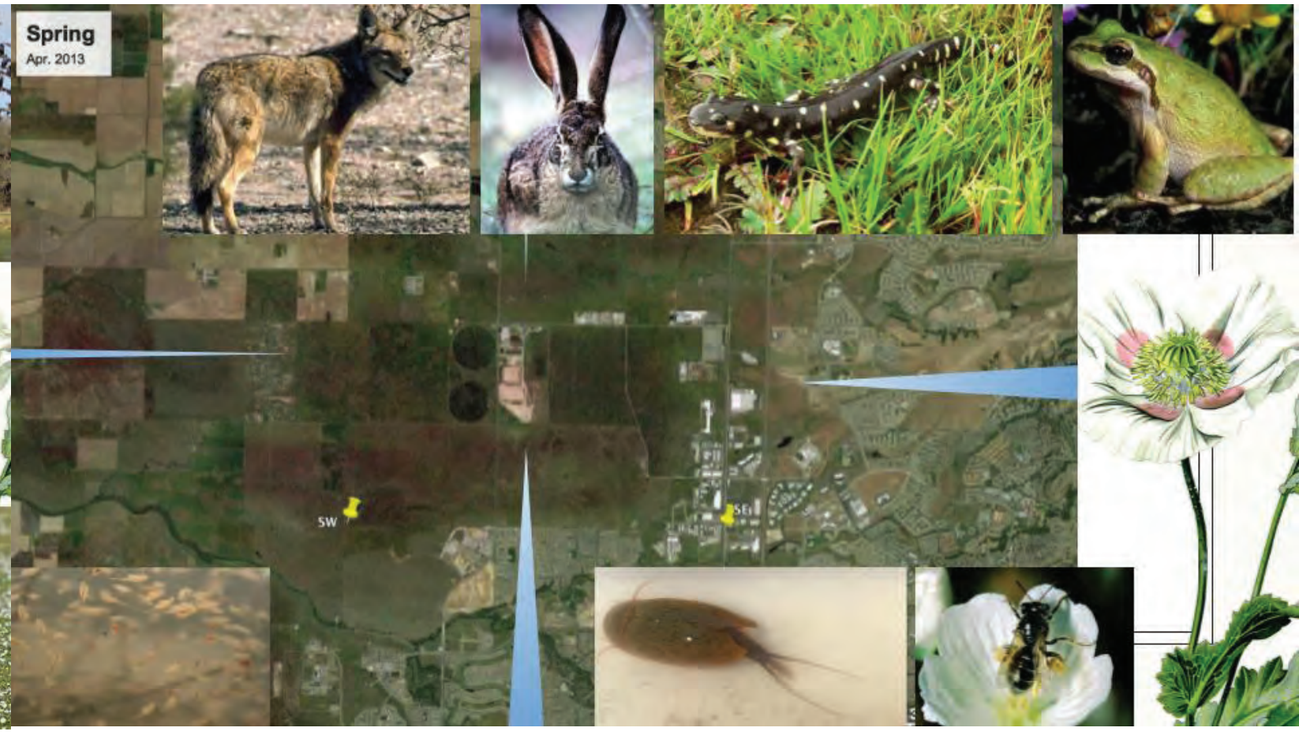
By July, the Swainson's hawks swoop through the sky eating the grasshoppers and caterpillars. Flocks of listed endangered tri-colored blackbirds chase insects in unison, flashing their red shoulder pads. Meadowlarks walk in the grass foraging for seeds. These birds are for the moment lucky, for birds of grassy habitats are among the fastest declining species in North America.

Fall

As November comes, the peak growing season ends. The winds pick up and shift to the south east, blowing in cloud cover. As the climate cools and rains start, the Botta Pocket Gophers look forward to enjoying their stockpiles. Cosy in their shallow burrows, they remember tilling the ground to fertilize the native grasses, observing the roots of their labor poke through their ceilings, and harvesting the lot by stuffing their fur-lined cheek pouches to the brim. Yet they must not become sedate, as the California king snake laid eggs in their tunnel mid summer. Any day they will hatch and begin exploring the tunnel system.

Images and Information from:
American Audubon Society, Sac Splash, and www.weatherspark.com





Wet Season

Winter

Winter is wet and temperatures range from days in mid-50s to nights in mid-40s. The sky is overcast half of the time and 4-5 inches of rain will fall each month from December to March. The Pacific Flyway becomes full of winged traffic, as the Winged Migration enters our region. Early winter, waterfowl arrive and hang out at water treatment ponds and rice fields during the night and forage in the grasslands during the day. Burrowing owls explore gopher holes for burrows.

As the season progresses, the rich soil becomes saturated as a layer of clay below slows water's decent to the aquifer. Soon, the water will puddle on the surface and form vernal pools. In these, amphibians will lay their eggs and mate.

By mid December the vernal pools begin to fill. By returning to these vernal pools, small and mid sized white cheeked goose populations sustain themselves in the winter, during spring migration and also during the subsequent nesting season.

Spring

Amphibians and insects team in the vernal pool breeding grounds. Micro-life and invertebrates, including the listed endangered fairy shrimp and the listed endangered tadpole shrimp, flourish in their wet world. Their population booms attract the rest of the food chain– migratory and regional birds, mammals and reptiles are drawn into the vernal pool grasslands to feast! Each vernal pool has its own specialized biodiversity, adapted to its specific micro conditions, making a buffet with endless variety.

Through early spring, half of the days are cloudy and rainy with a southeasterly wind, refreshing the pools and keeping the biosphere cool. As temperature warms mid march, prairie growing season takes off and amphibians travel away from the drying vernal pools in search of burrowing places. The solitary bee juggles pollen collection with digging egg tunnels in the dirt before the ground hardens.

The race now begins for amphibians to travel away from the drying vernal pools in search of burrowing places. The solitary bee juggles pollen collection with digging egg tunnels in the dirt before the ground hardens. Notice the wildflower color on the satellite map coming in.

Images and Information from:
American Audubon Society, Sac Splash, and www.weatherspark.com

Watersheds

The Sunset Area is home to the headwaters of two watersheds, the Auburn Ravine and Coon Creek Watershed and the Pleasant Grove and Curry Creek Watershed. Both of these watersheds drain into the Sacramento River, irrigate crops, and flow through the delta to the Pacific Ocean. The below image shows the Sunset Area in relation to watersheds throughout the county.

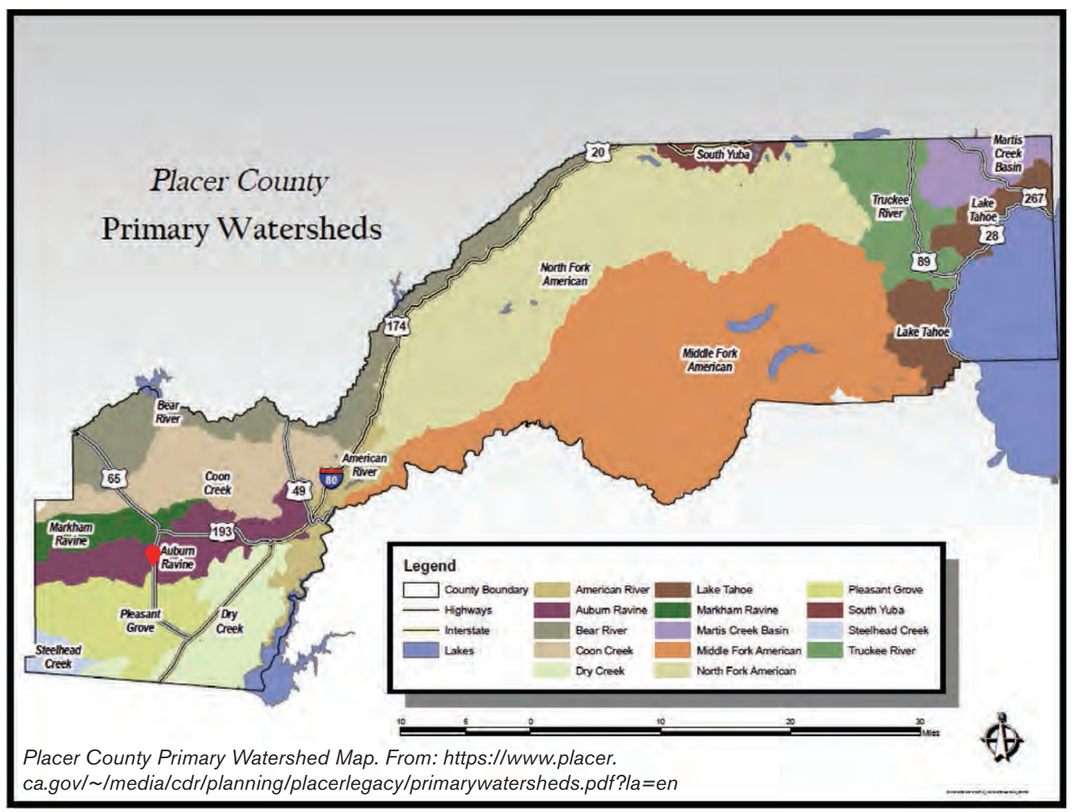
On the facing page, the Sunset Area is overlaid on both watershed maps. The top map, featuring the northern watershed of the site, Auburn Ravine, shows that the last headwaters enter the stream from the SA. All headwaters upstream run through urbanized areas.

In the Pleasant Grove Curry Creek map, the health of the streams is indicated by their color. It shows that when streams flow through urban areas, their health is diminished. The streams in the SA follow this pattern.

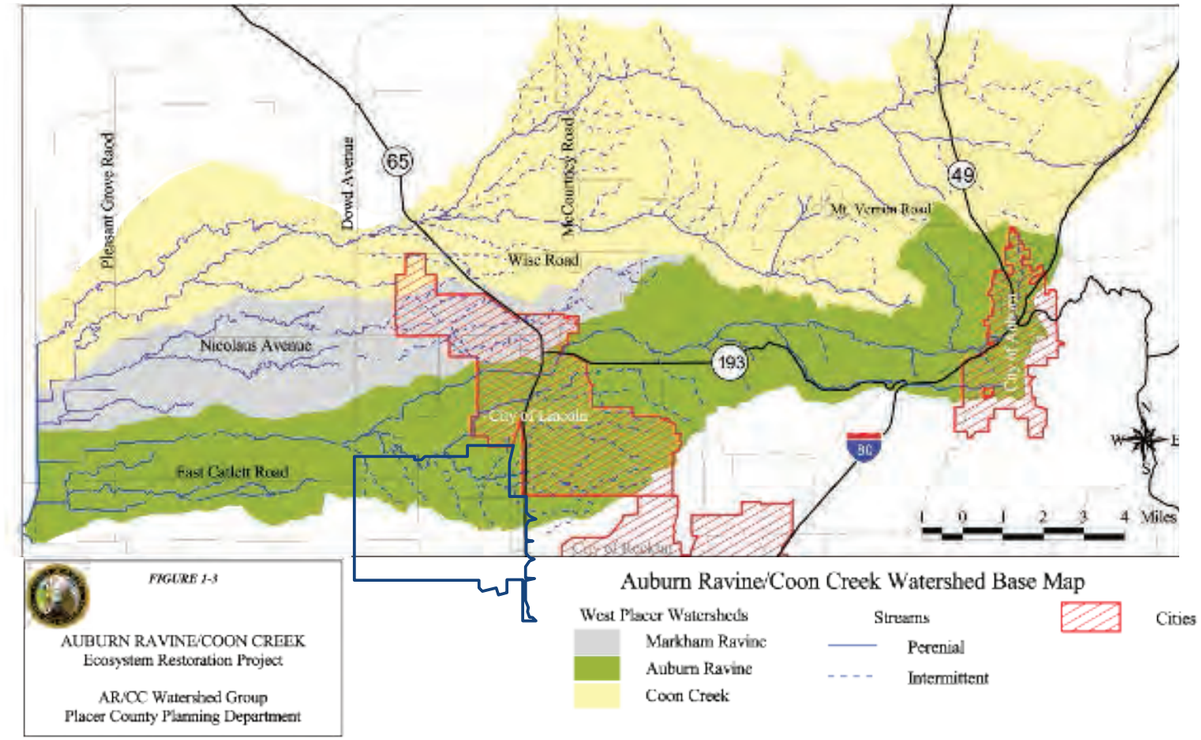
Water Dynamics

The map on the following spread examines how the headwaters engage with the terrain and calls out areas of interest. The divide runs NW to SE. The SA has first, second and third order streams. The arrow heads show the direction the water flows. The map includes:

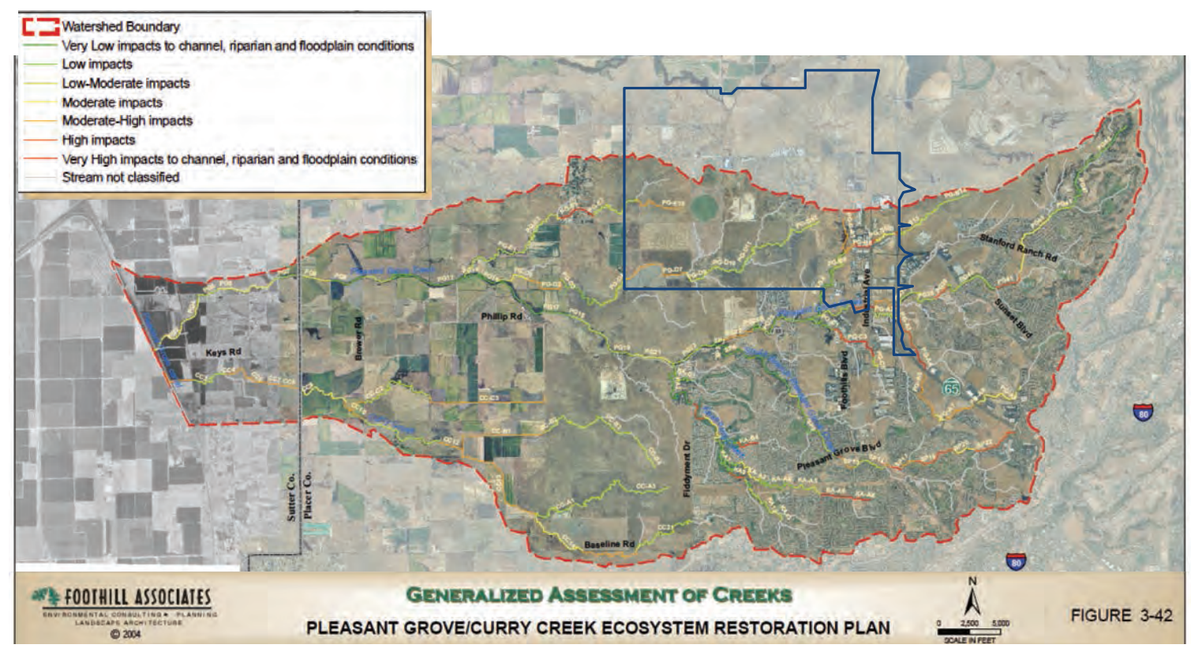
- USGS National Hydrography Dataset
- USGS National Watershed Boundary Dataset
- FEMA National Flood Hazard Map
- Holding Ponds traced from Satellite
- Placer County Grassland and Vernal Pool Complex Map (used for PCCP)



Placer County Primary Watershed Map. From: https://www.placer.ca.gov/~/media/cdr/planning/placerlegacy/primarywatersheds.pdf?la=en



Above: "Auburn Ravine/Coon Creek Watershed Base Map" Figure 1-3. Auburn Ravine/Coon Creek Ecosystem Restoration Project. ARCC Watershed Group & Placer County Planning Department. 2002.
Below: "Generalized Assessment of Creeks" Figure 3-42. Pleasant Grove/Curry Creek Ecosystem Restoration Plan. Foothills Associates, 2004.



Legend

SIA_Boundary

FEMA National Flood Hazard Layer

High Water Marks

Water Lines

Levees

General Structures
- Flood Structure
- Bridge
- Dam, Weir, Jetty
- Other Structure

Hydrologic Reaches

Flood Hazard Boundaries
- Limit Lines
- SFHA / Flood Zone Boundary
- Other Boundaries

Flood Hazard Zones
- 1% Annual Chance Flood Hazard
- Regulatory Floodway
- Special Floodway
- Area of Undetermined Flood Hazard
- 0.2% Annual Chance Flood Hazard
- Future Conditions 1% Annual Chance Flood Hazard
- Area with Reduced Risk Due to Levee

Alluvial Fans

Water Areas

USGS National Hydrography Dataset (NHD) - External Service

Point
- Dam/Weir
- Other

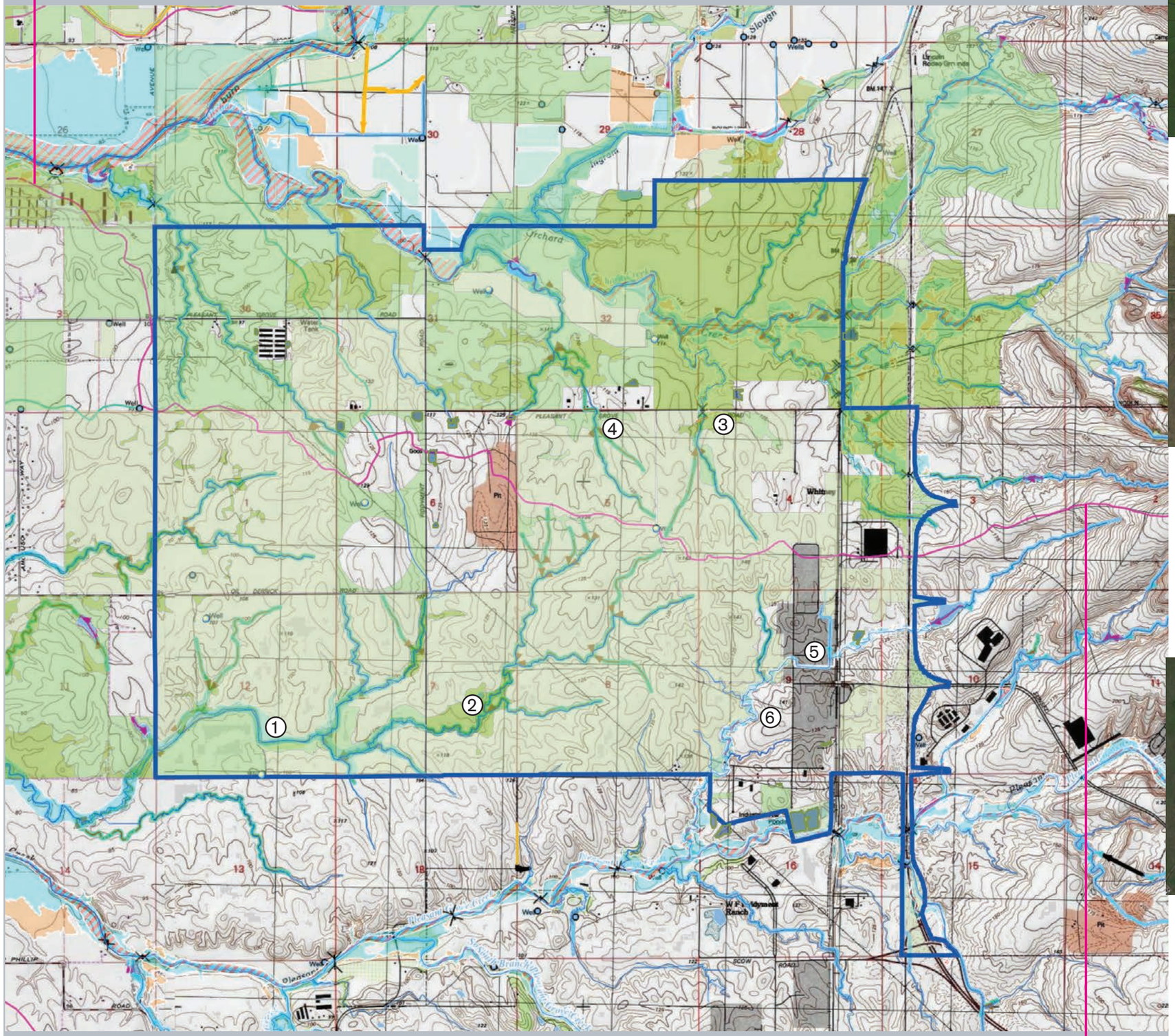
Point Event
- Dam
- Gaging Station
- Divergence Structure
- Other

Line - Large Scale
- Tunnel
- Line

Flow Direction
- Connector
- CanalDitch
- Underground Conduit
- StreamRiver
- StreamRiver - Perennial
- StreamRiver - Intermittent
- StreamRiver - Ephemeral
- Pipeline
- Artificial Path

Flowline - Large Scale
- Perennial
- Intermittent
- Ephemeral
- Artificial Path
- Canal Ditch
- Coastline
- Connector
- Pipeline
- Underground Conduit

Auburn Ravine Watershed, Orchard Creek Tributary



Pleasant Grove and Coon Creek Watershed

Headwater Tributary of Pleasant Grove Creek covers an approximately 1 mi x 3 mi area. (1) Altered stream course for rice field. (2) Healthy meanders.

(3) Athens Ave. divides the upper and lower catchment area for the Orchard Creek Tributary. The headwaters pass under the road in two areas and frequently pool near the culvert. (4) The stream course has been realigned and tunneled to pass through the Athens Industrial Area. These crossings deliver headwaters from a large catchment area to conservation protected vernal pool lands near the tributary. The headwaters also feature many upland vernal pools in intermediate complexes.

(5) Headwater Tributary of Pleasant Grove Creek passes under Hwy 65 and is paved over through the current industrial area. As this tributary has a large catchment area, it has high value as a Riparian Corridor, much needed habitat within the site boundaries. (6)After the tunnel, the stream course is healthy with good meanders.

Streams

The stream courses provide drainage throughout the year and are pleasing natural features with lots of meanders. The proper stream course setback enables the natural water system to filter and acclimate water before it enters larger aquatic habitats. This minimizes the disruption of the aquatic ecosystem, such as that of Pleasant Grove creek adjacent to development.

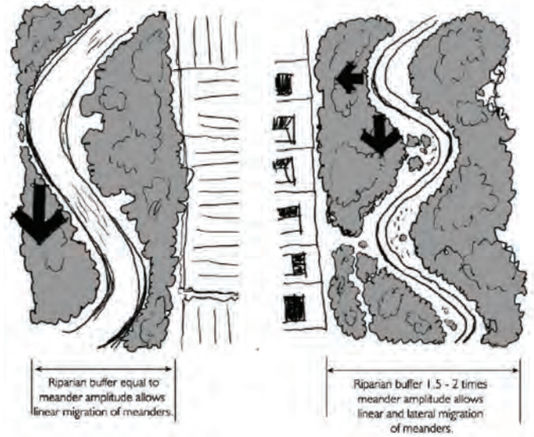
What makes a good stream course setback?

A good stream course setback lets the local natural hydrological system continue to function. There are many ways to calculate setbacks, and we have chosen a setback system determined from a scientific study of the stream courses in Western Placer County. These setbacks take account of the unique prairie conditions that more general setback methodologies do not include. It also encompasses recommend setbacks from both relevant watershed ecosystem restoration plans.

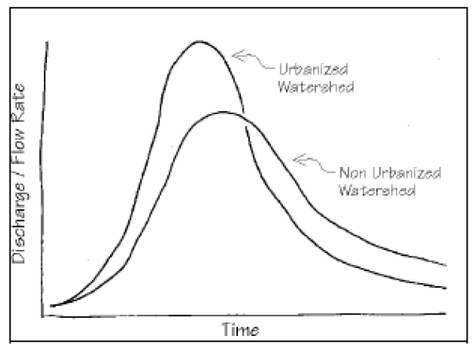
In Setbacks, Placer County Zoning Ordinance, Section 17.54.130.D.3 of the General Plan, it states that Community Plans, such as the SAP, will specify the required watercourse setbacks for the area they cover. The specified set backs should be:

1st & 2nd Order Streams: 98 ft. + floodplain
3rd + Order Streams: 656 ft. + floodplain

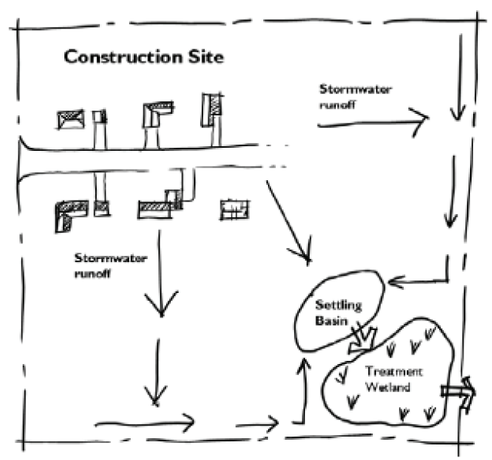
Unlike the county-wide setback standards, this recommendation takes account of the floodplain and width of water course as well as the stream hierarchy. It will provide enough space for the water courses to continue to meander and shift across the prairie. This is illustrated in the Riparian Buffer Widths as a function of Meander Amplitude diagram from the Pleasant Grove/Curry Creek Ecosystem Restoration Plan. The wider setback also aids in slowing the speed of the water discharge after a rain event. Hard surfaces create faster run off which create many problems, from more erosion to less water absorbed for the dry season.



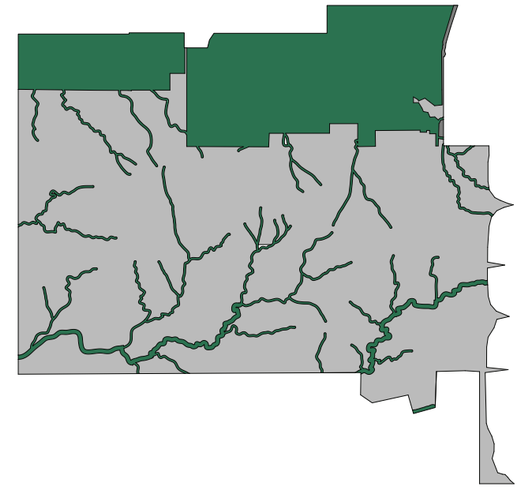
Riparian Buffer Widths as a function of Meander Amplitude



Hydrograph comparison between non-urbanized and urbanized watersheds.



Detention Wetland Used to Filter Sediment on Construction Site.
Above three diagrams from: Foothills Associates. Pleasant Grove and Curry Creek Ecosystem Restoration Plan. 2004.

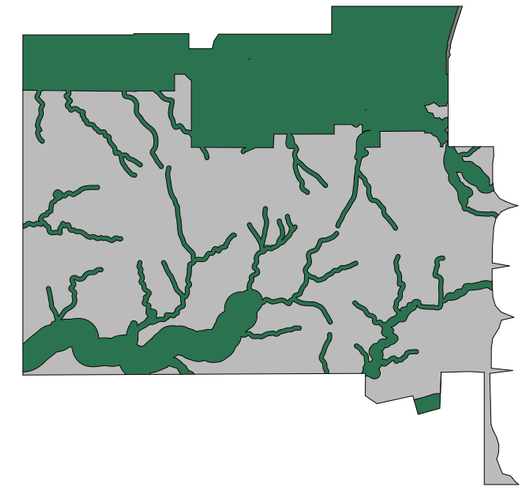


General Plan Stream Course Setbacks and Existing Protected Areas

Stream Course Setbacks from Placer County Zoning Ordinance, Section 17.54.130:

Intermittent Streams: 50 ft.
Permanent Streams: 100 ft.

This delineates 29% of the site open space.



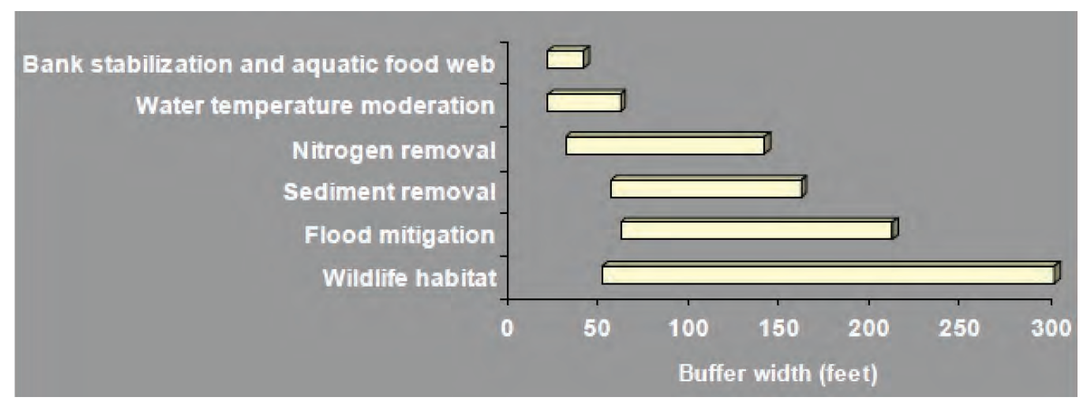
West Placer Specific Stream Course Setbacks and Existing Protected Areas

Stream Course Setbacks from "Setback Recommendations to Conserve Riparian Areas and Streams in Western Placer County" prepared for Placer County Planning Department by Jones & Stokes and PRBO Conservation Service, 2005:

1st and 2nd Order Streams: 98 ft. + floodplain
3rd + Order Streams: 656 ft. + floodplain

This delineates 37% of the site as open space.

Slow discharge is also fundamental to filtering of the water. As shown in the construction site diagram, surface water should first go to a settling basin and then through a treatment wetland before entering a stream course. The wider setback accommodates this process.



Minimum Riparian Buffer Widths, featuring the space needed for various functions. Foothills Associates. Pleasant Grove and Curry Creek Ecosystem Restoration Plan. 2004.

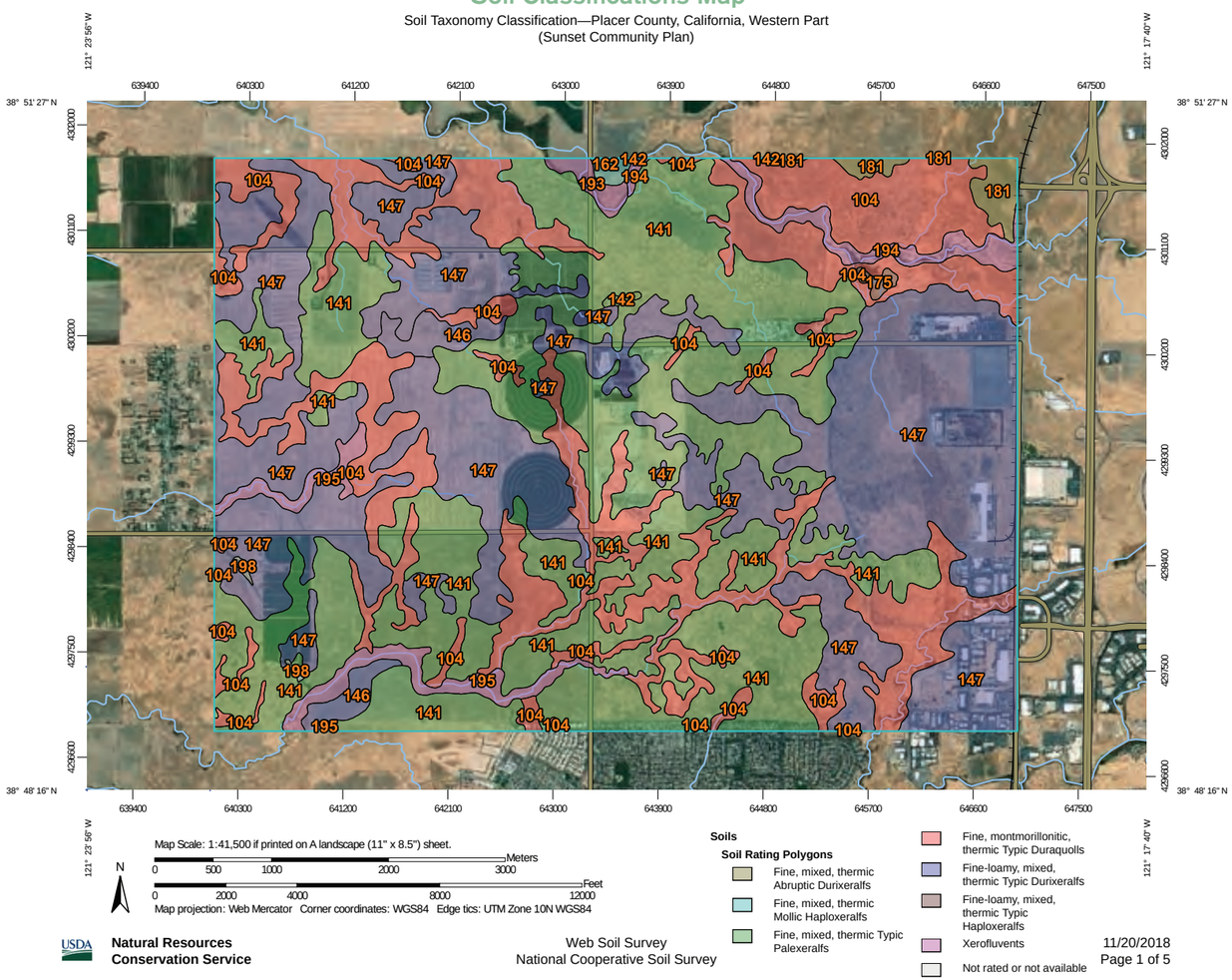
Soil Dynamics

Three main soil taxonomies dominate the composition, covering 98.3% of the surface area: the Cometa-Fiddyment complex, Fiddyment-Kasebery loams, and the Alamo-Fiddyment complex. Eight other taxonomies make up the remaining 1.7% and are primarily located in the existing reserve area stream beds. The soil types have 12" to 18" of fluffy sponge-like topsoil resting on nearly water-repellent clay hard pans 1" to 16" thick. The fluffiness of the sponge determines how much water the soil can hold, and the hard pan directs water along it's surface to the stream system. A small amount of water will infiltrate through the clay to the water table. Together, the interaction of the water and soil enable the emergence of vernal pools.

Each of the three main soil taxonomies have different ratios of soils: cometa soil, fiddyment soil, kaseberg soil, and alamo soil. Alamo soil is entirely clay. The bedrock can be quite shallow and is sandstone and siltstone. For the full breakdown see the Soil Properties Table on the next spread.

Soil Classifications Map

Soil Taxonomy Classification—Placer County, California, Western Part
(Sunset Community Plan)



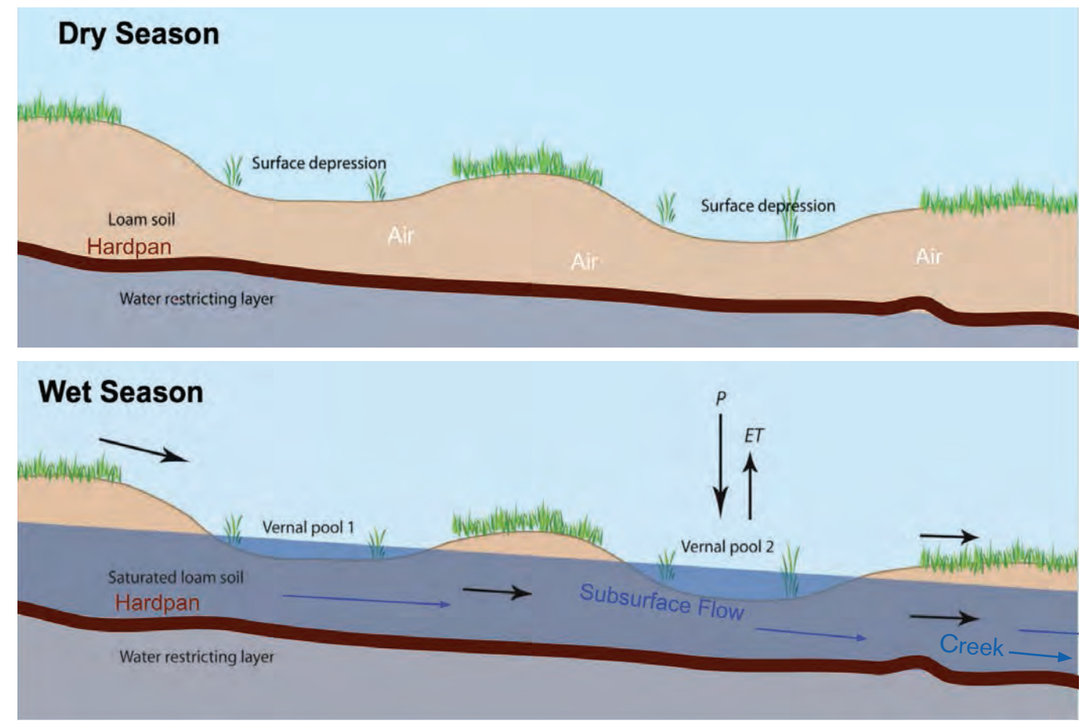
Preparing for Construction

The Natural Resources Conservation Service identifies all the main soil types as having properties that severely limit their abilities to support buildings. Fiddyment soil is the most accommodating soil, providing only moderate limitations for shallow excavation. The limitations for the other types are either related to water or the shallowness of bedrock/cemented clay pan. These limitations for construction are the features that enable and sustain the vernal pool landscape.

To prepare th soil for construction, it is likely that the soil will be scraped deeply and compacted with lime or other stabilizers to manufacture the desired structural properties. This will require specialty equipment. To eliminate complexity, entire parcels will be compacted and shaped by deeply cut roads, drains and overflow ponds. Such soil preparation is irreversible.

Vernal Pool Conceptual Cross Section

During the dry season, the soil is 45-50% air. Rain fully saturates the soil in the wet season, pushing the air out. 40-60% of the water content at any given place is from direct rainfall, while the rest comes from subsurface flow from adjacent uplands.



Vernal Pool Conceptual Cross Section. Niall McCarten, UC Davis, Dept of Land, Air and Water Resources, with subsurface flow and creek added by Genevieve Marsh

Soil Properties Table

Map unit symbol & color	Map Unit Name	Description	Acres in AOI	Percent of AOI	Topsoil	Clay Pan Layer	Restrictive Soil Features: Restrictive Soil Features	Restrictive Soil Features: Small Buildings no basements	Restrictive Soil Features: Local Roads and Streets
141	Cometa-Fiddyment complex, 1 to 5 percent slopes	35% Cometa Soil: Deep well-drained claypan soil with slow surface runoff. Available water capacity is 4 to 6 inches.	2,993.0	35.8%	18" sandy loam	18" to 29"	Severe. Too clayey.	Severe. Shrink-swell, low strength.	Severe. shrink-swell, low strength.
		35% Fiddyment Soil: Well drained and moderately deep over a hardpan. Water capacity is 2 to 3.5 inches. Permeability is very slow. Underlain with silica-indurated siltstone.			12" loam and silt	12" to 28"	Moderate. Depth to rock, cemented pan, too clayey.	Severe. Shrink-swell.	Severe. Shrink-swell, low strenth.
147	Fiddyment-Kaseberg loams, 2 to 9 percent slopes	50% Fiddyment Soil	2,932.4	35.1%	12" loam and silt	12" to 28"	Moderate. Depth to rock, cemented pan, too clayey.	Severe. Shrink-swell.	Severe. Shrink-swell, low strenth.
		30% Kaseberg Soil: Shallow well drained soil over a hardpan. The available water capacity is 1.5 to 3.5 inches. Underneath is siltstone. Permeability is moderate.			14" loam and motiles in top 8"	16" to 17"	Severe. Depth to rock, cemented pan.	Severe. Depth to rock, cememted pan.	Severe. Cemented pan, depth to rock.
104	Alamo-Fiddyment complex, 0 to 5 percent slopes	50% Alamo Soil: poorly drained clay this is moderately deep over a hardpan. The availiable water capacity is 2.5 to 6 inches. Surface run off is slow or ponded.	1,915.9	22.9%	37" clay	37" +	Severe. Wetness, too calyey, floods.	Severe. Wetness, floods, shrink, swell.	Severe. Wetness, low strength, shrink-swell.
		30% Fiddyment Soil: Underlain with hard sandstone.			12" loam, 23" clay loam	28" to 35"	Moderate. Depth to rock, cemented pan, too clayey.	Severe. Shrink-swell.	Severe. Shrink-swell, low strenth.
195	Xerofluvents, hardpan substratum	Along intermittent stream courses in Pleasant Grove Watershed catchment area.	154.0	1.8%	x				
194	Xerofluvents, frequently flooded	Orchard Creek bed.	105.2	1.3%					
146	Fiddyment loam, 1 to 8 percent slopes	Two pockets, both on the western side of the site, one near the conservation parcels and the other near crossing the south border.	103.0	1.2%					
181	San Joanquin Sandy loam, 1 to 5 percent slopes	In NE existing reserve area.	69.7	0.8%					
193	Xerofluvenets, occasionally flooded	Adjacent to Orchard Creek bed in existing reserve area.	33.9	0.4%					
162	Kilaga Loam	Adjacent to Orchard Creek bed in existing reserve area.	15.9	0.2%					
175	Ramona sandy loam, 2 to 9 percent slopes	In NE existing reserve area.	12.5	0.2%					
142	Cometa-Ramona sandy loams, 1 to 5 percent slopes	In existing reserve area.	7.0	0.1%					
198	Water	SW corner of site.	6.9	0.1%					
Total AOI	Total		8,349.4	99.9%					

The Soil Properties Table summarizes the findings of the Natural Resources Conservation Service. The right side of the table evaluates each type for its ability to support shallow excavation, small buildings, and paved roads.

Soil Compaction Resistance

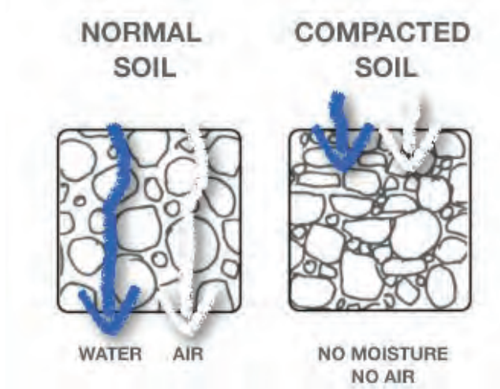
Normal soil has large air pockets, called pores, that allow water and nutrients to move down to plant roots and the water table. Compaction squeezes the air out of the soil and reduces the size of pores, limiting water infiltration and increasing runoff. These factors change plant production and composition and the arrangement of organisms living in the soil within the compacted areas as well as adjacent normal soil areas. With greater runoff, erosion increases. **To best protect the reserve areas, the natural water flow on top of and in the soil should be maintained and mimicked.**

The Soil Compaction Map rates each soil for its resistance to compaction. Red, representing "Low resistance", indicates that the soil has one or more features that make it susceptible to compaction and will not re-expand to its initial state overtime.

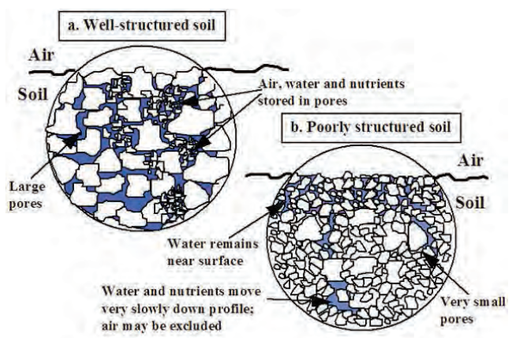
To avoid compaction, these soils should not be cultivated or driven on when wet. Dwelling and road construction can be designed to offset the shrink-swell potential and the load-bearing strength of the soils.

Shrink-Swell

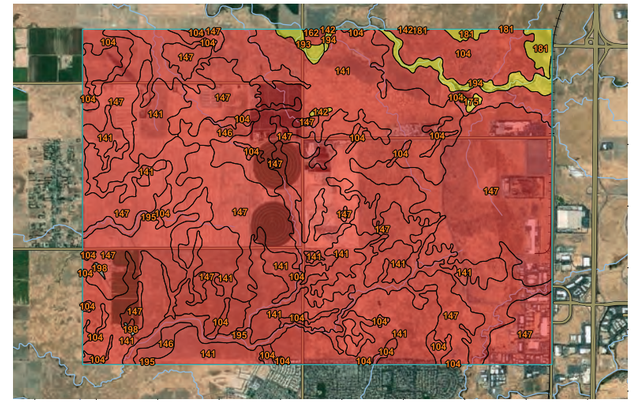
As the soil sponge absorbs and releases water, it expands and contracts– moving everything on top of it. For brittle objects, such as roads and foundations, cracking occurs. In the Expansive Soil Process Diagram, notice how when the rain falls on a new road, the edges of the road curl up because water has only infiltrated the soil accessible to direct rainfall. As the road ages, subsurface flow saturates the soil under the road. The water in soil under the road cannot evaporate, and does not have roots collecting it. The water in the soil next to the road depletes faster and the soil shrinks. With the soil under the road still expanded, it creates a bulge effect. Shrink-swell, along with other factors listed in the Soil Properties Table, are why the Suitability of Local Roads and Streets and Suitability for Small Buildings is Somewhat Limited (yellow) to Very Limited (red).



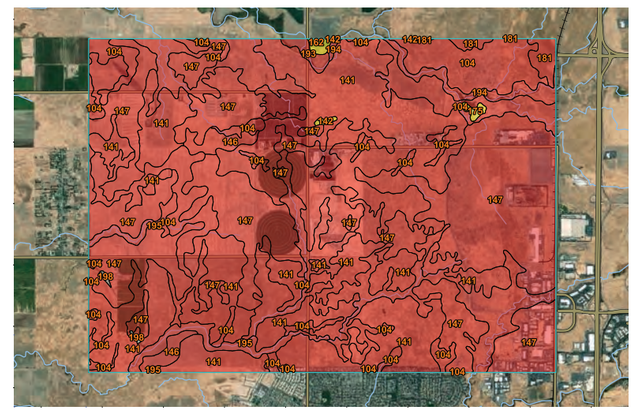
Michael-Anne Foley, Butte County Master Gardener. The Real Dirt Blog. University of California Division of Agriculture and Natural Resources.



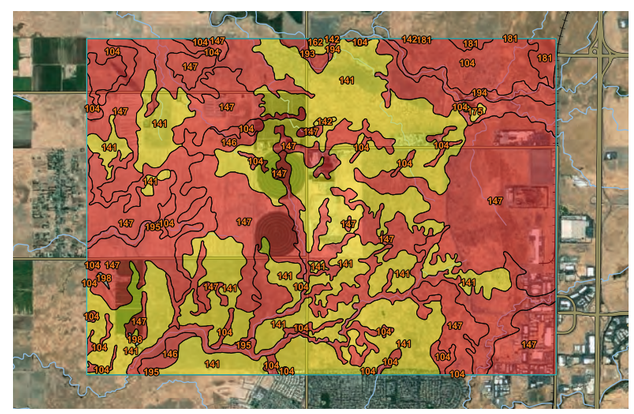
Dr. Adriana Arango, Department of Forestry and Horticulture. The Connecticut Agricultural Experiment Station.



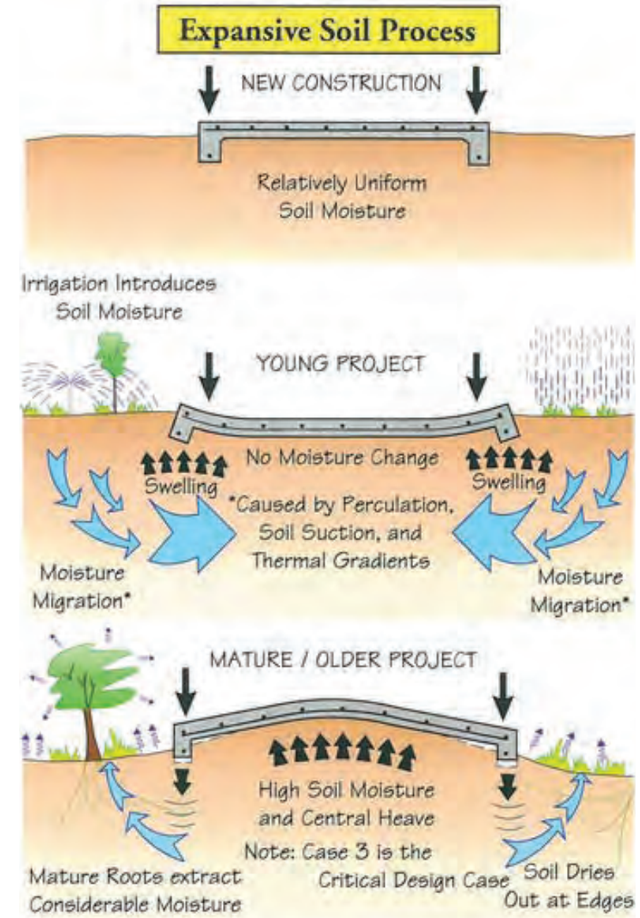
Soil Compaction Resistance Map. Web Soil Survey, Natural Resources Conservation Service.



Suitability of Local Roads and Streets. Web Soil Survey, Natural Resources Conservation Service.



Suitability for Small Buildings. Web Soil Survey, Natural Resources Conservation Service.



Expansive Soil Process Illustration. Integrated Concrete Services Inc. https://ic.services/soil-stabilization/.

Species Displacement & Migration

Developing the Sunset Area will shift the ecosystem from grassland-dependent species to urban-riparian species.

Currently, predominantly grassland-dependent bird species make their home in the West Placer Prairie. It hosts a plethora of migratory and annual raptors, migratory waterfowl, and small bodied year-round grassland birds. Some of the migratory birds arrive in the winter from snowy northern states, Canada, and even the arctic. Large sweeping grasslands with little variation, few trees or telephone poles make excellent hunting grounds for raptors. Their prime hunting grounds are well-grazed where rodents are more visible. According to the annual Christmas Bird Count, the grassland around Antonio Mountain Ranch (in the existing reserves area) is the second best location for spotting raptors, including ferruginous hawk, prairie falcon, and golden eagle. The migratory water fowl congregate en mass at the waste water treatment plant north of the area and the flooded rice fields to the southwest.

Grassland-dependent birds are very sensitive to elements added in habitat, including power lines and trees, and will absolutely be displaced. Even the lingering smell of a dog will move them to other fields. The ground nesters will be ousted by next predators, such as raccoons and possums, that come with development. The PCCP with off-site, large scale mitigation is the best solution for preserving grassland bird habitat. There is likely no way to facilitate grassland bird's continued use of the site if human presence and associated development increases. Any preserved grassland, such as the reserve areas, will need to be fenced so no dogs can run through a leave scent trails. It will also need to be grazed to keep the invasives down. Industrial and commercial areas can be good buffers for grasslands because nest predators are less attracted to those areas.

Current Species Mix

Survivors of Displacement

Species Mix with Development

Providing for Riparian-Urban Species

Riparian corridors provide the greatest habitat value amidst development. Cavity nesters will have the best chance of survival against urban predators-- raccoons, possums, cats and dogs. These birds need plenty of trees with little hollows. These trees tend to be older, dead and dying and should be left in place. The vegetation along watercourses on site is currently minimal, due to historic tree harvesting and grazing. New trees that produce cavities should be planted along the stream courses with berry-producing under-stories. Native and non-native Ashes form cavities in middle age. Native oaks also form cavities, but tend to be slow to grow and messy. Species not native to our region should be avoided, such as Redwoods, because they provide little habitat value as they do not form cavities or provide food, and acidify the soil preventing other plants to grow.

A Bushy under-story is crucial for protecting the small birds and providing foraging opportunities for nesting. Winter berry-producing shrubs and trees, such as elderberry, should make up a majority of the planting. According to the California Native Plant Society, 70% of a garden must produce food value for local species if it is to sustain them.

Nest boxes should be placed in open areas and can be used to enrich habitat between corridors. These boxes accommodate birds that prefer to be on the edges of open fields.

The listed bushes and trees are easy to buy, will thrive on the site, and provide high quality food and habitat for birds, butterflies and bees: Blue Elderberry, Black Elderberry, Coffee Berry, California Grape, Southern California Black Walnut, Northern California Black Walnut, Sandbar Willow, Oregon Ash.

Preserving Grassland Value

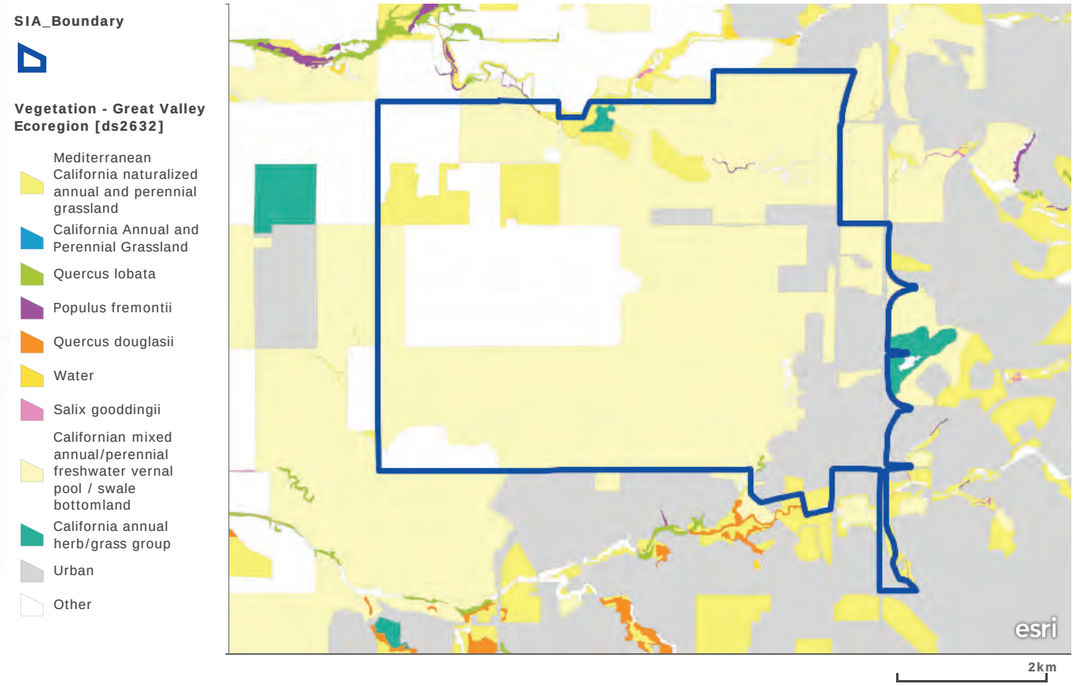
Grassland in the SA is predominantly native Californian annuals and perennials with less than 5% invasives. These grasslands host freshwater vernal pools in the wet season. Several parcels have 25-50% Mediterranean California naturalized annual and perennials, which are introduced grasses from European

Collage of flora that provide reliable food sources for native species.

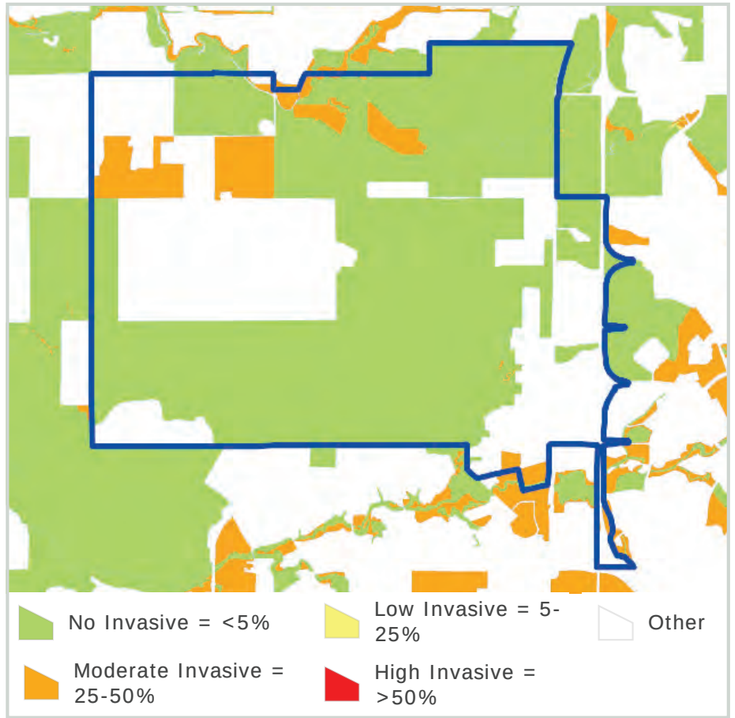
Settlers that gradually displace native grasses. In the Vegetation Type Map, many 'other' parcels are agriculture and landfill.

In reviewing satellite imagery, color changes in ground cover along fence lines indicate grazing. This is likely contributed to the low percentage of invasives, because cows eat introduced species first. If moved before they eat everything down, the native species thrive. Maintaining this grazing practice is crucial for keeping the invasives out.

Grasslands Map



Invasive Species Map



Data for the grassland and invasive species maps provided by the Geographic Information Center, Chico Research Foundation.

Vernal Pools

The most significant ecological factor on site are the vernal pools. Their ephemeral nature and dependence on rain makes it difficult to observe the whole system. Properly understanding their distribution through the region and site is a fundamental step in determining ecological value and determining mitigation fee classification.

The Report of Science Advisors[1] states that, "In Placer County, urbanization, industrial development, and infrastructure construction have resulted in substantial losses of vernal pool ecosystems. To date, most conservation efforts have focused on fencing off single pools or tightly confined small pool complexes and surrounding them by various types of development. The majority of these conserved pools reside in an urban or suburban landscape...The creation of new vernal pools in mitigation banks is of marginal long-term conservation value at best. Rather, effective conservation must focus on the protection of archipelagos of pools containing a number of pools and pool types plus a substantial portion of the surrounding catchment area."

Historically, Vollmar Natural Lands Consulting estimates that Placer County had 117,289 acres of vernal pool habitat. 75% of that has been destroyed as of 2013 and 25,893 acres remain (25%). The SA contains 17% of the remaining vernal pool habitat in Placer County and also the largest continual vernal pool complex. The maps from Vollmar on the following pages show the predicted habitat and it's decline. The white dots represent sitings of vernal pool faerie shrimp, a species that lives solely in vernal pools.

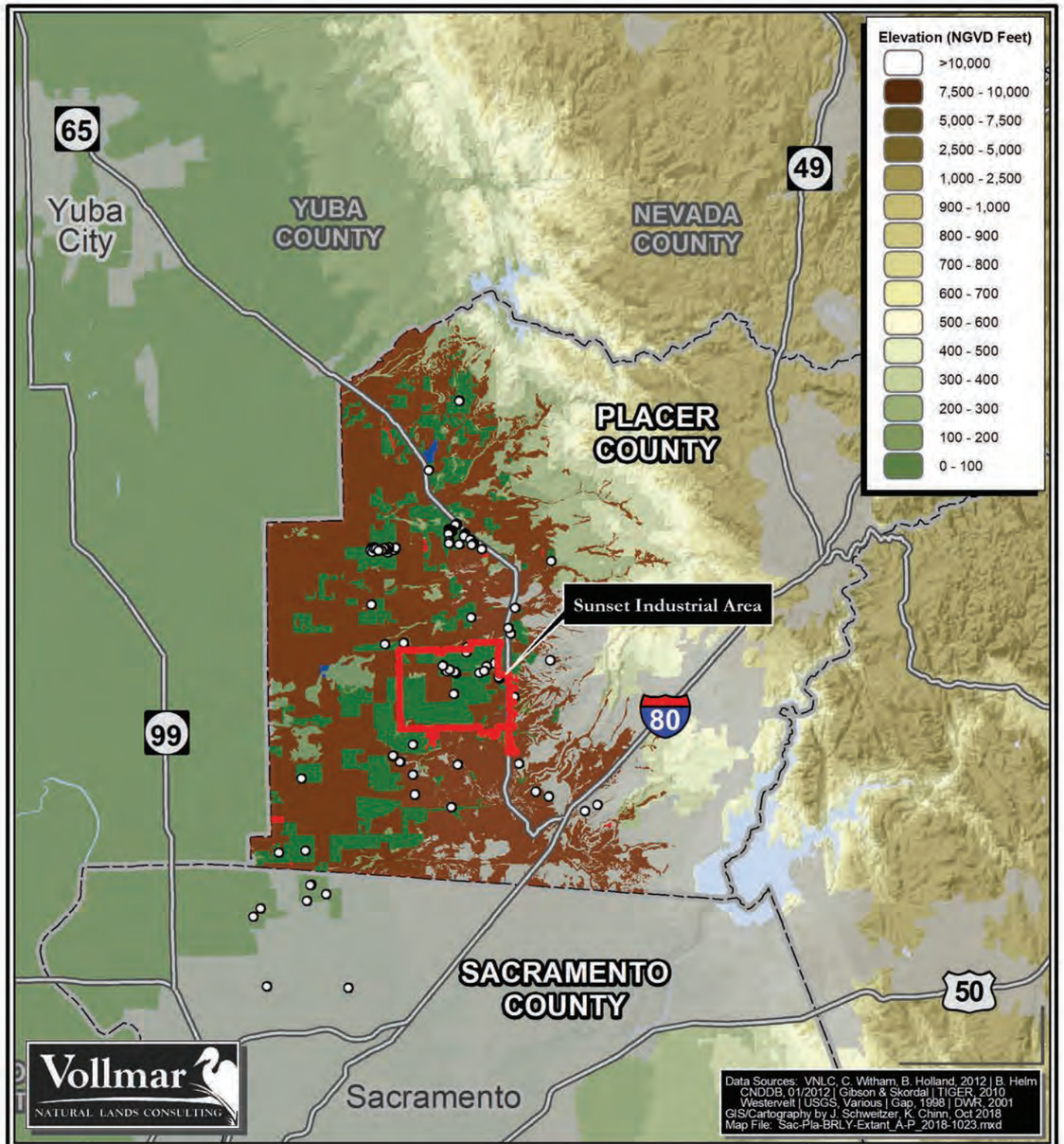
Preliminary Analysis of Extirpated and Remaining Vernal Pool Habitat within Placer County and the proposed Sunset Area Plan and Placer County Conservation Plan Area. Courtesy of Vollmar Natural Land Consulting.

Geographic Area	Acreage	% of Historical Total
Placer County Estimated Historical Acreage	117,389	100%
Placer County Estimated Extirpated Acreage	87,496	75%
Placer County Remaining Acreage	29,893	25%
		% of Remaining Habitat
Placer County Remaining Acreage	29,893	100%
PCCP Existing Reserves	5,235	18%
PCCP Proposed Reserve Acquisition Area	9,330	31%
Sunset Area Plan	5,152	17%

Top: Recreated Vernal Pools in the SA, April 2014.

Bottom: Natural Vernal Pools in the SA, April 2014.

1"County of Placer Natural Community Conservation Plan Habitat Conservation Plan, Report of the Science Advisors, Phase 1." Burssard, P. et al. January 8, 2004.



Legend

- *Branchinecta lynchi*
- Predicted Habitat, Extant in 2010
- Predicted Habitat, Extant in 2005 Extirpated as of 2010
- Predicted Habitat, Created Between 2005 and 2010
- Predicted Habitat, Extirpated as of 2005 and 2010
- Water Body
- Urban Area
- County Boundary
- Highway

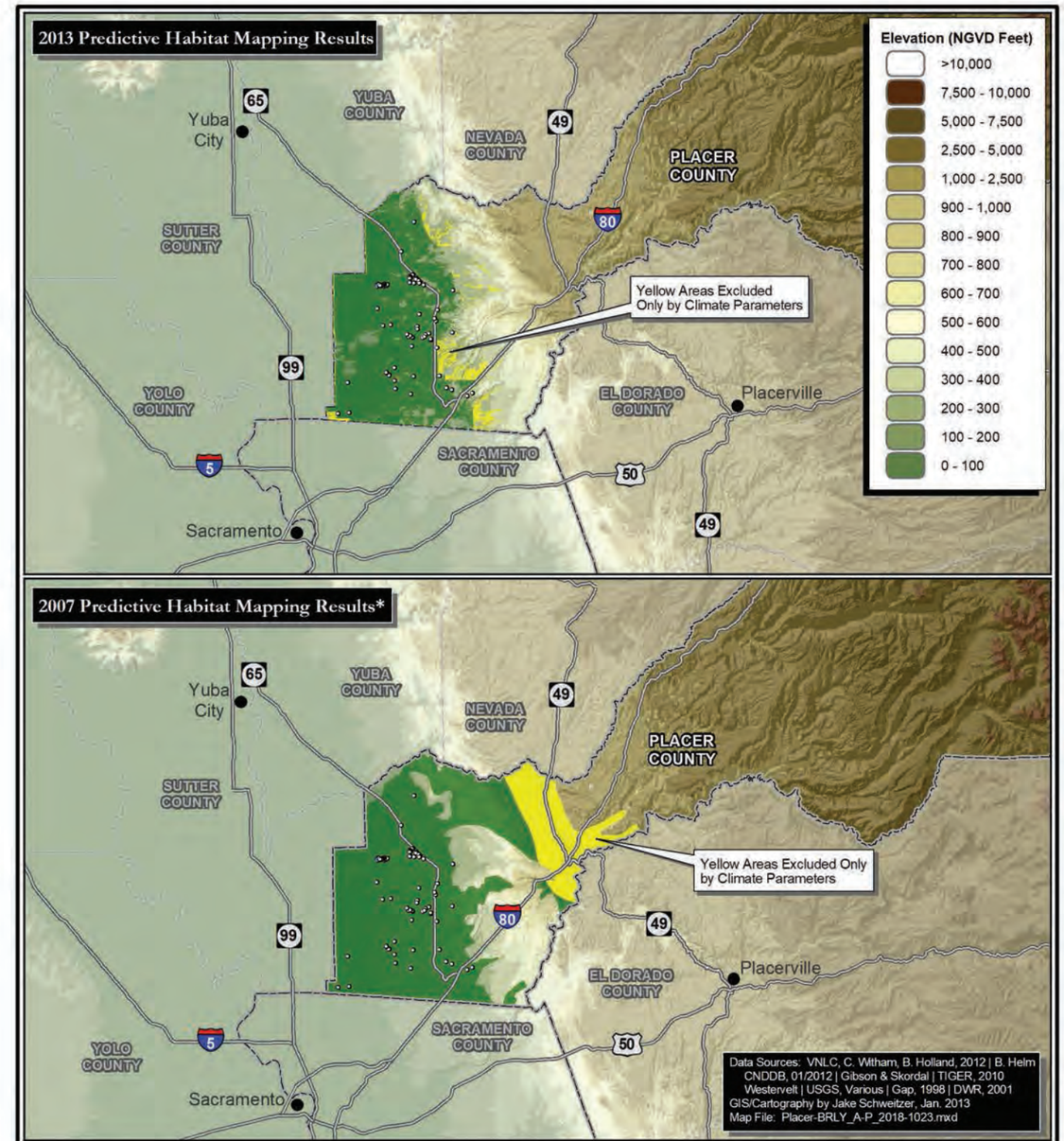
Note: Acreages represent totals for both counties

FIGURE 3
Branchinecta lynchi
Status of Predicted Habitat
Placer County

Vernal Pool Species Predictive Habitat Study

1:350,000

0 5 10 20 KM
0 7.5 15 Miles



Legend

- *Branchinecta lynchi*
- Predicted Habitat, All Parameters
- Area Excluded from Predicted Habitat by Climate Parameters
- County Boundary
- Highway

* Holland and Hollander, 2007

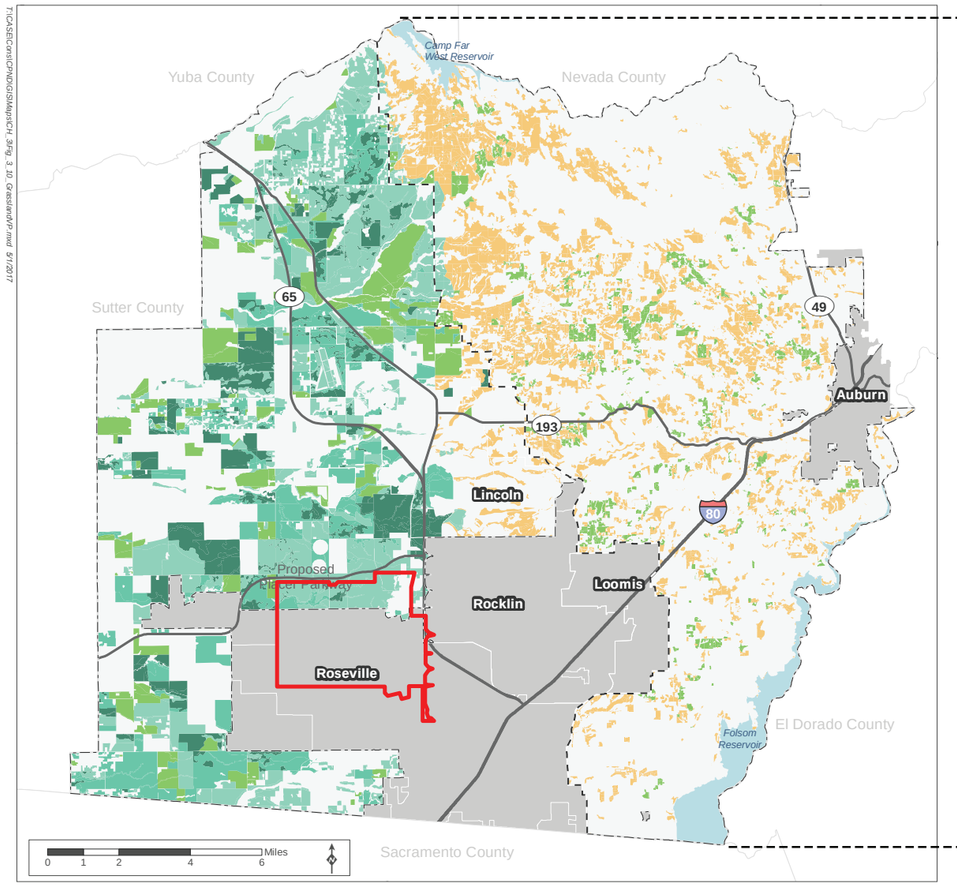
FIGURE 4
Comparison of *Branchinecta lynchi* Predicted Habitat Results, 2007 vs. 2013

Placer County, California

0 13 26 KM
0 13 26 Miles

Figure 3-13 Grassland and Vernal Pool Complex

Placer County Conservation Program - Western Placer County HCP/NCCP



Source: Placer County, 2014; MIG | TRA, 2015

Community and Land Cover Type

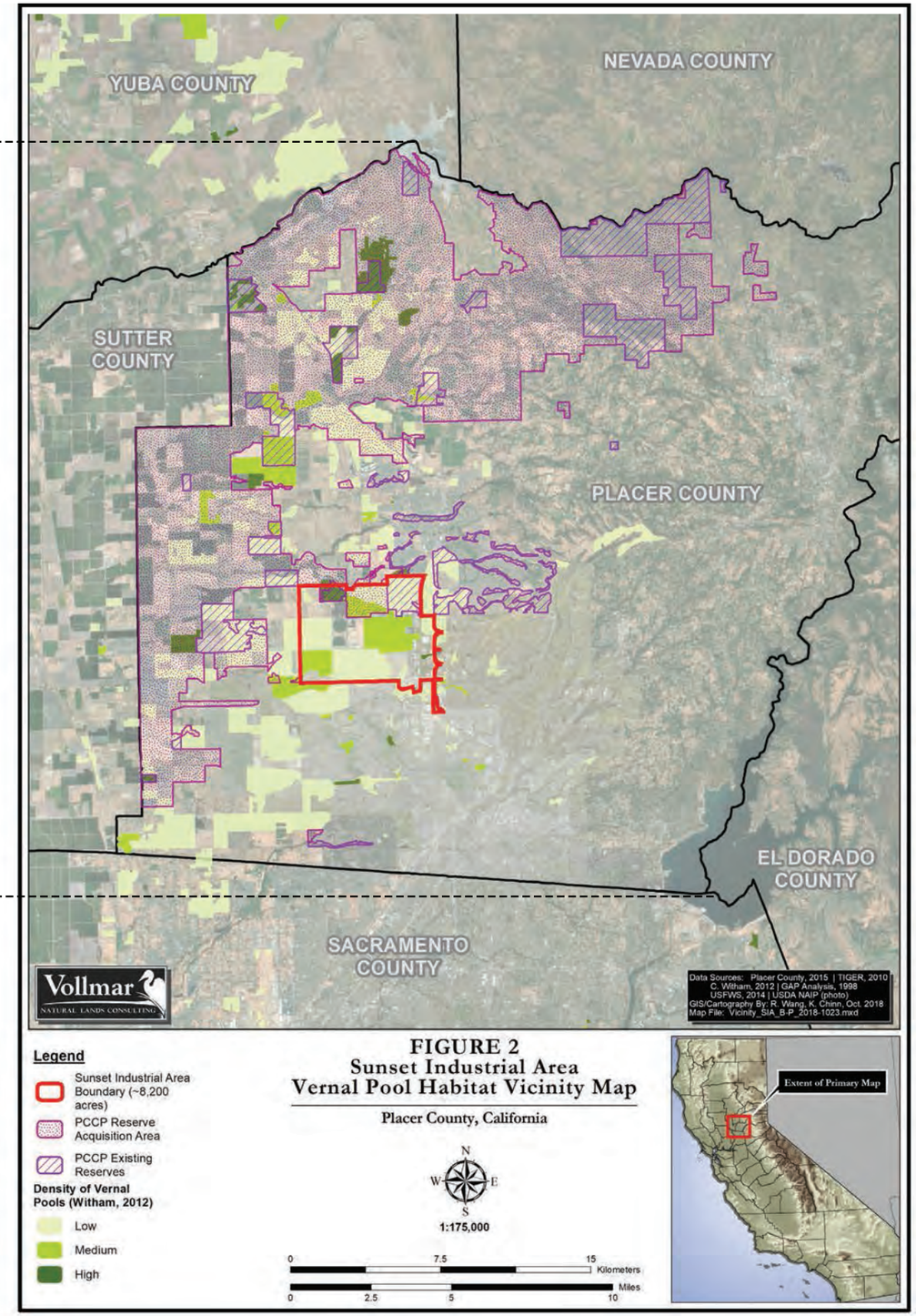
Grassland

- Annual Grassland
- Pasture

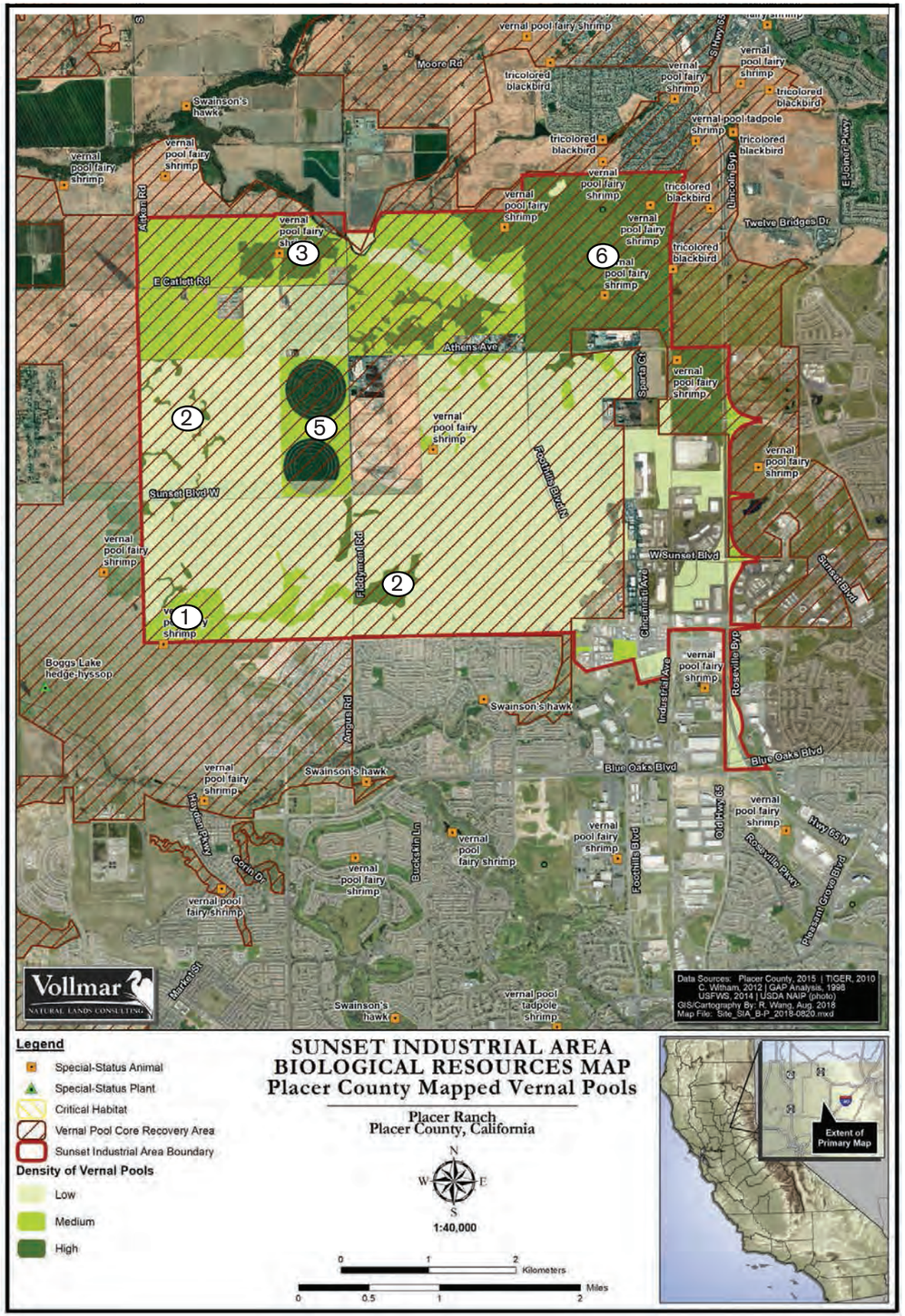
Vernal Pool Complex

- VPC High Density
- VPC Intermediate Density
- VPC Low Density

- Non-Participating City
- Major Road
- Valley/Foothill Divide
- Plan Area A



These two maps feature existing vernal pools. The County's Grassland and Vernal Pool Complex map (left) was created through aggregating multiple sources and thus does not have a consistent research method. It is the definitive map for the PCCP, SAP and PR. The other map (right) is from a comprehensive single study by vernal pool expert Carol Whitham, John Vollemar and John Schweitzer, commissioned by US Fish and Wildlife Services and the Bureau of Reclamation. These two maps have many differences in both the location and density of vernal pools, highlighted on the next spread.



Differences in Vernal Pool Maps

(1) Rice Terraces; cannot support vernal pools

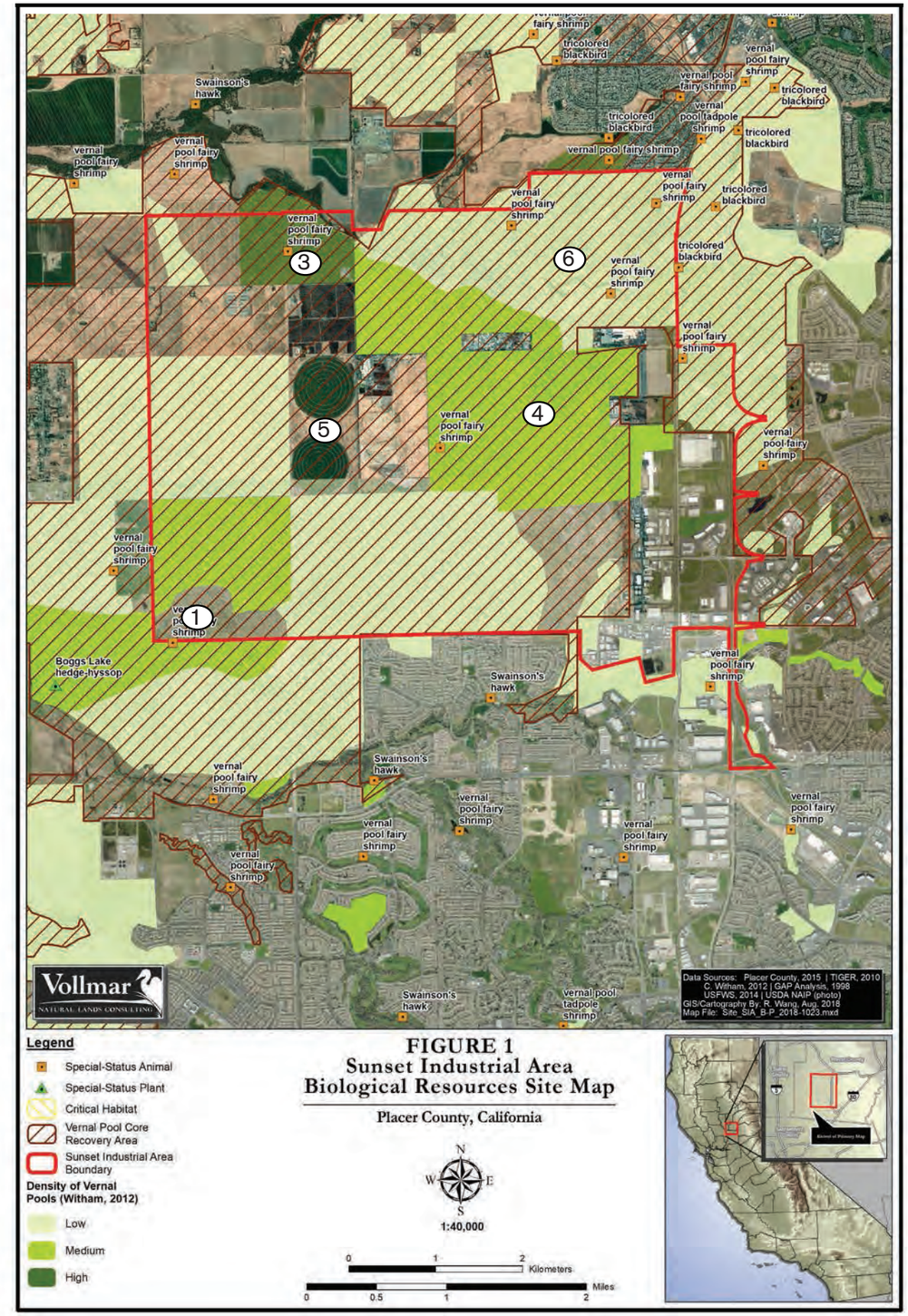
(2) Follows intermittent stream course

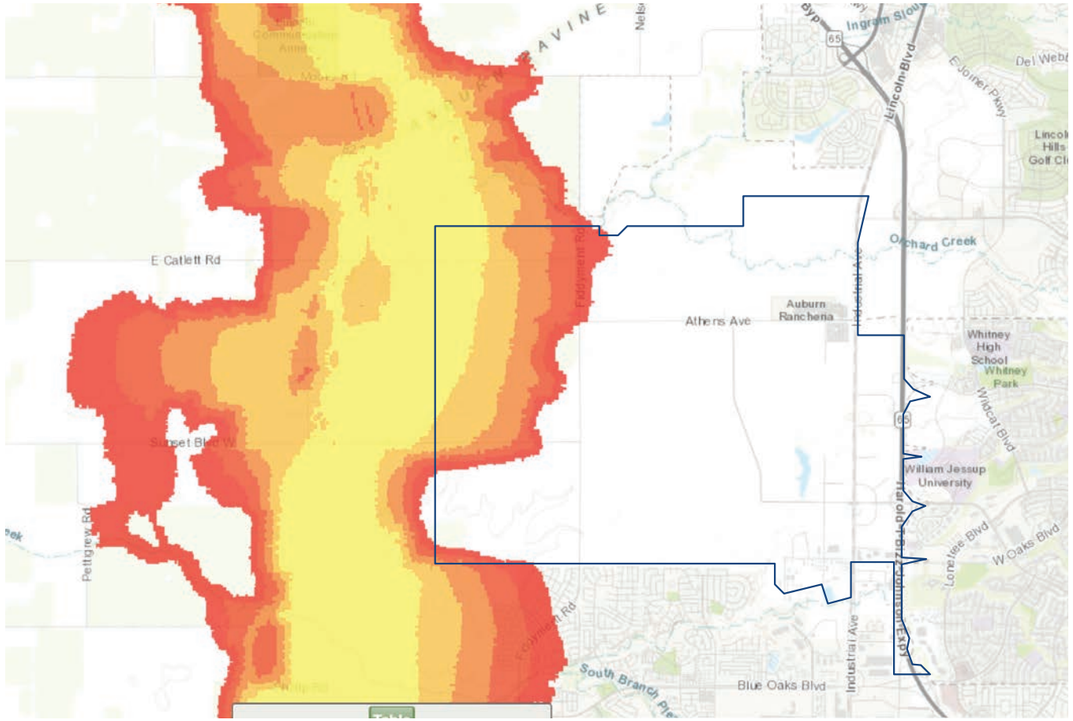
(3) Man-made vernal pool mitigation bank

(4) Second highest concentration of vernal pools in satellite images; Corresponds with Orchard Creek watershed divide

(5) Patterns of agriculture use make vernal pools unlikely

(6) Highest concentration of vernal pools in satellite images

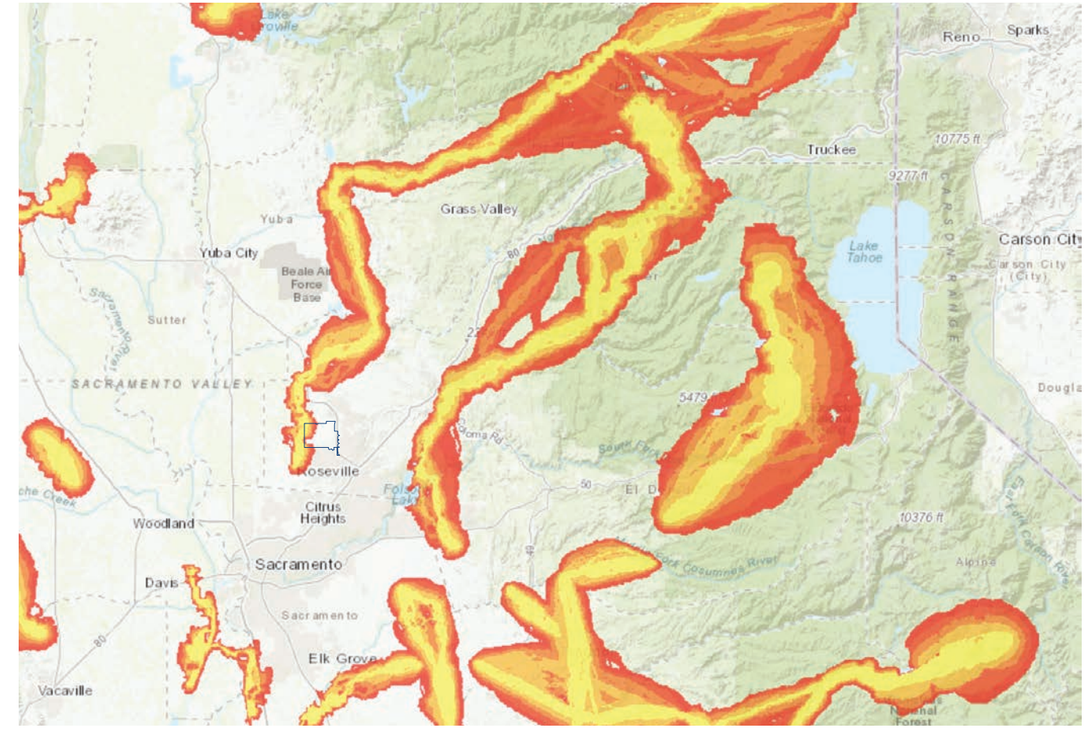




1/2 mile

Essential Connectivity Areas

The California Essential Habitat Connectivity Map shows the farmland to the west of the SA as a major migration corridor. Various fauna use this corridor to move between the grasslands and the high Sierras. At Roseville the habitat corridor is cut off. It may be surmised from the zoomed out map that it once connected with the a corridor in Davis or a corridor southeast of interstate 80.



10 miles

California Essential Habitat Connectivity (CEHC) [ds620] Map, California Department of Wish and Wildlife & CalTrans, 2010.

Legend
More Permeable
Less Permeable

Existing Conservation Areas

The north of the site currently has 4 existing reserves, some recreated habitat and some original habitat. The PCCP includes three of these reserves in it's green belt plan, WSMB excluded. The SAP does not specify any additional reserve besides for stream corridors in PR. The four reserves are as follows:

Warm Springs Mitigation Bank, WSMB
Not identified by PCCP
Owned by an out-of-state investment company possibly featuring recreated vernal pools

Moore Ranch Conservancy, MRC
Mitigation Bank with man made vernal pools
Mitigation Credits Sold Out

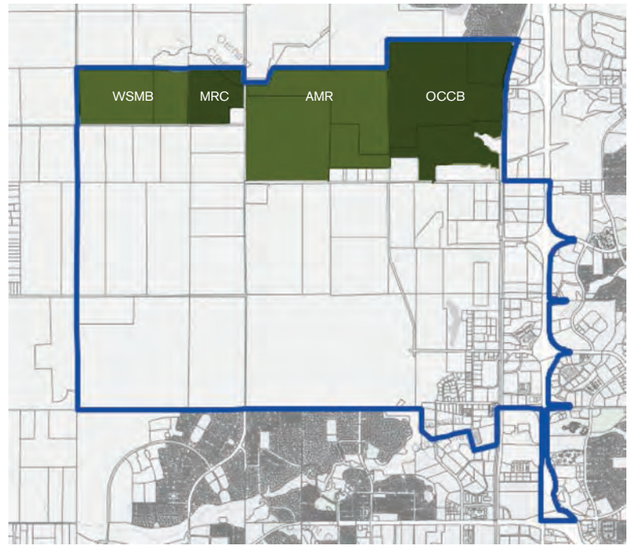
Antonio Mountain Ranch, AMR
Desired Acquisition for PCCP
Second best place for spotting falcons
Conversion from conservancy to mitigation bank 2018.
Owned by the Tsakopoulos family, SAP interest holders

Orchard Creek Conservation Bank, OCCB
Williamson Act Parcels
Included in PCCP
Mitigation Credits Sold Out

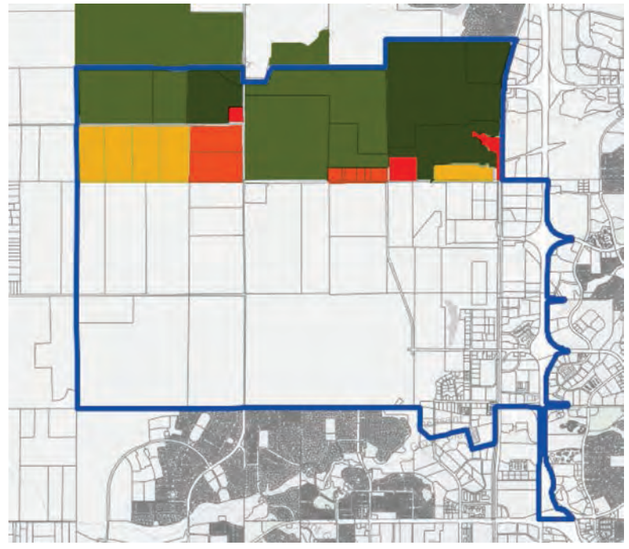
Adjoint Parcels of Concern

The parcels of concern are proposed as business parks and industrial zones in the SAP. These parcels are immediately adjacent to the conservation zone on at least two sides and have the potential to impact the reserves.

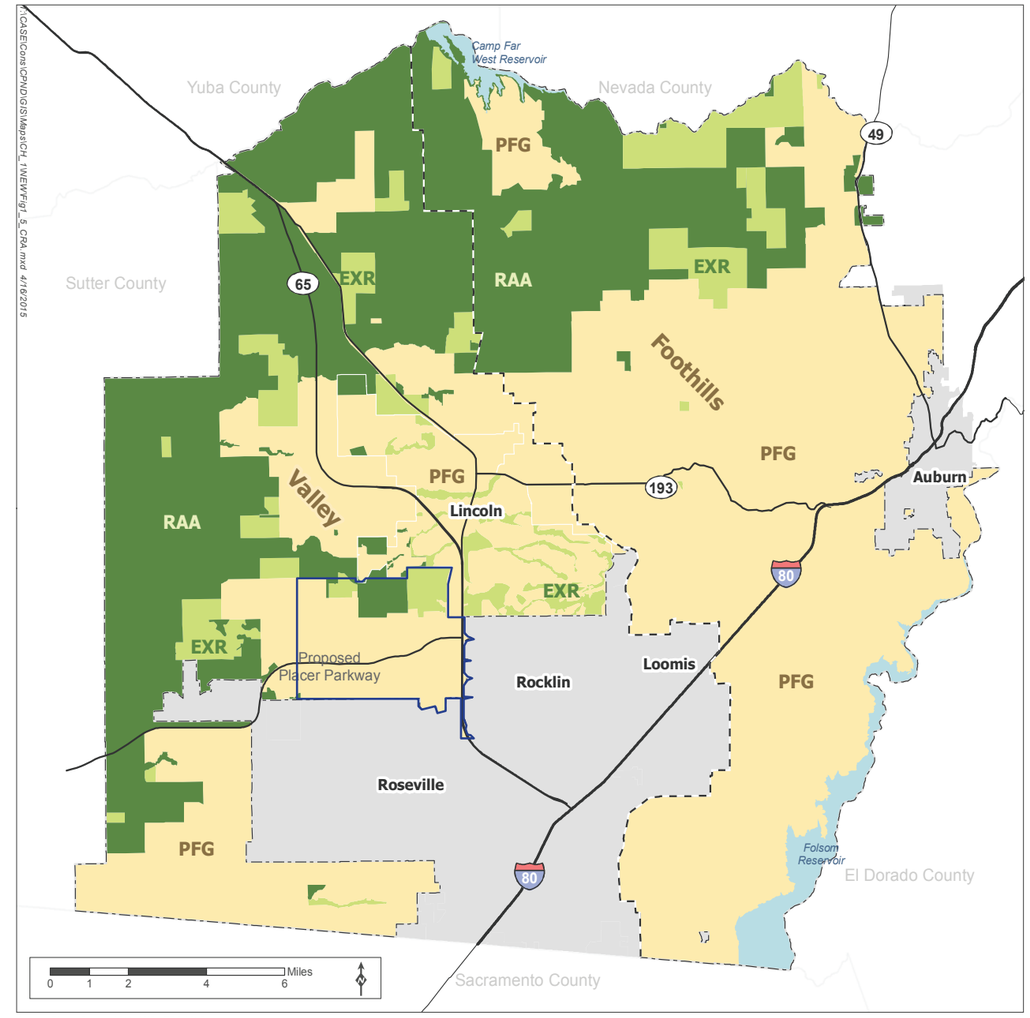
Development of the western parcels of concern would create a bottle neck for animals and plants crossing the east-west corridor. These parcels also provide the headwaters that feed the vernal pools. The eastern parcels of high and medium concern are proposed for large development expansion. The high concern parcels are currently greenfield while the medium concern parcel is the low density Athens Industrial Park. The low concern is Thunder Valley Casino, already built out.



Existing Reserves Map. Underlaying Parcel Map from the Placer County Assessor Office.



Parcels of Concern
- High
- Medium
- Low
- Conservation Zones



Source: Placer County, 2014; MIG | TRA 2015

- Reserve Aquisition Area (RAA)
- Potential Future Growth Area (PFG)
- Existing Reserve (EXR)
- Non-participating City
- Area A Boundary
- Highways
- Valley/Foothill Divide

MIG TRA

Figure 1-5 PCCP Designation Map
Placer County Conservation Program - Western Placer County HCP/NCCP

Conservation Management in the SA

These management strategies are from the Report of Science Advisors[1]:

1. Management strategies must include fencing for the protection of pool archipelagos from off-highway vehicle use, trash dumping, unauthorized hunting, and watershed alteration. Off-highway vehicles can alter hydrology, damage vegetation, and kill or injure small animals, especially when they are migrating to breeding areas.

2. Ground squirrels and other rodents must not be shot or poisoned because of their importance to the vernal pool community.

3. Pool complexes must be sufficiently free from disturbance so that ducks and other aquatic birds are able to move freely from pool to pool. Fairy shrimps are an important part of the diet of many birds, and the resistant cysts of the shrimps are dispersed from pool to pool in the guts of these birds or in the mud adhering to their feet.

4. Artificial drainages that alter pool hydrology must be eliminated, and the natural drainage pattern must be restored.

5. Vernal pools and their associated Valley Grassland habitats could be managed as grazing systems. In the absence of grazing, annual grasslands often become dominated by tall, dense stands of grasses such as ripgut brome and wild oats that are not used by many wildlife species. Fall grazing is also necessary to keep the vernal pools free of invasive vegetation.

6. Prescribed fire also may be considered as a management tool to mimic natural conditions and maintain the natural vegetative community.

7. Many other human uses including hiking, horseback riding, and other types of "soft" (less invasive) recreation are compatible with vernal pool conservation.

8. In the absence of protected areas, large areas of ranch land managed for both conservation and livestock production, provided that the grazing regime is consistent with vernal pool conservation, may be the best conservation prescription for vernal pools and their associated species. The latter strategy fits in well with Placer Legacy's agricultural conservation goals.

PCCP Off-site Mitigation

Wherever relevant the SA will be mitigated by the PCCP. In this process a developer will pay a land conversion fee and relevant special habitat fees per acre. The PCCP oversight body uses the money to purchase and protect habitat in the reserve acquisition area. The reserve area will include 20,000 acres of vernal pool grasslands and impacts to vernal pools must meet a no net loss standard of 2:1. By using the PCCP mitigation measure, we ensure the creation of effective reserves backed by scientific research. For a description of the different special habitat fees, see the Special Habitats Fee Schedule to the right[2].

The PCCP Mitigation Fee Estimate Table gives a range of $427 million to $566 million for allowable land conversion in the CISGP and SAP. It costs $ 134,473 to convert one acre of vernal pool habitat. Over fifty years, the Placer County valley region is budgeted to contribute $627 million in land conversion and special habitat fees.[3] Mitigation fees for the SA alone would cover 68% to 90% of the valley's estimated fees.

1 "County of Placer Natural Community Conservation Plan Habitat Conservation Plan, Report of the Science Advisors, Phase 1." Burssard, P. et al. January 8, 2004.

2 To see the Land Conservation Fee Schedule visit https://www.placerconservation.com/uploads/4/8/8/9/48899225/land_conservation_fee_schedule.pdf

3 Valley and Foothills Share of Plan Funding, HCP/PCCP Table 9-4. https://www.placerconservation.com/cost--funding.html

PCCP Mitigation Fee Estimate Table

		CISGP		SAP	
Land Conversion Fee	**$/acre**	**Acres**	**Total**	**Acres**	**Total**
All Development Projects	$24,923	4237	$105,598,751	5505	$137,193,638
Special Habitats Fee					
Vernal Pool Direct Effects					
County Vernal Pool Map	$109,550	3753	$411,086,375	3923	$429,730,690
Whitham & Vollmar Vernal Pool Map	$109,550	2942	$322,303,769	3515	$385,112,070
Vernal Pool Immediate Watershead Effects	$18,296	n/a		n/a	
Stream System Encroachment	$101,020	n/a		n/a	
Salmonoid Stream Channel	$591/lf	0		0	
Total Fees Max			$516,685,126		$566,924,328
Total Fees Min			$427,902,520		$522,305,708

This estimate uses two vernal pool maps to establish a range of possible fees. The actual vernal pool acreage will be determined on site. Special habitat fees other than direct effects to vernal pools have not been included. The total fees are not to be taken as final or definitive.

Special Habitats Fee Schedule

ID	Fee Name	Fee
4a	Vernal Pool Direct Effects	$109,550 per acre of vernal pool wetland constituent habitat altered by ground disturbance; includes entire delineated wetland area if any part is affected
4b	Vernal Pool Immediate Watershed Effects Applies to wetted area of vernal pool constituent habitats affected by ground disturbance in immediate watershed rather than affected directly. Not subject to temporary effects fee.	$18,296 per acre of wetland on project site not altered by ground disturbance, but within an immediate watershed that is altered by ground disturbance
4c	Aquatic/Wetland	$74,964 per acre of aquatic/wetland constituent habitat altered by ground disturbance
4d	Riverine/Riparian	$101,020 per acre of riverine/riparian constituent habitat altered by ground disturbance
4e	Stream System Encroachment Not subject to temporary effects fee.	$101,020 per acre of natural, semi-natural, and other agricultural communities in stream system altered by ground disturbance and not subject to a separate special habitat fee
4f	Salmonid Stream Channel Not subject to temporary effects fee.	$591 per linear foot; paid in addition to any other special habitat fee

Notes: All special habitat fees are paid in addition to the land conversion fee.
All amounts are in 2017 dollars. The PCA will update fees on an annual basis to reflect cost inflation.
Source: HCP/NCCP Table 9-7

Table 2 Notes: All amounts are in 2017 dollars. The PCA will update fees on an annual basis to reflect cost inflation.
"Existing Parcel" is a parcel at time of Plan adoption.
"Single Family Residential" is construction of one or more buildings designed for occupation by one family, including factory-built housing (modular housing).
"Per acre" applies to total parcel acreage, except where avoidance occurs pursuant to HCP/NCCP Section 6.3.1.3, General Condition 3, Land Conversion.
Source: HCP/NCCP Table 9-6

Special Habitats Fee Schedule, HCP/NCCP Table 9-6. https://www.placerconservation.com/uploads/4/8/8/9/48899225/special_habitats_fee_schedule.pdf

Human Systems

Leverage what Exists

Growing smarter means we locate development where infrastructure and services already exist or where infrastructure is already planned to provide adequate capacity. Doing so saves taxpayers money and maximizes the benefits of public investment. Steering development toward established places can help to revitalize neighborhoods that are languishing. It saves government funds by avoiding the unnecessary expenses of recreating or expanding roads, water and sewer capacity and schools.

Walkable Neighborhoods

Housing

Transport

Energy

Human Settlements

Designing Walkable Communities

Walkable communities have fundamental amenities within walking distance and are inherently mixed use. Their scale is similar to traditional towns, before people become reliant on cars, and have compact development to minimize walking distance and infrastructure. They have clear pedestrian routes and public spaces that extend the private realm. The smart growth standard uses a quarter mile diameter for walkable communities. This is also how far people will walk to reach a transit stop, the equivalent of a five minutes stroll.

The Quarter Mile Diagram shows how many walkable communities are possible in the SA. There are 40 circles in the diagram, 17 of which make up the Industrial Mixed Use zone and 8 which make up the University District. Of the 20 in the Industrial Mixed Use zone, 9 are far enough from the major roads to be suitable places to live.

The small parcel size in the mixed use area, featured in the SAP Parcel Size Diagram, enables a diversity of landowners and land uses to coexist within a quarter mile.

Guidelines

The following guidelines apply to the Innovation Mixed Use District. The guidelines are from the Smart Growth Tool Kit produced by Smart Growth America.

Strengthen and Direct Development Towards Existing Communities

1. Discourage sprawl-generating subsidies and encourage structured incentives for urban infill or transit-oriented development.
2. Locate schools and coordinate school investments to support existing neighborhoods.
3. Require schools to be centrally located to avoid extensive transporting and to minimize student travel distance and traffic congestion.
4. Establish regulations that support land reuse and require new urban growth to be coordinated with provision of infrastructure capacity.
5. Encourage infill development with specific zoning ordinances.
6. Establish tax credits/incentives or other policies to encourage infill over greenfield development.
7. Establish regulations that promote redevelopment of previously developed, underused or derelict properties (greyfields) for housing and/or mixed-use.
8. Establish land use strategies and incentives for redevelopment of brownfields.
9. Promote brownfields redevelopment for housing and/or mixed-use.
10. Establish minimum clean-up standards associated with brownfield proposed land uses.
11. Favor the use of existing infrastructure over new, and require that new development either is self-paying or that any required subsidization is made explicit.
12. Encourage regional tax sharing to discourage fiscalization of land use and destructive sales tax competition.
13. Establish an urban growth boundary.

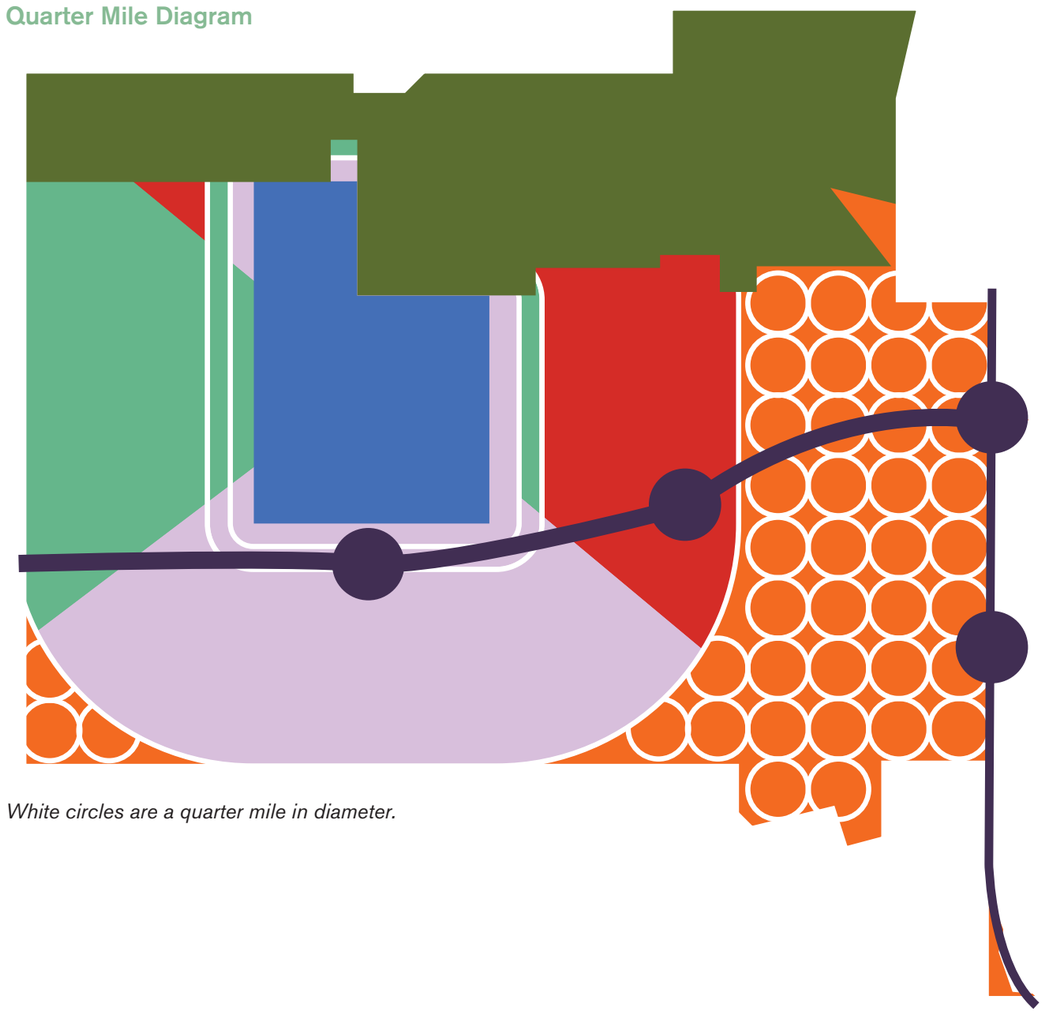
Mixed Land Use Policy

1. Encourage mixing of uses at building, site, and neighborhood levels.
2. Designate appropriate areas for mixed-use developments.
3. Encourage residential uses in the downtown districts.
4. Allow for home/office use in residential areas.

Adopt Compact Building Patterns and Efficient Infrastructure Design

1. Connect infrastructure decisions to land use planning.
2. Invest in rehabilitation of existing neighborhood schools over construction of new schools. Remove all minimum school acreage requirements.
3. Encourage energy efficient buildings and public infrastructure.
4. Encourage utilization of the full development capacity (density or floor area ratio).
5. Encourage reduced lot size and setback guidelines to encourage higher density.
6. Establish minimum densities for higher density development.
7. Allow for conversion of existing underutilized and/or abandoned nonresidential sites into housing and/or mixed-use developments.
8. Allow density bonuses along transit corridors.
9. Adopt reduced parking ratio requirements or establish maximums.
10. Provide for shared parking.
11. Allow for reduction in parking requirements in transit-oriented development (TOD).

Quarter Mile Diagram



White circles are a quarter mile in diameter.

Sense of Place Policy

1. Encourage or require the inclusion of places for interaction among residents within neighborhoods--such as parks, community centers, schools, commercial areas, churches and other gathering places.
2. Public and private development should support or strengthen the character of existing neighborhoods and enhance the sense of neighborhood identity.
3. Discourage new development that introduces elements that will cause neighborhood instability or create barriers within or among neighborhoods. Encourage development that abates any existing disruptive elements.

Create Walkable Neighborhoods Policy

1. Allow for narrow street widths to promote walkability and bicycle friendliness.
2. Adopt traffic-calming measures and pedestrian-controlled traffic signals to encourage bike and pedestrian friendliness.
3. Require sidewalks on both sides of the street.
4. Regulate curb cuts to enhance pedestrian use of sidewalks.
5. Connect sidewalks to amenities such as parks and open space.
6. Establish a trail system or other non-motorized public access to amenities.

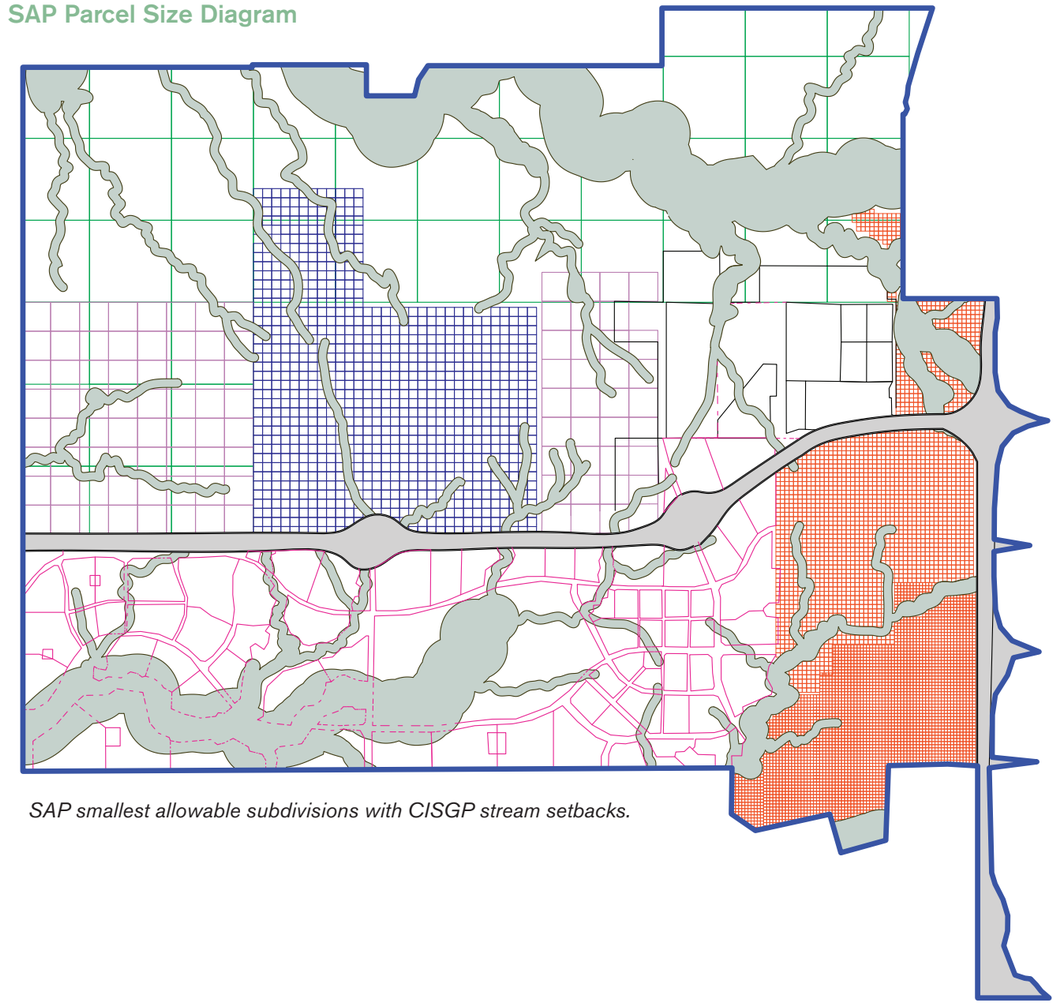
Diversity of Housing Opportunities and Choices Policy

1. Encourage traditional neighborhood residential patterns, which include diverse housing types (e.g. large family homes, cottages, boarding houses, duplexes and small apartments) and configurations (e.g. town homes, condominiums, or garden courtyard cottages).
2. Provide opportunities for a wide range of housing types (e.g. duplexes, apartments, live/work units, assisted living facilities, pre-fab houses).
3. Allow local zoning flexibility in housing sizes (smaller dwelling units).
4. Encourage mixed income housing developments.
5. Meet housing needs for all income groups.
6. Allow minimum lot-sizes low enough to accommodate all income groups.
7. Meet or exceed the fair share housing allocation for both market-rate and affordable housing within the region.
8. Allow for accessory housing within single-family residential zoning districts.
9. Encourage live-work homes by establishing zones where residents' businesses may share location with their homes. These uses are differentiated from "home occupations" in that they allow for non-resident employees and visitors. Uses may range from professional services to small manufacturing concerns.

Make Development Decisions Predictable, Fair, and Cost Effective

1. Incentives for historic preservation and infill development that make these projects as attractive to developers as building on green fields.
2. Clear design and construction standards, and review and approval processes set out for all types of development.
3. The local comprehensive plan, government regulations and action plans should be consistent with one another.

SAP Parcel Size Diagram



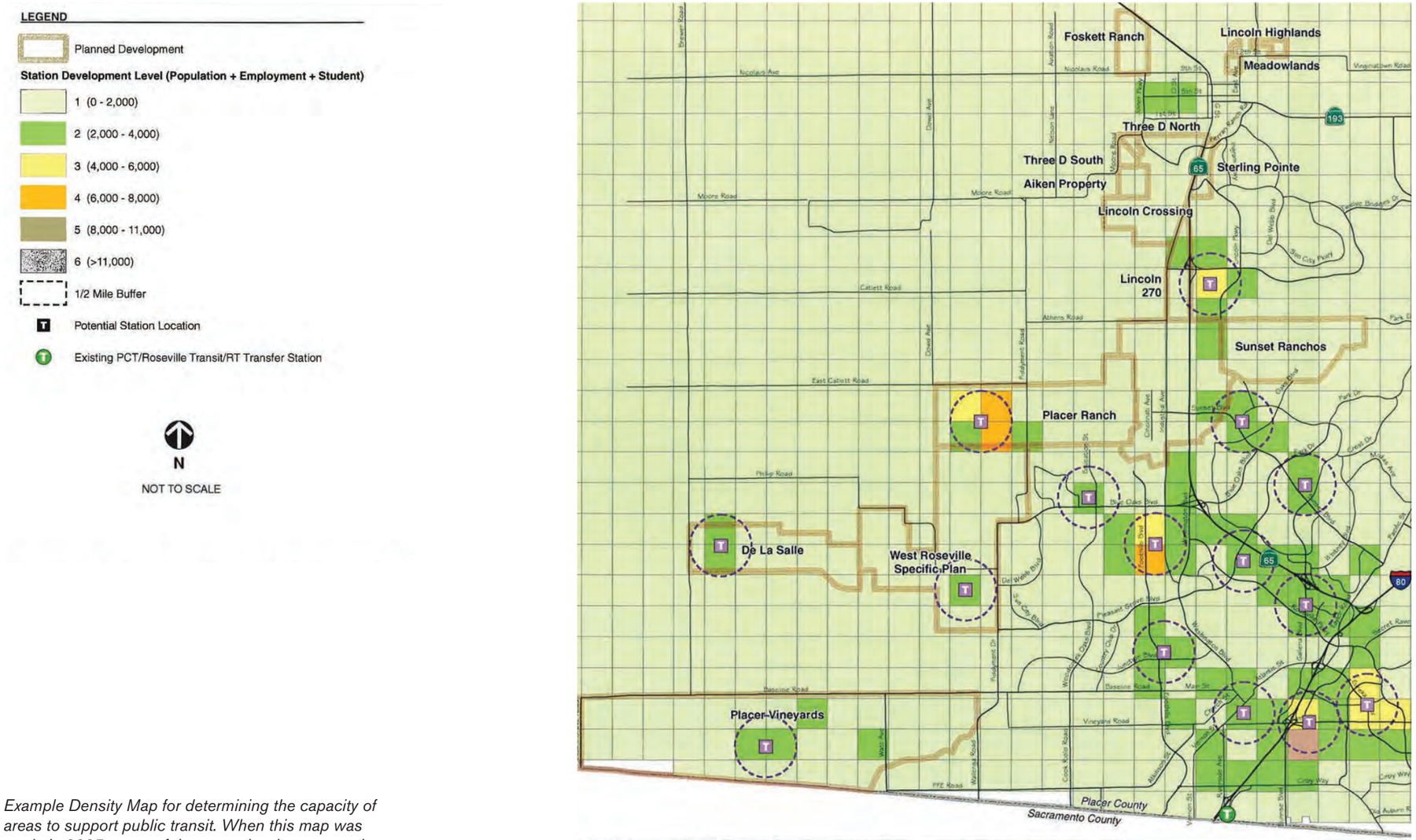
SAP smallest allowable subdivisions with CISGP stream setbacks.

Public Transit

Certain population and employment densities are the foundation to support public transit. The more people per acre, the more robust a transit system can be supported. A study commissioned by the Placer County Department of Public Works found that Bus Rapid Transit (BRT) in South Placer needs 9 du/ac in residential areas and a minimum FAR of 1.0 in non-residential areas. These densities enable the proper spacing of stops and the level of ridership for financial feasibility. Light-rail requires an average density of 9 du over the entire length of the corridor. The corridor must be between 25 and 100 miles long and connect downtowns with 20 to 50 million square feet of non-residential uses. While the light-rail density does not currently exist in South Placer, a light-rail corridor should be reserved.

The main features of BRT include dedicated running ways, attractive stations, distinctive and easy-to-board vehicles, off-street fare collections, use of ITS technologies, and frequent all-day service (typically between 5 a.m. and midnight). The Federal Transit Administration (FTA) defines BRT as "a rapid mode of transportation that can provide the quality of rail transit and the flexibility of buses." Currently Placer County uses dial-a-bas and a minimal local bus system. BRT would be a substantial upgrade to public transit.

One of the key conditions for developing an effective BRT system is that the proposed location be an urbanized area with a strong central business district or activity centers with dense patterns that facilitate transit use. To make transit effective, the land use patterns should be complementary, meaning high residential densities and concentrated employment near stations. The CISGP includes these conditions to establish the foundation for BRT.



Example Density Map for determining the capacity of areas to support public transit. When this map was made in 2005, many of the same development projects were in the pipeline. While it does not include the CISGP, it does still have relevance regionally.

Bus Rapid Transit Conceptual Plan for South Placer County. Fehr & Peers, 2005. Commissioned by Placer County Department of Public Works.

Station Development Level	Sacramento Analogue Low	Sacramento Analogue High	Bay Area Analogue Low	Bay Area Analogue High (Adjusted Ridership)
Level 1 Ridership:	N/A	Marconi/Arcade 1,540	San Martin 370	Orinda 1,770
Level 2 Ridership:	Marconi/Arcade 1,540	Roseville Rd 2,130	Atherton 490	N. Concord/Martinez 2,450
Level 3 Ridership:	Roseville Rd 2,130	65th St 3,620	Morgan Hill 720	Dublin/Pleasanton 8,550
Level 4 Ridership:	College Greens 1,540	Watt/I-80 4,400	Millbrae 1,610	El Cerrito Del Norte 9,950
Level 5 Ridership:	Watt/I-80 4,400	N/A	San Mateo 2,220	Balboa Park 11,000
TOD Scenario Level 6 Ridership:	N/A	N/A	Palo Alto 3,940	Berkeley 13,600

FEHR & PEERS
TRANSPORTATION CONSULTANTS

POTENTIAL BRT STATION AREA EVALUATION - YEAR 2025 CUMULATIVE POPULATION PLUS EMPLOYMENT AND STUDENT
FIGURE 6

TABLE 1. TRANSIT MODES RELATED TO RESIDENTIAL DENSITY CRITERIA

Mode	Service	Minimum Necessary Residential Density (dwelling units per acre)	Remarks
Dial-a-bus	Many origins to many destinations	6	Only if labor costs are not more than twice those of taxis
	Fixed destinations or subscription service	3.5 to 5	Lower figure if labor costs twice those of taxis; higher if thrice those of taxis
Local bus	"Minimum," ½ mile route spacing, 20 buses per day	4	Average, varies as a function of downtown size and distance from residential area to downtown
	"Intermediate," ½ mile route spacing, 40 buses per day	7	
	"Frequent," ½ mile route spacing, 120 buses per day	15	
Express bus -reached on foot	Five buses during two hour peak period	15 Average density over two square mile tributary area	From 10 to 15 miles away to largest downtowns only
Express bus -reached by auto (Park & Ride)	Five to ten buses during two hour peak period	3 Average density over 20 square mile tributary area	From 10 to 20 miles away to downtowns larger than 20 million square feet of non-residential floor space
Light rail	Five minute headways or better during peak hour	9 Average density for a corridor of 25 to 100 square miles	To downtowns of 20 to 50 million square feet of non-residential floor space
Rapid transit	Five minute headways or better during peak hour	12 Average density for a corridor of 100 to 150 square miles	To downtowns larger than 50 million square feet of nonresidential floor space
Commuter rail	Twenty trains a day	1 to 2	Only to largest downtowns, if rail line exists

Source: Pushkarev and Zupan, 1977.

18

FEHR & PEERS
TRANSPORTATION CONSULTANTS

Densities required to support various types of public transit.

Bus Rapid Transit Conceptual Plan for South Placer County. Fehr & Peers, 2005. Commissioned by Placer County Department of Public Works.

Bus Rapid Transit Guidelines[1]

1 Develop BRT alignment options that connect the potential stations with the greatest opportunity for transit-oriented development.
2. Provide transit-oriented land use development criteria for the ~ mile radius surrounding potential BRT stations.
3. Provide high-quality design with passenger amenities (such as shelters, seating, and lighting) to support a positive public perception of BRT service.
4. Respect the unique character of neighborhoods and districts and provide the appropriate balance between system continuity and contextual design.
5. Integrate with the current and future land use to generate greater patronage and develop design concepts cooperatively with the surrounding community.
6. Support an integrated system identity by keeping the transit service visible and recognizable to the community.
7. Provide an opportunity to improve streetscapes by incorporating new amenities such as landscaping and recreational trails.
8. BRT station should be located at major passenger concentrations (e.g., high-density residential areas, high-density employment areas, universities and high schools, and recreational centers).
9. BRT station should be located near major bus routes and major arterial roadways .
10. BRT station should be placed as far apart as possible and the recommended guidelines for BRT station spacing by arrival mode are show below.

0.25- 0.33 miles for pedestrians
0.5- 1.0 miles for bus
2.0 miles for automobile

10. BRT service plans generally prefer to have few high-frequency BRT routes than more routes with long headways.
11. Through service, at least for basic all-stop routes, is desirable when the round trip can be made in 2 hours (3 hours maximum).
12. Busway route structure should include basic all-stop service complemented by express (or limited-stop), feeder, and connector service.
13. The basic all-stop service should run all-day, from about 6 a.m. to midnight, 7 days a week; and the express service should operate weekdays throughout the day or just during peak hours.
14. The basic BRT service should operate at an interval of 5-10 minutes during peak hours, and 12-15 minutes at other times.

Provide a Variety of Transportation Choices[2]

1. Provide transportation choices to densely populated areas as well as major employment centers.
2. Link land use and transportation choices at the local and regional levels.
3. Address jobs and housing balance in the General Plan.
4. Locate new development, especially public facilities, in areas supported by a balanced transportation network.
5. Require roadway design standards that protect pedestrians and support transit and non-automotive modes.
6. Encourage transit-oriented (TOD) and transit friendly developments.
7. Grant density bonuses in transit or mixed -use districts.
8. Offer TOD-promoting incentives such as down payment assistance, reduced transit passes, and location efficient mortgages.
9. Encourage public transit use by integrating multi-modal use and connectivity (Park and Ride lots, transit centers, etc.).
10. Plan or maintain high-occupancy vehicle (HOV) lanes.
11. Encourage the formation of vanpools and carpools.

1 Guidelines from Bus Rapid Transit Conceptual Plan for South Placer County. Fehr & Peers, 2005. Commissioned by Placer County Department of Public Works.

2 Guidelines from the Smart Growth Tool Kit produced by Smart Growth America.

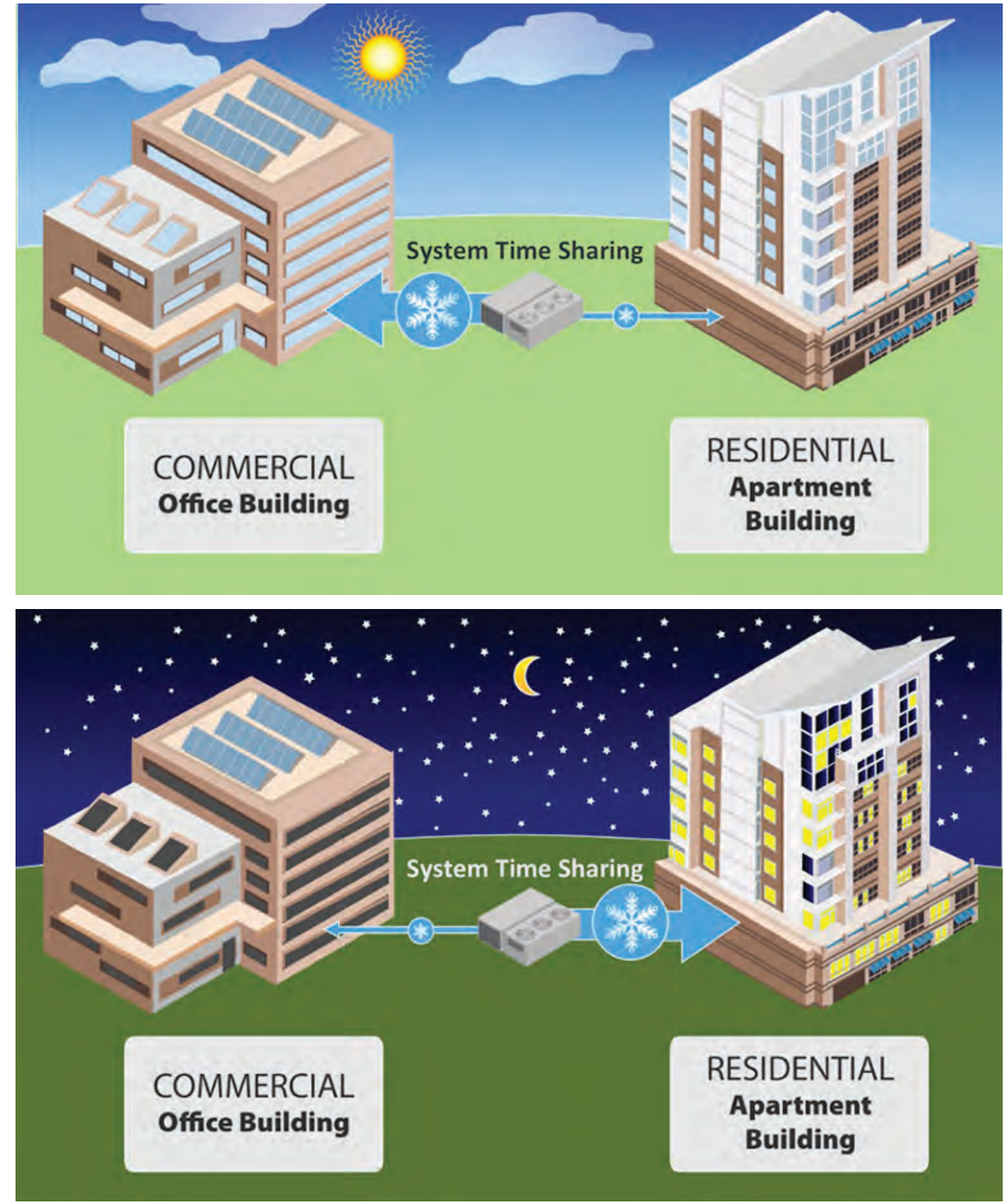
Energy

With a variety of socioeconomic residential units, industrial and commercial zones, energy efficient construction must be required, not simply encouraged. Placer County should expand and increase the mPOWER program to expedite energy efficiency renewal projects and retrofit older buildings in the proposed development area and the surrounding neighborhoods. The County should actively advertise county and state grant and incentive programs to residential and commercial sites within and around the Sunset Area.

Half of all new commercial and industrial construction to meet energy efficiency rating standards such as LEED, Living Building Challenge, WELL Building Standard, BOMA 360, NZEB, or other highly rated national building rating standard programs. These programs promote energy-efficient building practices which incorporate efficient technologies and offer incentives for on-site electricity generation.

All construction within the SA must comply with CALGreen building standards to ensure construction materials and waste are properly recycled. This includes encouraging the use of recycled materials throughout the construction of new projects.

Public parks and community areas should have electric outlets for landscape maintenance equipment. All new equipment purchased should be electric. The County shall require all new residential buildings to have south facing rooftops and solar panels. The County shall require and incentivize solar hot water heaters, efficient HVAC systems and appliances, and energy efficient lighting wherever possible. The County shall use its position to encourage energy infrastructure innovation.



URBANopt (Urban Renewable Building and Neighborhood optimization) is an example of an emerging energy infrastructure innovation. It leverage the U.S. Department of Energy's open-source building energy modeling ecosystem to analyze and optimize the distribution of electricity on the grid. These images show how district systems can take advantage of diversity in building loads.
Schott, Marjorie. "Figure 2." NREL Transforming Technology, www.nrel.gov/buildings/urbanopt.html.

Call to Action

At AEL, we believe we are stronger together. Join us in advocating for sustainable communities and equitable planning. Your voice counts! Here are some actions you can take:

Stay Informed

Join our email list to stay up to date:
allianceforenviroleadership@gmail.com

Communicate

Supervisor Robert Weygandt has jurisdictional authority over the West Placer Prairie / Sunset Area. Tell him and your own supervisor about your Sunset Area Plan (SAP) concerns and share the Citizen-Initiated Smart Growth Plan.

Robert Weygandt
Placer County Supervisor, District 2
175 Fulweiler Avenue
Auburn, CA 95603

rweygand@placer.cs.gov
Office Phone: 530-889-4010
Home Phone: 916-408-1264

Crystal Jacobsen, SAP Project Manager
cjacobe@placer.ca.gov
Michelle Kingsbury, **Placer Ranch Project Manger**
mkingsbu@pkacer.ca.giv

Attend

Show your support at the Board of Supervisors Meeting. Speak about the SA in the Draft Environmental Impact Report comment hearing on 2/14 or write in during the official comment period through 2/22. Join our mailing list to learn details!
allianceforenviroleadership@gmail.com

Mingle with us at our monthly workshops. Each month we invite speakers to address a specific topic in a group dialog and relate the topic to Sunset Area. This is a great place to give your input for the CISGP or volunteer to fact-find for a specific topic. Workshops are casual and held at a local brewery.

Share

Share the CISGP with the Press! With silence the County's SAP will slip through. Write a newspaper editor and accompany it with CISGP graphics.

Join the Alliance for Environmental Leadership on facebook, share our posts, and post your own! @allianceforenviroleadership

Citizen-Initiated Smart Growth Plan

© 2008 by the Society for the Study of Amphibians and Reptiles
Urban Herpetology. J.C. Mitchell, R.E. Jung Brown, and B. Bartholomew, editors
Herpetological Conservation 3:239–256.

CHAPTER 16

Effects of Artificial Night Lighting on Amphibians and Reptiles in Urban Environments

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Abstract — Amphibians and reptiles have evolved with natural lighting cycles. Consequently, alteration of natural variation in diurnal and nocturnal light intensities and spectral properties has the potential to disrupt their physiology, behavior, and ecology. We review the possible effects of night lighting on many species of amphibians and reptiles, noting that few studies of the consequences of artificial lights to amphibians and reptiles have been conducted to date. The one exception is the information available on the negative impacts of artificial lights on hatchling sea turtles, which have received considerable coverage in both scientific and popular media. In many studies that might be relevant, researchers have not recorded the illumination or irradiance at which experiments were conducted. We identify light pollution as a serious threat that should be considered as part of planning and management decisions in the maintenance or conservation of urban areas containing amphibians and reptiles. However, we consider it too early to precisely gauge the effects of artificial night lighting on other taxa found in light-polluted environments or provide specific management recommendations, beyond pointing out the urgent need for more information.

Key Words — Activity Pattern, Amphibians, Behavior, Conservation, Ecology, Invasive Species, Light Pollution, Night Lighting, Photopollution, Physiology, Reptiles, Suburban, Urban

Conservation biologists have long been concerned about anthropogenic effects on species and environments. There is good reason for herpetologists to share this concern: both amphibians and reptiles are declining worldwide (e.g., Alford and Richards 1999; Gibbons et al. 2000). Much work has focused on habitat loss and the consequences of water and air pollution, particularly on amphibians. Other anthropogenic impacts, such as light pollution, remain poorly studied and are of concern for urban herpetofauna (defined here as those species that are present within or adjacent to urbanized areas). Light pollution is a by-product of anthropogenic outdoor illumination from sources such as street lighting, sports arenas, and porch lights (e.g., Dawson 1984). When discussed in the context of adverse effects on wildlife, light pollution is also known as photopollution (Verheijen 1985). Its effects on herpetofauna are the focus of this chapter.

Five decades ago, Verheijen (1958) documented illumination patterns produced by lighting devices in urban habitats. The abnormal lighting patterns from these artificial sources resulted in locally elevated contrast in brightness between lighted and background areas which attracted invertebrates, a phenomenon known as "light trapping" (Robinson and Robinson 1950). Artificial lighting has become much more pervasive since 1958, affecting most of the world's urban areas and adjacent habitats (Cinzano et al. 2001; Longcore and Rich 2004). Street and security lights can be more than one million times brighter than natural ambient illumination (S. Wise and B. Buchanan unpubl. data). Additionally, skyglow, caused by

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reflection of artificial night lights from clouds, may increase nocturnal ambient illumination indirectly in less urban areas near cities (Cinzano et al. 2001). Sources of light pollution are often referred to as "night lighting," and the relatively new habitat created by the presence of artificial lights has sometimes been termed the "night-light niche" (Garber 1978).

With the exception of negative consequences for sea turtles, data on the effects of night lighting on amphibians and reptiles are uncommon. A recent book (Rich and Longcore 2006) focuses on many ecological aspects of light pollution. To avoid duplication, this review provides an updated synthesis of information we presented separately there (Buchanan 2006; Perry and Fisher 2006; Salmon 2006; Wise and Buchanan 2006). We focus on what little is known about the relationship between artificial lighting and urban herpetofauna and suggest areas that require further work. Special attention is paid to taxa that appear to be at greatest risk of being effected: species that are edificarian, feed at lights (or are simply positively phototactic), inhabit permanent and ephemeral ponds (parks, ditches), or are found in greenbelts or habitat reserves in or near city limits that are affected by skyglow or glare. Roads that connect urban areas, many of them illuminated by fixed lights in addition to vehicle headlights, may also have effects on species occurring nearby (Outen 2002; Spellerberg 2002), although few papers address this problem (e.g., Baker 1990; Mazerolle et al. 2005). In this chapter, we document the apparently positive (i.e., population-increasing) consequences of night lighting on some species and discuss effects that are clearly or possibly negative for others.

Taxonomic Preface

Information presented in the body of this chapter is arranged by habitat. However, some taxon-specific information pertains across habitats and is presented here. We use standard English names for large, well-recognized clades, but prefer scientific names when discussing specific species.

Salamanders — Salamanders are often nocturnal or crepuscular, with activity patterns regulated by photoperiod (reviewed in Wise and Buchanan 2006). Many species that have been studied are negatively phototropic or phototactic, although some species may show ontogenetic shifts in behavior, exhibiting positive phototaxis as larvae and negative phototaxis as adults (reviewed in Wise and Buchanan 2006). Artificial night lighting may affect physiology and behavior by (1) increasing ambient illumination, (2) lengthening photoperiod, and (3) varying the spectral properties of ambient light. Most studies of the effect of artificial light on salamanders have been conducted in the laboratory and focus on hormone levels or thermoregulation. These laboratory results, the basis for much of the information below, are important for generating field-testable hypotheses that may explain how artificial night lighting affects salamander populations in natural habitats.

Frogs — Frogs may be exposed to extreme changes in natural lighting patterns in urban environments. Few data exist that demonstrate direct effects of lighting on frogs, but many indirect effects are likely (Buchanan 2006). Adults of most taxa conduct the majority of their foraging and reproductive activities under twilight or nocturnal conditions. Eggs and larvae typically develop in aquatic environments, where they may be exposed to artificial illumination. Unfortunately, very few experimental data exist on the effects of artificial illumination on frogs in natural environments. Consequently, most of the data presented in this chapter have been extracted from papers dealing with the general effects of light on the physiology or behavior of frogs.

Caecilians — As with most subterranean taxa, relatively little is known about the biology of caecilians (Gower and Wilkinson 2005). Although many caecilians are of conservation concern, night lighting seems unlikely to be a significant cause of population decline, because these animals spend so little time above-ground and possess such poor eyesight. We have found no information to suggest otherwise and therefore do not discuss caecilians in the sections that follow.

Tuataras — The remaining range of this taxon is limited and does not overlap major population centers. Thus, night lighting is unlikely to affect populations. The current recovery plan (Gaze 2001) does not refer to lights as a source of concern, and as we have found no information to suggest otherwise, do not discuss tuataras in the sections that follow.

Crocodilians — Relatively few crocodilians occur in abundance in urban areas. When they do, as in parts of Florida, USA, and Darwin, Australia (Nichols and Lentic 2008), they are often considered a source of concern in terms of human safety rather than a target for conservation efforts. Perhaps because of this bias, we have been unable to locate evidence of possible effects of night lighting on these organisms. Thus, no information on crocodilians is presented in this chapter. Given that most crocodilian species are under some degree of threat and that urban sprawl is likely to bring more of them into contact with humans and night lighting, we feel that studies to explore these effects are urgently needed.

Turtles — Marine turtles are diving specialists (Lutcavage and Lutz 1999) whose vision is adapted to finding food, locating mates, and avoiding predators underwater. Seawater differentially absorbs both the shorter (UV, violet) and longer (yellow to red) light wavelengths, while best transmitting wavelengths between 450–500 nm (blue-green to green). Some turtles have spectral sensitivities that are "tuned" (most sensitive) to the latter; sensitivity declines rapidly as wavelength increases (Witherington 1992a; Lohmann et al. 1997; J. Gocke, M. Salmon, and K. Horch unpubl. data). Negative influences of light pollution on sea turtles, especially those of artificial lights near beaches on the seaward locomotion of hatchlings,

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have been well-studied (reviewed in Witherington and Martin 1996), and have led to the only attempts we are aware of to reduce such negative influences. However, the attention given to sea turtles has not resulted in investigations of other turtles. We suggest that field research on non-marine turtles is another area that needs to be addressed.

Lizards — Lizards are often terrestrial and can be either diurnal or nocturnal. More anecdotal information about the effects of night lighting on lizards is available than for any other group (Perry and Fisher 2006). Although this effort has identified some intriguing preliminary patterns (e.g., positive effects for invading species, discussed below), the lack of experimental or systematic observational data is a source of concern.

Snakes — Snakes can be either diurnal or nocturnal, and some species show an ontogenetic switch (Clarke et al. 1996). No studies directly link artificial light to positive or negative effects on snake populations. However, declines have been noted in snake populations in many populated regions, making such work very timely. Perry and Fisher (2006) discussed possible positive predator-prey interactions between snakes and their prey, such as geckos, that are attracted to artificial lights. They also reviewed the probable negative predator-prey interactions associated with prey, such as the apparent decline of heteromyid rodents due to artificial lights, and increased exposure to snake predators. Snakes generally elicit a negative response in the general public, placing them at a special disadvantage in urban areas.

Effects of light in urban habitats

Although irradiance (defined as the density of radiant flux on a surface and typically measured over 180 degrees in units of W/cm^2) is the more appropriate measure of light intensity to use when describing light levels, we often refer to illumination (lux, $lumen/m^2$) because it is more commonly reported in the literature making for easier comparisons.

In this section, we focus on species found within or near human dwellings (i.e., edificarian species). Taxa common in urban cores are often familiar to many; some of them have had a long history of co-residence with humans. Although the number of species capable of surviving close to humans is low, edificarian species can reach high densities in their adopted habitat. Responses of edificarian amphibians and reptiles to artificial lights are well documented (Tables 1, 2), but ecological consequences remain much less obvious.

Salamanders — Few salamanders are found in urban cores. However, Garden Slender Salamanders (*Batrachoseps major*), California Slender Salamanders (*B. attenuatus*), and Arboreal Salamanders (*Aneides lugubris*) often occur around houses or along rock walls in California, USA (Cunningham 1960; Petranka 1998). We have not been able to find any information on effects that night lighting might have on such species.

Frogs — Some species of frogs commonly associate with edificarian habitats, including several species that feed on insects at lights (Table 2). Such species are typically only active at night, normally foraging under low ambient illumination (Woolbright 1985; Buchanan 1992). Some nocturnal frogs, such as the widely introduced Cane Toads (*Bufo marinus*), regularly forage under enhanced illumination near buildings (Table 2). Many nocturnal frogs show positive phototaxis (Jaeger and Hailman 1973), and laboratory studies have demonstrated that enhanced lighting can facilitate foraging in edificarian species (Larsen and Pedersen 1982; Buchanan 1998). However, it is unclear whether frogs are attracted to the increased abundance of insects available at lights, the light itself, or a combination of the two. How much light or what illumination differential is necessary to elicit this effect also remains unknown.

Although additional foraging opportunities can be beneficial, frogs aggregating at lights may also experience increased mortality. For example, Baker (1990) suggested that frogs feeding under streetlights are particularly susceptible to being killed by automobiles. In addition, radical and rapid changes in illumination can reduce visual sensitivity and require hours for complete light adaptation (Cornell and Hailman 1984). The frog eye tends to adapt to the brightest available source of light (Fain et al. 2001). Once they are light-adapted, frogs moving through areas with different ambient illuminations may suffer reduced visual capabilities, particularly when moving into shadows cast by artificial lights (Cornell and Hailman 1984; Buchanan 1993; Fain et al. 2001).

Turtles — Some terrestrial turtles, such as Box Turtles (genus

Table 1. Non-nocturnal amphibians and reptiles reported to use the night-light niche.

Species	Location	Source
Lizards		
Geckos (Gekkonidae)		
Gonatodes humeralis	Peru	Dixon and Soini 1975
Gonatodes vittatus	Trinidad	Quesnel et al. 2002
Lygodactylus capensis	South Africa	V. Egan unpubl. data
Phelsuma laticauda	Hawaii	Perry and Fisher 2006
Phelsuma madagascariensis	Madagascar	García and Vences 2002

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Table 1. Continued

Species	Location	Source
Sphaerodactylus cinereus	Florida, USA	J. Lazell unpubl. data
	Haiti	J. Lazell unpubl. data
Sphaerodactylus elegans	Florida, USA	Meshaka et al. 2004
Sphaerodactylus difficilis	Hispaniola	R. Powell unpubl. data
Sphaerodactylus macrolepis	Guana Island, BVI	Perry and Lazell 2000
Sphaerodactylus sputator	Anguilla	Howard et al. 2001
Anoles (Iguanidae)		
Anolis aeneus	Grenada	R. Powell unpubl. data
Anolis bimaculatus	St. Eustatius	R. Powell unpubl. data
Anolis brevirostris	Hispaniola	Bowersox et al. 1994
Anolis carolinensis	Hawaii	Perry and Fisher 2006
	Mississippi, USA	J. Lazell unpubl. data
	Texas, USA	McCoid and Hensley 1993
Anolis cristatellus	Dominican Republic	Schwartz and Henderson 1991
	Guana Island, BVI	Perry and Lazell 2000
	Puerto Rico	Garber 1978
Anolis cybotes	Hispaniola	Henderson and Powell 2001
Anolis distichus	Hispaniola	R. Powell unpubl. data
Anolis gingivinus	St. Maarten	Powell and Henderson 1992
	Anguilla	Hodge et al. 2003
Anolis leachii	Antigua	Schwartz and Henderson 1991
Anolis lineatopus	Jamaica	Rand 1967
Anolis luteogularis	Cuba	J. Losos, unpubl. data
Anolis marmoratus	Guadeloupe	Powell and Henderson 1992
Anolis richardii	St. George's, Grenada	Perry and Fisher 2006
Anolis sabanus	Saba	Powell and Henderson 1992
Anolis sagrei	Bahamas	Schwartz and Henderson 1991
	Florida, USA	Meshaka et al. 2004
Anolis schwartzi	St. Eustatius	Powell et al. 2005
Anolis trinitatis	St. Vincent	R. Powell unpubl. data
	Young Island	R. Powell unpubl. data
Other iguanids (Iguanidae)		
Agama agama	Cameroon	Böhme 2005
	Gabon	Pauwels et al. 2004
Basiliscus basiliscus	Costa Rica	A. Vega unpubl. data
Leiocephalus carinatus	Florida, USA	W. Meshaka in prep.
Tropidurus plica (= Plica plica)	Trinidad	Werner and Werner 2001
Skinks (Scincidae)		
Cryptoblepharus poecilopleurus	Cocos Island, Guam	McCoid and Hensley 1993
Lamprolepis smaragdina	Pohnpei	Perry and Buden 1999
Snakes		
Racers (Colubridae)		
Alsophis portoricensis	Guana Island, BVI	Perry and Lazell 2000

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Table 2. Nocturnal amphibians and reptiles reported to use the night-light niche.

Species	Location	Source
Frogs		
Toads (Bufonidae)		
Bufo americanus	Oklahoma, USA	J. Lazell unpubl. data
Bufo bufo	England	Baker 1990
Bufo cognatus	Texas, USA	S. Rideout unpubl. data
Bufo gutturalis	South Africa	V. Egan unpubl. data
Bufo maculatus	Cameroon	Böhme 2005
Bufo marinus	Costa Rica	A. Vega unpubl. data
	Florida, USA	Meshaka et al. 2004
	Guadeloupe	Henderson and Powell 2001
	Hawaii, Fiji, American Samoa	R. Fisher unpubl. data
Bufo melanostictus	China	Lazell 2002
Bufo terrestris	Florida, USA	W. Meshaka unpubl. data
Bufo woodhousii	Oklahoma, USA	J. Lazell unpubl. data
Bufo viridis	Europe	Balassina 1984
Schismaderma carens	Tanzania	V. Egan unpubl. data
Rain frogs (Leptodactylidae)		
Eleutherodactylus coqui	Puerto Rico	Henderson and Powell 2001
Eleutherodactylus johnstonei	Saba, Netherlands Antilles	Perry 2006
Treefrogs (Hylidae)		
Hyla cinerea	Florida, USA	Goin 1958
	Mississippi and Louisiana, USA	B. Buchanan unpubl. data
Hyla femoralis	Florida, USA	W. Meshaka unpubl. data
Hyla gratiosa	Florida, USA	W. Meshaka unpubl. data
Hyla squirella	Florida, USA	Goin and Goin 1957
	Mississippi and Louisiana, USA	B. Buchanan unpubl. data
Osteopilus septentrionalis	Anguilla	Henderson and Powell 2001
	Guana, British Virgin Islands	G. Perry in MS
	Florida, USA	Carr 1940
Scinax eleochroa	Costa Rica	A. Vega unpubl. data
Old World treefrogs (Rhacophoridae)		
Chiromantis xerampelina	South Africa	V. Egan unpubl. data
Lizards		
Geckos (Gekkonidae)		
Afrogecko porphyreus	South Africa	E. Baard unpubl. data
Bunopus tuberculatus	United Arab Emirates	Perry and Fisher 2006
Cosymbotus platyurus	Southeast Asia	Case et al. 1994
Cyrtopodion scabrum	Jordan	Disi et al. 2001
Gekko chinensis	China	J. Lazell unpubl. data
Gekko gecko	China	J. Lazell unpubl. data
	Florida, USA	W. Meshaka unpubl. data
	Thailand	R. Fisher unpubl. data

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Table 2. Continued

Species	Location	Source
Gekko subpalmatus	China	J. Lazell unpubl. data
	Philippines	J. Lazell unpubl. data
	Indonesia	J. Lazell unpubl. data
Gehyra mutilata	China	J. Lazell unpubl. data
	Hawaii	J. Lazell unpubl. data
	Sapwuahfik Atoll	Buden 2000
Gehyra oceanica	Sapwuahfik Atoll	Buden 2000
	Pacific Region	R. Fisher unpubl. data
Hemidactylus brookii	China	J. Lazell unpubl. data
Hemidactylus bowringi	China	J. Lazell unpubl. data
Hemidactylus flaviviridis	Egypt	Ibrahim and Ghobashy 2004
	United Arab Emirates	Perry and Fisher 2006
Hemidactylus frenatus	Australia	Cogger 1979:179
	Costa Rica	Savage 2002:484-485
	Florida, USA	W. Meshaka unpubl. data
	Guam	G. Perry unpubl. data
	Hawaii	Case et al. 1994
Hemidactylus garnotii	Costa Rica	Savage 2002:484-485
	China	J. Lazell unpubl. data
	Pacific Region	R. Fisher unpubl. data
	Florida, USA	Meshaka 2000
Hemidactylus haitianus (recently renamed *H. angulatus*)	Dominican Republic	Bowersox et al. 1994
Hemidactylus mabouia	Anguilla	Howard et al. 2001
	Brazil	Perry and Fisher 2006
	Cameroon	Böhme 2005
	Gabon	Pauwels et al. 2004
	Dutch Antilles	Powell and Henderson 1992
	Florida, USA	Meshaka 2000
	Guana Island, BVI	G. Perry unpubl. data
	Puerto Rico	R. Powell unpubl. data
	South Africa	V. Egan unpubl. data
	Venezuela	Fuenmayor et al. 2005
Hemidactylus persicus	United Arab Emirates	Perry and Fisher 2006
Hemidactylus turcicus	Israel	Werner 1966
	Egypt	A. Ibrahim unpubl. data
	Jordan	Disi et al. 2001
	United Arab Emirates	Perry and Fisher 2006
	Alabama, Florida, and Mississippi, USA	Nelson and Carey 1993
	Texas, USA	G. Perry unpubl. data
Hemiphyllodactylus typus	Pacific Region	R. Fisher unpubl. data
Homopholis wahlbergi	South Africa	V. Egan unpubl. data

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Table 2. Continued

Species	Location	Source
Lepidodactylus lugubris	Costa Rica	Savage 2002:486
	Guam	G. Perry unpubl. data
	Hawaii	Case et al. 1994
	Sapwuahfik Atoll	Buden 2000
Nactus pelagicus	South Pacific	Perry and Fisher 2006
Pachydactylus bibronii	Namibia	Perry and Fisher 2006
	South Africa	E. Baard unpubl. data
Pachydactylus turneri	Namibia	Perry and Fisher 2006
	South Africa	V. Egan unpubl. data
Ptyodactylus guttatus	Israel	Werner 1965
Ptyodactylus hasselquistii	Israel	Y.L. Werner unpubl. data
	United Arab Emirates	Perry and Fisher 2006
Ptyodactylus puiseuxi	Israel	Y.L. Werner unpubl. data
Tarentola annularis	Egypt	Ibrahim 2004
Tarentola mauritanica	Egypt	A. Ibrahim unpubl. data
	Libya	Ibrahim and Ineich 2005
Thecadactylus rapicauda	Anguilla	R. Powell unpubl. data
	Dominica	J. Lazell unpubl. data
	Necker, BVI	J. Lazell unpubl. data
	Trinidad	Kaiser and Diaz 2001
Snakes		
Racers (Colubridae)		
Lamprophis fuliginosus	Namibia	Cunningham 2002
Boiga irregularis	Guam	Perry and Fisher 2006
	Papua New Guinea	Perry and Fisher 2006
	Solomon Islands	Perry and Fisher 2006

Terrapene), are known to inhabit urban cores (Dodd 2001). Most of these species are diurnal and could conceivably be affected if night lighting extends their activity period or disturbs their nocturnal rest. Whether such an effect actually occurs remains unknown.

Lizards — Night lighting can benefit some urban lizards. Species that are not normally active after dark, especially *Anolis* lizards, have been observed foraging or being active near artificial lighting at night (Table 1), taking advantage of the "night-light niche" (Garber 1978). Normally nocturnal species, especially members of the family Gekkonidae, have also been documented around night lights (Table 2). At least some of these taxa are also known to occasionally be active during the day (McCoid and Hensley 1993; Teynié et al. 2004). Presumably, the attraction of invertebrates to artificial lights attracts lizards because of the greater quantity of food and the increased predictability of finding prey. Intriguingly, the work of Werner (1990) suggests that artificial lights can also provide basking sites, and thus a second important resource, for lizards (and possibly other amphibians and reptiles). Observations from Egypt (Ibrahim 2004; Ibrahim and Ghobashy 2004) suggest this may be a broad pattern, especially in winter, but additional studies are desirable.

Negative effects of lights on non-introduced urban lizards have not been documented, but some species are more likely to take advantage of the presence of lights, and asymmetric competition can cause locally negative effects for other taxa. The best-documented example is the interaction between two introduced geckos, the Common House Gecko *Hemidactylus frenatus* and the Mourning Gecko *Lepidodactylus lugubris*, in the Pacific. Although *H. frenatus* has negatively affected populations of *L. lugubris* and the Oceanic Gecko *Gehyra oceanica* in some lighted locations (Case et al. 1994), the two species appear to coexist in native and less-disturbed habitats (Case et al. 1994) and on other lighted structures (Perry and Fisher 2006).

Taxa that would not normally interact might nonetheless meet where artificial lights are available. Perry and Fisher (2006) reported a more extreme example from Hawaii. *Hemidactylus frenatus* (nocturnal), the Gold Dust Day Gecko

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Phelsuma laticauda (a diurnal gecko), and the Green Anole *A. carolinensis* (also diurnal) sometimes forage together at the same light source and may compete for food resources. Ironically, all three are not native to Hawaii and their ranges do not naturally overlap anywhere. Observations conducted in 2007 indicate that *P. laticauda* was successful in competing for these habitats, at least in the area around Kona, Hawai'i, where it now dominates both the diurnal and nocturnal lizard communities (R. Fisher, unpubl. data). In a different example, Perry and Lazell (2000) reported that *Anolis cristatellus* forages at artificial lights in the British Virgin Islands. Its predator, the snake *Alsophis portoricensis* (Puerto-Rican Racer), was also observed at the same lights. These species would normally interact during the day, but such additional interactions are of interest for two reasons. First, if common enough, added interactions can exacerbate normal predation effects. Second, and more importantly, this example shows that night lighting can affect more than a single species at a time, perhaps allowing species to interact that would otherwise not do so and possibly creating novel food webs. More severe or pervasive consequences might occur when night lighting exposes native species to competition with or predation by native or introduced species with which they would not normally interact.

Snakes — The effects of night lighting are difficult to separate from other problems that snakes face in urban environments, such as persecution. Only two published reports have been found of nocturnal snakes foraging under lights (Table 2). Other nocturnal species, such as the Brahminy Blind Snake *Ramphotyphlops braminus*, are found near houses in tropical areas and in cities where they have become established, but what effect lights have on their populations is not known.

Urban Water Bodies and Greenbelts

Many cities and towns have areas of natural or semi-natural aquatic or terrestrial habitats, such as city parks and water runoff storage areas, within or just outside their limits. These are typically managed for aesthetics, recreation, and/or flood control. They may be connected to each other by corridors or isolated, and the intensity of management can range from heavy (e.g., channeled streams) to very low. In these areas, skyglow may chronically increase ambient illuminations to levels substantially greater than normal nocturnal light levels (Cinzano et al. 2001; Buchanan 2006). As a result, artificial illumination around urban ponds can be brighter than even the brightest natural nocturnal light levels. For example, nocturnal light intensity around Utica Marsh in Utica, New York was measured at 0.1–1 lux (S. Wise and B. Buchanan unpubl. data), equivalent to illuminations at dawn or dusk. High-density urban cores are typically surrounded by less developed areas (e.g., agriculture, waterways, and greenbelts). In such areas, human density gradually decreases with distance from the core and species absent from the city core are often present here. Despite greater diversity, however, these areas remain influenced by the urban matrix in which they are embedded and the resulting light pollution.

Salamanders — Salamanders, such as those of the genera *Ambystoma* (Mole Salamanders) and *Notophthalmus* (Eastern Newts), are commonly found in ponds and surrounding terrestrial habitats within or near urban areas. Completely terrestrial taxa, such as those of the genus *Plethodon* (Woodland Salamanders), may be found in large wooded city parks and greenbelts. Where ponds are located near roadways, salamanders can be subject to very high probabilities of automobile impacts when crossing roads during nocturnal activity (Fahrig et al. 1995; Hels and Buchwald 2001; Mazerolle 2004). Most Spotted Salamanders (*Ambystoma maculatum*) and Blue-Spotted Salamanders (*Ambystoma laterale*) respond to disturbance and lights from approaching automobiles by halting their movements, perhaps further increasing the probability of automobile-induced mortality by increasing the time that salamanders spend on the roadway (Mazerolle et al. 2005).

The physiology and behavior of salamanders are influenced by a variety of biotic and abiotic factors, including ambient light. Introduction of artificial light during normally dark periods can disrupt the production of melatonin, a hormone responsible for many aspects of photoperiodic behavior and physiology (Vanecek 1998). Common Mudpuppy (*Necturus maculosus*) aquatic adults kept on a 12L:12D photoperiod exhibited higher plasma melatonin levels during the dark phase than during the light phase (Rawding and Hutchison 1992). When the photoperiod was reversed, melatonin production was also reversed. Aquatic adults of the Eastern Tiger Salamander *Ambystoma tigrinum* also had significantly higher plasma levels of melatonin during scotophase (the dark period of a day-night cycle) than during photophase (the light period of a day-night cycle) (Gern and Norris 1979). Gern et al. (1983) found that *A. tigrinum* kept under constant light (a condition that can occur under bright point sources of artificial night lighting) did not show significant differences in plasma levels of melatonin during photophase and scotophase as they would under natural lighting conditions. Although not tested statistically, levels of melatonin during scotophase were similar to levels during photophase for salamanders kept on a regular 12L:12D photoperiod.

Melatonin has multiple effects in amphibians, including reducing tolerance to high temperatures and lowering body temperature (Erskine and Hutchison 1982; Hutchison et al. 1979). One prediction, therefore, is that decreased nocturnal plasma melatonin levels will cause higher metabolic rates. Whitford and Hutchison (1965) compared physiological functions of terrestrial adults of *A. maculatum* kept on a 16L:8D photoperiod to those kept on an 8L:16D photoperiod. As predicted, animals kept on a 16L:8D photoperiod had significantly higher pulmonary, cutaneous, and total rates of O_2 consumption and higher cutaneous and total rates of CO_2 production (Whitford and Hutchison 1965). Wise and Buchanan (2006) therefore hypothesized that artificially increasing the length of photophase

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through night lighting may disrupt normal cyclical changes in metabolic rates, changing the energy demands of salamanders. This effect could become problematic during periods of low food availability or when energetic demands are especially high, such as during egg production or periods of drought.

The diel pattern of vertical migration exhibited by larval salamanders (genus *Ambystoma*: *A. jeffersonianum* (Jefferson Salamander), *A. opacum, A. talpoideum* (Mole Salamander), and *A. tigrinum*) is influenced by ambient light, temperature, competition, and predation risk (Anderson and Graham 1967; Stangel and Semlitsch 1987). Anderson and Graham (1967) observed that *A. opacum* exhibited more activity on overcast days and less vertical migration on bright nights. Interruption of vertical migration may reduce size at metamorphosis or survival (Semlitsch 1987).

Changes in light intensity during scotophase as a result of artificial night lighting can also affect other behaviors, such as foraging. Buchanan (unpubl. data) tested adult Red-backed Salamanders (*Plethodon cinereus*) in the laboratory in the absence of olfactory cues but under a range of illuminations (complete darkness, 10^{-5}, 10^{-4}, or 10^{-3} lux). Salamanders oriented toward prey sooner at higher ambient illuminations, indicating improved visually-based foraging ability with higher light levels. Although increased ambient light may allow salamanders to see prey better, it can also delay the nocturnal foraging activity of *P. cinereus*, which typically emerge from the leaf litter approximately 1–2 h after dark (B. Buchanan and S. Wise unpubl. data; Fig. 1). Buchanan and Wise conducted forest censuses 1–2 h after sunset in six dark (no artificial illumination; 10^{-4} lux) and six lighted (with white holiday lights; 10^{-2} lux, equivalent to bright moonlight) transects. Fewer salamanders were active in the lighted transects than in the unlighted transects during the census. B. Buchanan and S. Wise (unpubl. data) hypothesized that delayed emergence may reduce the length of time salamanders are able to forage, especially on dry nights, when reduced humidity decreases the amount of time spent foraging (Keen 1984).

Agonistic behavior is also affected by nocturnal ambient illumination. Adults of *P. cinereus* are territorial, guarding cover objects that provide access to food, moisture, and potentially mates (Mathis et al. 1995). In the laboratory, B. Buchanan (unpubl. data) examined the threat displays exhibited by territorial residents towards intruding salamanders under different levels of illumination (complete darkness, 10^{-4}, or 10^{-2} lux). Residents used more visual displays as light intensities increased. Presumably, visual threat displays are energetically costly to produce (Wise and Jaeger 1998); thus, increased use of visual displays with increased ambient illumination may negatively affect energy budgets. On the other hand, increased visibility may also allow individuals to assess better the outcome of agonistic interactions, thereby reducing the probability of contests escalating to overt aggression and injury (Jaeger 1981).

Spectral properties of light may affect migration to and from ponds. Metamorphosed juvenile Red-spotted Newts

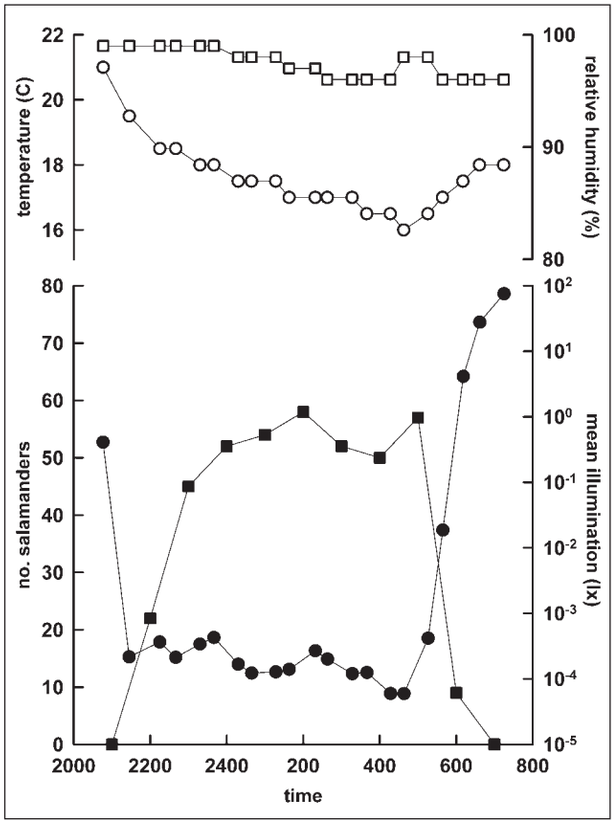

Fig. 1. Activity of *Plethodon cinereus* (Red-backed Salamander) during a representative night census (from dusk until dawn, 2100 – 0700 h, 1-2 July 2003) of two 50 x 1 m transects (B. Buchanan and S. Wise unpubl. data). The study was conducted at Mountain Lake Biological Station, University of Virginia, Giles County, VA. Plotted are the numbers of salamanders detected on the leaf litter or vegetation (■), the mean illumination from the 4 cardinal directions (●), temperature (○), and percent relative humidity (□) for each sampling period.

(*Notophthalmus viridescens*) migrate from their natal ponds to nearby forests a few months after hatching and return to their natal ponds as adults. Adults also leave the ponds during periods of drought or when ponds freeze (Petranka 1998). These salamanders use a light-dependent magnetic compass (Phillips et al. 1995) involving extraocular photoreceptors (Adler 1970; Deutschlander et al. 1999) for navigation. Phillips and Borland (1992a,b,c, 1994) demonstrated experimentally that orientation and homing behavior were disrupted by monochromatic, long-wavelength light (yellow spectrum, especially 550–600 nm). Common outdoor lights emit light at 540–630 nm (Massey et al. 1990). Their use, therefore, could negatively affect the ability of *N. viridescens*, and perhaps other species of salamanders that use a similar light-dependent magnetic compass, to navigate to home ponds for breeding. Thus, spectral properties of artificial night lighting should be considered as part of conservation or management efforts in urbanized habitats containing semi-aquatic salamanders.

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Frogs — Frogs are typically aquatic breeders, and in urban settings they are likely to use both ephemeral breeding sites (e.g., ditches) and permanent sites (e.g., ponds or streams). Such sites are frequently exposed to increased light levels due to roadway lighting and skyglow (Buchanan 2006). Effects of altered lighting may be seen as early as during embryonic growth and larval development. Decreasing the duration of scotophase slowed growth in larval Painted Frogs *Discoglossus pictus* (Gutierrez et al. 1984) and African Clawed Frogs *Xenopus laevis*, causing the latter to metamorphose at a smaller size (Delgado et al. 1987; Edwards and Pivorun 1991). Conversely, constant lighting accelerated larval development in Northern Leopard Frogs, *Rana pipiens* (Eichler and Gray 1976). Thus, artificial night lighting has the potential to affect time to metamorphosis or size at metamorphosis.

The behavior and physiology of tadpoles may also be affected by night lighting. For example, larval American Toads (*Bufo americanus*) use photoperiodic cues to thermoregulate behaviorally (Beiswenger 1977) and vertical migration in *Xenopus laevis* larvae is dependent upon changes in illumination (Jamieson and Roberts 2000). Exposure at night to artificial light for as little as 1 min can disrupt production of precursors required for larval melatonin production (Lee et al. 1997), which may in turn have important effects on physiological performance (Vanecek 1998). For example, *X. laevis* larvae exposed to constant lighting did not experience normal diel patterns of color change (Binkley et al. 1988).

Adult frogs living in greenbelt or park areas, like those of many species, would traditionally be active at very low environmental illuminations (reviewed in Buchanan 2006), and may thus be affected by artificial night lighting. Species such as the Western Tailed Frog *Ascaphus truei*, normally active only at the darkest natural nocturnal illuminations (Hailman 1982), are likely to be influenced when environmental illuminations increase to levels at which the frogs typically seek refugia. Artificial night lighting can disrupt foraging, fat storage, and growth in adult frogs (e.g., in Fowler's Toad *B. fowleri*, Bush 1963). Reproductive behavior is also sensitive to changes in illumination. For example, calling males of Panamanian Cross-banded Treefrogs *Smilisca sila* exhibit illumination-dependent changes in anti-predator behavior under natural conditions (da Silva Nunes 1988). In another example, females of the Tungara Frog (*Physalaemus pustulosus*) become less likely to exhibit mate choice at higher ambient illuminations (Rand et al. 1997), and vary their oviposition behavior in response to changes in illumination (Tárano 1998). Other nocturnally breeding species, such as the Squirrel Treefrog *Hyla squirella* (Taylor et al. 2007) and the Sarayacu Treefrog *H. parviceps* (Amézquita and Hödl 2004), use visual cues in mate choice and male-male competition. Artificial lighting may allow these and other visually-based behaviors to occur at uncharacteristic times or intensities (Buchanan 2006).

Frogs moving across roadways while foraging or breeding have a high probability of being killed by automobiles (Fahrig et al. 1995; Hels and Buchwald 2001; Mazerolle 2004). Many frogs are primarily active at night, and the moving lights of oncoming cars create cycles of increasing and decreasing illumination that may make dark adaptation difficult. Buchanan (1993) found that rapid increases in illumination similar to that produced by oncoming traffic slow visual foraging in the Gray Treefrog (*H. chrysoscelis*). Mazerolle et al. (2005) similarly found that nocturnally active American Toads (*B. americanus*), Spring Peepers (*P. crucifer*), Green Frogs (*R. clamitans*), and Wood Frogs (*R. sylvatica*) are more likely to become immobile on the road when approached by automobile-related stimuli than when left undisturbed. Although their experiment did not completely control for disturbance, making it impossible to separate out the effects of light and disturbance, their results are consistent with the idea that rapid shifts in illumination can alter the behavior of frogs at night.

Physiological consequences are also possible. For example, Leopard Frogs (*Rana pipiens*) kept under constant lighting suffered from retinal irregularities (Bassinger and Matthes 1980) and Common Asian Toads *B. melanostictus* show reduced sperm production when maintained in constant light (Biswas et al. 1978). The expression of genes that, in turn, regulate other physiological processes can also be altered by constant illumination (Green and Besharse 1996; Steenhard and Besharse 2000; Baggs and Green 2003). The number of species that may be susceptible to these various effects and the magnitude of change in illumination intensity or duration that is necessary to elicit such responses remain unknown.

Turtles — A number of freshwater turtles survive within urban matrices, perhaps because of their unusual resistance to various pollutants (Gasith and Sidis 1984). Increasingly, species common in the pet trade, such as the Red-Eared Slider *Trachemys scripta elegans*, are also becoming widely established in urban settings (e.g., Lever 2003; Perry et al. 2007), presumably following their release or escape. Information about the ecology of such species in urban and near-urban environments and on the influence of lights upon them is lacking. The single exception involves a laboratory study in which Chinese Soft-Shelled Turtles (*Pelodiscus sinensis*) were shown to have lower food uptakes and growth rates at higher light intensities (Zhou et al. 1998). It is quite possible that species such as softshell turtles (Trionychidae) that sleep on shore at night would also be more exposed to predation due to increased visibility to predators in lighted landscapes.

Lizards — Many lizard species exist in urban peripheries. Nonetheless, we have not been able to find any studies showing effects of lights on these reptiles. Further study on the impacts of night lighting in these habitats is needed.

Snakes — Some aquatic snakes track the lunar cycle in their activity and foraging patterns (Madsen and Osterkamp 1982; Houston and Shine 1994; Andreadis 1997). The issue of artificial lights disrupting the lunar cycle in natural areas (i.e.

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biodiversity reserves) adjacent to urban areas is of concern, but studies exploring this potential problem are absent. Increased lighting may affect snake foraging success. Predation success rates for some species that prey on snakes increase with increased illumination (Bouskila 1995), and some snake prey reduce their foraging activity in response to increased illumination (e.g., Bouskila 1995; Bowers 1988).

Urban Beaches and Estuaries

Many of the world's largest cities originated as port towns. Other urban centers have more recently emerged around tourist destinations and often feature heavily-developed beaches. In many cases, the same sandy beaches treasured by vacationers are also the traditional sites for sea turtle nesting. Sea turtles at such locations probably offer the best case studies of the effects of artificial lighting on any taxonomic group (e.g., Witherington 1992b). Other species, such as the diurnal Fringe-Toed Lizard (*Acanthodactylus scutellatus*) and the nocturnal Leaf-Nosed Snake (*Lytorhynchus diadema*) also inhabit those same dunes (e.g., Perry and Dmi'el 1995) and may be exposed to ambient light from nearby cities.

Frogs — Although no species of frog tolerates the high salinity associated with marine beaches per se, some (e.g., Marine Toads *Bufo marinus*, Crab-Eating Frogs *Rana cancrivora*) are known to breed in brackish water. One of them, *B. marinus*, has been widely introduced around the world (Lever 2003) and is commonly found near urban centers. In Hawaii, Guam, and elsewhere, large numbers will forage under lights, clearly taking advantage of the increased prey abundance (J. Lazell pers. comm.; G. Perry unpubl. data). However, the consequences of lights for amphibian populations inhabiting beaches and estuaries remain unstudied.

Turtles — McFarlane (1963) described how hatchling turtles in Florida, after emerging from their nests, were attracted to street lighting visible at the beach. Many crawled inland, crossed a coastal roadway *en route* to the lights, and were crushed on the road by passing cars. We now know that hatchlings worldwide are commonly attracted to light fixtures (Philibosian 1976; Peters and Verhoeven 1994), and that most turtles attracted to lights die from exhaustion, dehydration, and predation. Other sources of illumination (such as abandoned campfires on land) can also be deadly (Mortimer 1979). Artificial lighting also affects adult turtles by degrading the quality of their rookery sites. Nesting attempts (crawls of gravid females up the beach to nest) each night by Green Sea-Turtles (*Chelonia mydas*) and Loggerheads (*Caretta caretta*) were reduced to almost zero at historically important sites (Melbourne Beach, Florida; Tortuguero, Costa Rica) when these locations were experimentally exposed to lighting (Witherington 1992b). When the lights were turned off, nesting attempts each evening immediately increased. In Florida, the spatial pattern of artificial lighting probably accounts for the present distribution of the "preferred" rookery sites along the East Coast (approximately 75,000 loggerhead nests annually). About 90% of all nests are deposited at five beach sites characterized primarily by their lower exposure to artificial lighting (Salmon 2003). The same sites are also preferentially used by Leatherbacks (*Dermochelys coriacea*), *C. mydas,* and *C. caretta*, which elsewhere tend to nest at different locations. This suggests that the negative effects of coastal development and its associated lighting, rather than features that have traditionally promoted female reproductive success and hatchling survival, currently determine where marine turtles nest.

Lizards — Some species of lizards inhabit beaches, and a few, such as Black Iguanas (*Ctenosaura similis*), may occasionally be seen near human habitation. Slightly further from the beach proper, species such as the Fringe-Toed Lizards *Acanthodactylus scutellatus* and *A. schreiberi* inhabit dune formations nestled within seaside urban communities (Perry and Dmi'el 1995). However, such cases are uncommon, and we are unaware of any studies examining the influence of lights on such species.

Snakes — A number of snake species in the family Elapidae (some authors place them in the families Hydrophiidae and Laticaudidae) spend their lives in the sea and most can at times be found near land, if only briefly. Some of these (e.g. *Laticauda* species) can be quite common along beach-retaining walls in urban south-Pacific cities that are exposed to lights. Another group of snakes, the Homolopsines, primarily occur in mudflats and forage at night. Finally, terrestrial species such as the Sand Snake (*Psammophis schokari*) and *Lytorhynchus diadema* inhabit dune formations nestled within sea-side urban communities in Israel (Perry and Dmi'el 1995). However, we are unaware of studies examining the effects of lights on such species.

Remediation

All of the work conducted to date on light pollution remediation for herpetofauna involves sea turtles. Recent tests on hatchling orientation, conducted in an arena setting, indicated that natural cues and artificial lights "compete." This work offers hope of identifying a technological fix because it shows that a reduction in the perceived "attractiveness" of artificial lighting makes it more likely that hatchling orientation will be based upon natural cues (Tuxbury and Salmon 2005).

A number of studies have examined the feasibility of using alternative lighting methods that would reduce or eliminate the negative influence on sea turtles but that would also be acceptable to humans. Turtle-friendly lights generally emit wavelengths between 540 and 700 nm (amber to red) and can be produced either by designing lights that emit only the longer wavelengths (Fig. 2) or by using filters that exclude the shorter wavelengths of "broad-spectrum" lights. Salmon and his colleagues (Halager et al. in press) developed a bioassay that can be used to evaluate the efficacy of "turtle-friendly"

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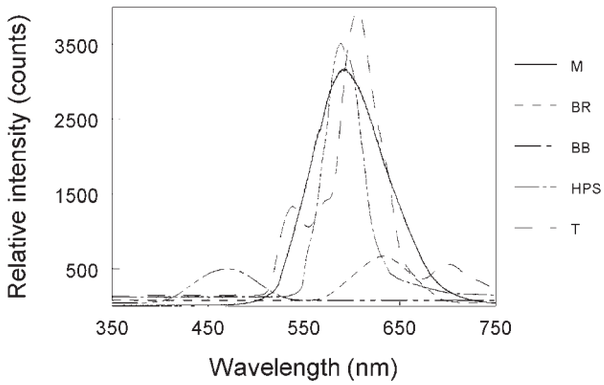

Fig. 2. Spectral energy distributions for four "turtle-friendly" lights (Magnaray, M; filtered High Pressure Sodium vapor, HPS; Twistee, T; and Beeman Red, BR). One short-wavelength light (Beeman Blue, BB) was used as a control. Filtered HPS lights are used on coastal roadway poled streetlights in Florida; the Twistee and Beeman red are lights designed for buildings (residential or commercial) that are visible at marine turtle nesting beaches.

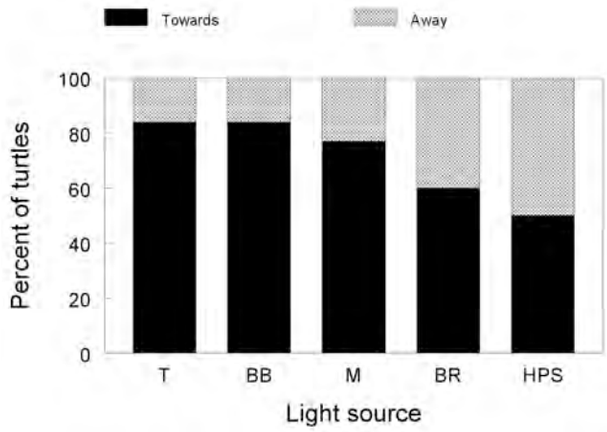

Fig. 3. Choices of hatchling sea turtles (Loggerheads, *Caretta caretta*) presented with various lights. A no-light control was used in each case. Differences among light sources in relative intensities were eliminated through the use of neutral density filters, so that responses shown by the turtles were based upon spectral differences alone. Results show that the turtles are statistically significantly attracted to the Twistee (T, n = 25 turtles), Beeman Blue (BB, n = 25), and Magnaray (M, n = 35) lights, but not to the Beeman Red (BR, n = 45) or Filtered HPS (HPS, N = 46).

lights by giving hatchlings choices between darkness and a light (single light experiments) or pairs of different lights. Using this bioassay, Halager et al. (in press) found that some lights are more attractive to turtles than others and that the strength of attraction declines as spectral energies become more concentrated in, and shifted toward, the longer wavelengths (Figs. 3, 4). Field experiments demonstrate that high-pressure sodium vapor lamps affect marine turtles, but passing such illumination through a filter that excludes wavelengths below 530 nm makes these lights far less attractive to hatchlings (Sella et al. 2006). In fact, when this filtered lighting is visible at nesting beaches, it no longer reduced nesting by adults (Pennell 2000).

The use of spectrally-modified outside lighting should increase the number of hatchlings that successfully locate the ocean, even at urban nesting beaches. Recently, lighting along a coastal roadway in the city of Boca Raton, Florida, was extensively modified. Streetlights placed on posts were turned off during sea turtle nesting season and replaced with light-emitting diodes installed in the pavement. These provided sufficient illumination for traffic safety, but none of the lighting was visible at the nesting beach. Behavioral tests at the beach demonstrated that the seaward orientation of hatchling Loggerheads was normal when the embedded lights were on, but disrupted when the elevated streetlights were on (Bertolotti and Salmon 2005). It remains to be seen to what extent use of similar technologies could help other taxonomic groups.

Discussion

Artificial light, long considered a problem for astronomers but of little concern to biologists, is increasingly viewed as a threat by conservation biologists. A recent volume (Rich and Longcore 2006) illustrated the pervasiveness of the problem of artificial lights, which affect a broad range of taxa. In this chapter, we focused on updating and summarizing the information for amphibians and reptiles, but emphasize that the problems associated with artificial night lighting likely do not stop with a particular group of organisms. It may impact entire communities, and we find it encouraging that solutions to this problem may also simultaneously benefit a broad range of taxa.

There are doubtlessly additional species and populations which use artificial lights and are not listed in Tables 1 and 2. For example, Outen (2002) and Spellerberg (2002), identified lights associated with roads as a potential source of concern, but could find few studies directly evaluating this potentially widespread risk (but see Mazerolle 2004; Mazerolle et al. 2005). The reports collected by Rich and Longcore (2006) also stress the magnitude of the lack of information on effects of artificial night lighting for many taxonomic groups, including amphibians and reptiles (Buchanan 2006; Perry and Fisher 2006; Salmon 2006; Wise and Buchanan 2006). However, there is reason to be concerned about the effects of artificial light on amphibians and reptiles in general: many species are nocturnal and many populations are in serious decline (e.g., Alford and Richards 1999; Gibbons et al. 2000). Unfortunately, the literature demonstrates a lack of information for caecilians, tuataras, and crocodilians, which are primarily nocturnal and could therefore be at risk from changes in light levels.

Urban ecology is a rapidly growing discipline, but herpetological research in urban environments remains notably underrepresented. Studies typically focus on relatively undisturbed habitats, and even herpetofaunal surveys rarely explicitly address taxa found in or near human habitation. The biology of edificarian taxa is even more rarely reported (but see Powell and Henderson 2008). We hope that the increased

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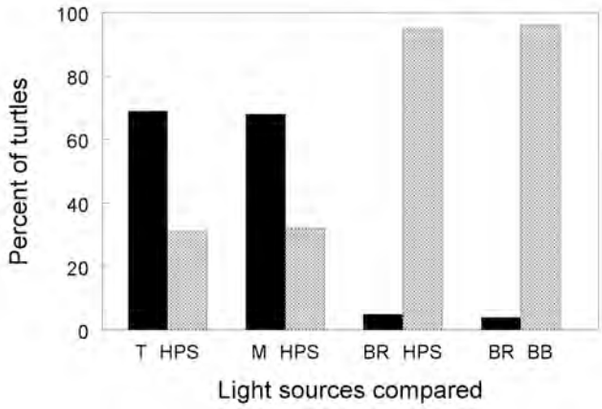

Fig. 4. Choices of hatchling sea turtles (Loggerheads, *Caretta caretta*) in tests in which paired light presentations were made. Turtles are significantly attracted to the Twistee (T) and Magnaray (M) lights when each is matched with a filtered HPS light (n = 29 and 60, respectively, for each test). However, turtles are significantly attracted to the filtered HPS light when it is paired with a Beeman Red light (BR, n = 40), which is also less attractive to the turtles than the Beeman Blue light (BB, n = 25).

interest in urban ecology will lead to more studies addressing light pollution and their effects on amphibians and reptiles. Although these influences are only beginning to be studied, a few general patterns appear to be emerging:

1) Species vary in their sensitivity to light pollution, which may have no effect, benefit, or negatively affect a particular taxon. Thus, it is important to consider the photobiology of all taxa found in a particular habitat. For example, sea turtle nesting problems may be reduced by shifting the spectra of lights to longer wavelengths. Shifting spectra to longer wavelengths can, however, disrupt migration in newts (which do not, fortunately, share the same habitat). Thus, there may not always be simple solutions to lighting problems other than the removal, reduction of use, or shielding of artificial night lighting.
2) Different aspects of a given species' biology can be affected differently by different lighting conditions at different life history stages.
3) There is a paucity of research available on the negative effects of lighting on herpetofauna. Negative effects of light pollution, such as the disruption of orientation in hatchling sea turtles (e.g., Witherington and Martin 1996) are well documented, but detailed studies for other taxa are not yet available.
4) There is a dearth of studies of the positive effects of lighting on herpetofauna. Positive influences, such as increased prey availability and thermoregulatory opportunities around artificial night lighting are better documented, if only anecdotally, in lizards (Tables 1, 2). We are not aware of studies that have elucidated population-level consequences, what mechanisms are involved, and which species are most likely to be affected.
5) Indirect effects are likely to be common. Benefits to one species may negatively influence another, as demonstrated by Case et al. (1994). However, studies of this phenomenon that do not involve invasive species are only now starting to reach the literature (Rich and Longcore 2006).
6) The ability of artificial light to enhance the invasive potential of some species should be a source of broad concern. Some of the species listed in Table 1 and many of those in Table 2 were observed in areas outside their native range. The ability to use human habitats, which are often characterized by having additional lighting during the night, can be beneficial to invasive species, many of which first colonize urbanized areas. For species that are not only tolerant of such conditions but can also take advantage of the night-light niche, establishment of viable populations may be easier. Almost no information is available on the impacts of invaders such as geckos, which are generally perceived as innocuous, yet it seems likely that at least some native species (particularly invertebrate prey) must be negatively affected. Light-aided invasive species may also spread disease and exotic parasites to native species.

Is it possible to resolve such conflicts of interest between urban residents and urban amphibians and reptiles? New technology, briefly reviewed above, offers some promising options for providing illumination that satisfies human requirements while minimizing effects on other species. However, solving the light pollution problem necessitates light management, including protocols that eliminate the influence of artificial lighting on wildlife by, for example, turning off unnecessary lights, reducing wattage, shielding and lowering luminaires, or creating natural light barriers, such as dune or wooded areas, between light sources and wildlife habitats (Witherington and Martin 1996). However, humans often perceive lighted environments as more pleasing or safe. For example, lighting along roadways and in city parks is often considered necessary for pedestrian and vehicular safety. Thus, there may be resistance to reducing the amount of lighting at urban sites. There is much room for research on the human dimensions of the problem and such work can hopefully help identify technological solutions that benefit wildlife and are broadly acceptable to the public. We hope that such solutions can be incorporated rapidly not just where a particular species of sea turtle or gecko is found, but on a global scale commensurate with the scope of the artificial light problem.

Management Recommendations

The information presented in this chapter clearly indicates the potential for multiple types of effects on amphibians and reptiles resulting from artificial night lighting. Although the most extensive work has been carried out on sea turtles at urban beaches, preliminary evidence indicates that many species are likely at risk. Although it is clear that much more

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research is needed in this area before firm conclusions can be drawn, work reviewed above has begun identifying potential problems and solutions to these problems, which we are hopeful can effectively be incorporated into standard practices. We recommend that managers adopt a precautionary approach and attempt to minimize consequences without waiting for researchers to confirm the impacts on a particular species or habitat. It is clear that the best approach for the conservation of native taxa involved is returning habitats as closely as possible to their natural lighting conditions, primarily through the removal of unnecessary lighting and shielding of necessary lighting. It is worth noting that several entities that have experimented with reducing lighting have also recouped their investment in reduced power costs (e.g., International Dark Sky Association: www.darksky.org/infoshts/pdf/is191.pdf, accessed 15 May 2006).

Summary

Amphibians and reptiles have not evolved with artificial lighting at night. Thus, alteration of the natural variation in diurnal and nocturnal light intensities and spectral properties of lights has the potential to disrupt their physiology, behavior, and ecology. Our review identified possible effects of night lighting on many species of amphibians and reptiles. However, it also reveals that conclusive data are often lacking. Few studies on the consequences of artificial lights for amphibians and reptiles have been conducted to date, and in many that might be relevant, researchers have not recorded the illumination or irradiance at which experiments are conducted. Thus, it is currently impossible to precisely gauge the effects of artificial night lighting on taxa found in urban, light-polluted environments. The one exception is the information available on the negative impacts of artificial lights on hatchling sea turtles, which has received considerable coverage in both scientific and popular media. With that exception, we believe it is too early to draw sweeping conclusions and to provide broad management recommendations, beyond pointing out the urgent need for more information. However, we identify light pollution as a serious threat that should be considered as part of planning and management decisions in the maintenance or conservation of urban areas containing amphibians and reptiles.

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Field Margins, Foraging Distances and Their Impacts on Nesting Pollinator Success

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Abstract

The areas of wild land around the edges of agricultural fields are a vital resource for many species. These include insect pollinators, to whom field margins provide both nest sites and important resources (especially when adjacent crops are not in flower). Nesting pollinators travel relatively short distances from the nest to forage: most species of bee are known to travel less than two kilometres away. In order to ensure that these pollinators have sufficient areas of wild land within reach of their nests, agricultural landscapes need to be designed to accommodate the limited travelling distances of nesting pollinators. We used a spatially-explicit modelling approach to consider whether increasing the width of wild strips of land within the agricultural landscape will enhance the amount of wild resources available to a nesting pollinator, and if it would impact differently on pollinators with differing foraging strategies. This was done both by creating field structures with a randomised geography, and by using landscape data based upon the British agricultural landscape. These models demonstrate that enhancing field margins should lead to an increase in the availability of forage to pollinators that nest within the landscape. With the exception of species that only forage within a very short range of their nest (less than 125 m), a given amount of field margin manipulation should enhance the proportion of land available to a pollinator for foraging regardless of the distance over which it normally travels to find food. A fixed amount of field edge manipulation should therefore be equally beneficial for both longer-distance nesting foragers such as honeybees, and short-distance foragers such as solitary bees.

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Introduction

Globally, evidence is accumulating that populations of both wild and managed pollinators are in decline [1–5]. Pollinator loss, particularly of bees, has drastic economic effects [6–8], and much effort has been put into both identifying the factors causing these losses, and attempting to reverse the declines [5,9–11]. With increasingly large areas of land being used to grow single crops, the resulting loss of structural diversity within the landscape has been suggested to be a key contributory factor to pollinator loss [12,13]. One strategy for reversing the decline land-use changes are causing is to add heterogeneous 'refuge' areas within the landscape. National and international agri-environment schemes offer subsidies to farmers for adding different forms of wildlife refuges within the agricultural landscape [9,14], which include both leaving fields fallow, and adding set-aside 'wild' regions at the edges of fields, which aim to enhance the connectivity between natural areas and the land used for agriculture.

Field edges consist of a wide diversity of different sub-habitats, and include landscape features such as hedgerows, ditches, wooded areas, and stream edges [15,16]. All of these have positive effects in enhancing the amount of local biodiversity [17–20]. Both floral [21,22] and invertebrate biodiversity [23–29] are increased by field margins, including species that are natural enemies of crop pests [30]. Most importantly for pollination, field edges are attractive to foraging native bees [20,31,32], and increasing their width or the bank of floral resources within them has positive effects upon pollinator presence [27,33,34]. Therefore, as a remediation strategy, field edges could be manipulated in many different ways, such as enhancing their wild flower seedbank, or altering their spatial scale within and between fields. Since a given area of land cannot be used both for crops and as a wild refuge, farmers choosing to add wild land face a trade-off between the services provided by wild land and the costs of not using the land for direct production. Therefore, exploring how wild land such as field edges can be used to the best advantage is crucial for successfully implementing them within intensive agricultural systems.

Identifying how best to allocate wild land within an agricultural environment involves identifying how the organisms using the land will respond to environmental manipulations. If we assume that bees nest within minimally disturbed wild patches, it follows that their interaction with the local environment will be limited by the distance that they will typically forage around their nest. Many studies have attempted to quantify the maximum range over which the many species of bee (sampled from across the Apidae) will forage away from their nest (*e.g.* [35–46]). With the exception of the honeybees *Apis* spp., most of the Apidae appear to forage a

maximum of 2km from their nests, and a majority of these forage under 1km [47], although they may not forage in the immediate range around their nest [48]. Therefore, if we are interested in addressing how the supplementation of field edges affects bee foraging success, we need to consider what type of land a manipulation makes available within this local area. If a particular species has a short foraging range, adding a given proportion of field edges into the local environment may have a different effect than it would to a longer-range forager, as such short foraging distance could be heavily affected by local landscape geometry.

Rands & Whitney [49] described a simple simulation model that explored the effects of field edge structure upon foraging success in bees. The quality of habitat available to a forager with a fixed foraging radius was considered, where the environment had a simplified grid-like structure. This model asked whether landscape structure could have an effect upon the availability of wild or crop forage to bees, dependent upon the bees' degree of constancy to the most abundant resource available ('neophobia', also discussed in [50,51]). If agricultural practices mean that bees that are foraging in a landscape filled with large fields are over-attracted to single dominant crop type, the over-representation of a single source of resource in the bees' diet could have detrimental effects upon development of the colony [52,53], as the lack of dietary diversity may lead to a lack of micro-nutrients essential to larval development. Rands & Whitney demonstrated that both the density of wild flowers within the field edge and the width of field edges relative to agricultural fields were important for enhancing resources available to bees. This became increasingly important if the bees showed some degree of preference for the most common resource available within the environment.

Although possibly representative of large-scale farms where the landscape structure is primarily homogeneous crop interspersed with very rare straight field edges, the grid-like structure of the fields considered by Rands & Whitney were arguably too artificial for most landscapes in Western Europe, where hedgerows and field margins are an integral part of the landscape. Here, we consider the effects of field edge manipulation upon the availability of wild area to bee-like foragers who are constrained by a need to return to a nest located within the field edges (which would make this comparable to economic models of central place foraging, *e.g.* [54–56]). Rands & Whitney [49] only considered changes in individual preference for monocultures in response to landscape manipulation. Here, we instead explore the overall availability of resources with respect to the flight distance of a nesting foraging and the degree to which the environment is manipulated. We consider both a landscape composed of randomly structured fields, and one composed of field forms that are extracted from British mapping, which we propose as a model system for exploring how the techniques could be used to consider any agricultural environment where landscape structure is known. As well as addressing whether the addition of space within field edges has an effect upon what is available to foragers, we also consider whether these effects vary for foragers who travel differing distances from their nest.

Methods

Models using a Voronoi-like randomised landscape

All simulations took place within a 500×500 grid of unit squares (figure 1 gives a simplified illustrative version of the process on a reduced grid). Fields were created by selecting a predefined number of seeds at randomly selected points within the grid: all the points were randomly selected non-integer coordinates, and no more than one point occurred within any unit cell within the grid. Each of these seeds was given a unique identifier, and then each cell within the grid was then labelled with the identifier of the seed closest to its centre (or, in the unlikely event of several seeds being equally closest, one of these seeds was randomly selected as being the closest). Field edges were then defined as the cells whose four touching neighbours included at least one cell that did not share the same label as the target cell. This gave a structure based on a Voronoi tessellation, implemented within a discretised grid.

For simulations where field edge width was set as 1, only the cells determined above were considered to be edges. If edge width was 2, all the cells immediately connected to previously-defined field edge cells were considered to be edge cells as well. If the edge width was n, the wild area was expanded to include all the cells connected to any cells that had been considered as edge cells when width was $n - 1$. Throughout, any cells that did not count as an edge cell was considered as a cultivated field cell.

For all simulations, a viable nesting site was selected by randomly selecting a field edge cell within the middle 98×98 cells of the arena (this area was confined to accommodate the maximum radius of foraging considered). The numbers of edge (e_{vis}, termed **'visible wild'**) and cultivated (c_{vis}) field cells whose centres lay within a pre-defined foraging radius of the nest cell's centre were counted, and the total number of cells visible was determined (as $n_{vis} = e_{vis} + c_{vis}$). At the same time, the total number of edge (e_{tot}) cells throughout the environment was calculated. The proportion of edge cells (**'proportion wild'**) visible to a nesting forager was calculated as e_{vis}/n_{vis}. We also calculated a **'coverage'** statistic that gave a description of how composition of the forager's available foraging environment compared to what was available throughout the entire 250,000 cells of the modelled environment: we did this by calculating the ratio of the proportion of locally visible cells that were edge cells to the overall environmental proportion was calculated as $(e_{vis}/n_{vis})/(e_{total}/250{,}000)$.

For the simulations, 10,000 replicates were conducted for each systematically altered parameter, with other parameters being selected using a randomisation function. When randomised, foraging radius was a real number from the range (0, 200); field edge width was an integer value from the range (1, 15); and the number of initial field seeds was an integer value from the range (2, 200).

In addition to the separate exploration of the three individual model parameters, we also examined the interactions of these parameters by generating 200 fields (each with independently randomised initial seed coordinates) for each of the 512 possible combinations where foraging radius = (25, 50, …, 200), edge width = (1, 3, …, 15) and field seeds = (25, 50, …, 200). The changes in the calculated values of 'visible wild', 'proportion wild' and 'coverage' were modelled using an analysis of variance which incorporated the three parameters, the three possible two-way interactions and the single three-way interaction between them.

Models using British landscape data

Areas of UK landscape were selected from land described within UK Ordnance Survey squares NN, NY, SE, SJ, SK, SO, SP, ST, SU and TL (these particular squares were chosen because they contained little or no sea), using the most current data available at a 1:10,000 scale on the 19th July 2010. To be acceptable as a representative of the British non-urban 'landscape', each valid square used could contain housing and associated small gardens on no more than 25% of the area. Similarly, squares were not deemed acceptable if they contained large bodies of water (lochs, lakes, or the sea). One hundred 2×2 km^2 squares that fit these criteria were randomly selected for processing.

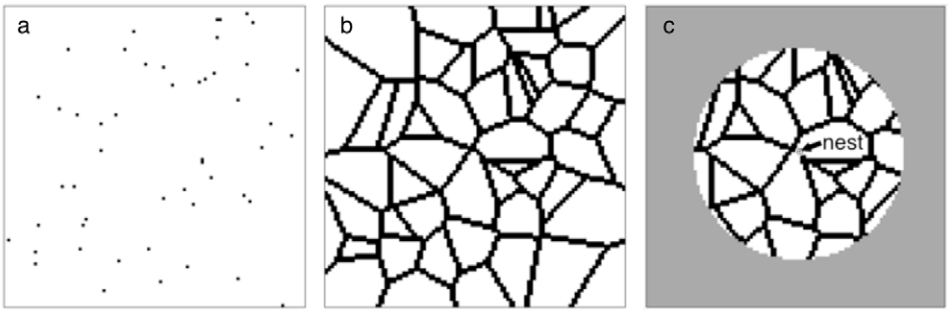

Figure 1. Simplified illustration of the Voronoi-like field generation process. Here, a 101×101 unit arena is populated with 50 field seeds that are randomly placed on unit cells (*a*). The nearest seed is calculated for all the cells within the arena (with random allocation if several seeds are equally closest). If a cell possesses at least one neighbour that does not share its nearest seed, it is designated an 'edge' cell, whereas cells where all four neighbours share the same nearest seed are designated 'field' cells: (*b*) shows black edge and white field cells for the field seeds given in (*a*). To calculate wild edge cell availability nest sites are randomly placed on edge cells, and the numbers of edge and field cells are tallied within a given foraging radius of the nest (the area within the grey circle in *c*).
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A traced outline of the field edges was made for each of the 100 samples, where streams, rivers, roads, walls, paths, and marked edges of wooded areas were considered to be field edges. This simplification is justified here as the areas selected for sampling were predominantly non-urban, and were intended to give an approximation of the form of the UK countryside rather than being an exact representation (the maps used could not give exact geographical information of the existing widths of many of the linear structures within the environment due to the scale of mapping available). The traced images were scanned, and converted to 813 × 813 best-quality JPG images using *Preview* 5.0.2 (Apple Inc., Cupertino, California, USA). These files were then converted to binary images using *ImageJ* 1.43*u* [57], and saved as text images.

As a result of this process, the unit squares in the 813×813 landscapes created in this manner were either 'edge' or 'field' cells. Therefore, the unit edges of each square considered corresponded to a geographical distance of 2.46 m (a constraint imposed by the pixel resolution of the scanned images – therefore, any geographical 'edge' feature as defined above was assumed to possess unit cell width). For each of these landscapes, the mean proportion of edge cells (relative to field cells) available to a forager nesting within the field margin that had a foraging radius of r units was assessed. To do this, all possible nesting sites within the landscape that were able to support this foraging distance were identified, and the numbers of edge and field cells were calculated for each of these. For example, the maximum radius of $r = 406$ could only be assessed if the central cell in the arena was an edge cell. A forager with a foraging radius of $r = 405$ could potentially nest in any of cells within the central 3×3 region of the arena, and if all of these were edge cells, the calculated mean proportion for $r = 405$ would be the mean for the nine foraging areas centred on these nine cells. For a forager with $r = 1$, the nest could potentially be located in any of the central 811 × 811 cells. A single mean value for all values of r between 1 and 406 was calculated (if possible) for each of the 100 landscapes assessed.

To assess the effects of field margin manipulations within these natural landscapes, the field edge cells as extracted above were manipulated by adding one, two or three extra layers onto them, using identical techniques to those described for the Voronoi-like edge width manipulations. The mean wild space available to foragers travelling $r = 1 - 406$ units were then assessed for these manipulated landscapes as described above.

Results

Voronoi-like randomised landscape

Increasing the number of field seeds used to generate the Voronoi landscapes would have increased the density of fields within the simulated environments, and we would therefore expect the amount of hedges available to increase, which we see in the increase in both wild space visible to the forager (Fig. 2*a*) and the proportion of the visible environment that was wild (Fig. 2*b*). If fewer field edges are available, the ratio of wild habitat that a forager experiences will be much greater than the overall ratio seen in the environment (Fig. 2*c*), because nesting within a field margin will mean that the forager has a disproportional amount of adjacent wild space available for it forage in. As the amount of edges increases, this relationship becomes much more representative of what we see on average within the environment.

Increasing the width of the wild field strip should have a similar effect, as more foraging area is made available to a forager who is already nesting within the wild area. This is reflected in the increase in visible wild habitat (Fig. 2*d*) and the proportion available (Fig. 2*e*), and the corresponding decrease in coverage as wild margin habitat becomes more available within the environment (Fig. 2*f*).

The radius over which a forager will forage away from its nest has obvious effects upon the amount of wild habitat available: increasing foraging distance increases the amount of wild space encountered (Fig. 2*g*). The proportion of the foraging area that is wild shows a different relationship however. With the exception of foragers who only travel a very small distance (who experience slightly more wild habitat because the immediate environment around the nest is very likely to contain field edge), there is negligible change in the proportion of wild habitat that foragers experience relative to the distance that they travel (Fig. 2*h*), suggesting that manipulations of margin availability should have similar effects upon foragers regardless of their commuting radius. The proportion of wild encountered relative to the amount actually seen within the environment only differs strongly for short-distance foragers (Fig. 2*i*), again suggesting that manipulations should have a scale-free effect with regard to foraging distance.

All the described relationships held within the additional datasets that were generated to explore the interactions between all three parameters. The relationships for each of the parameters

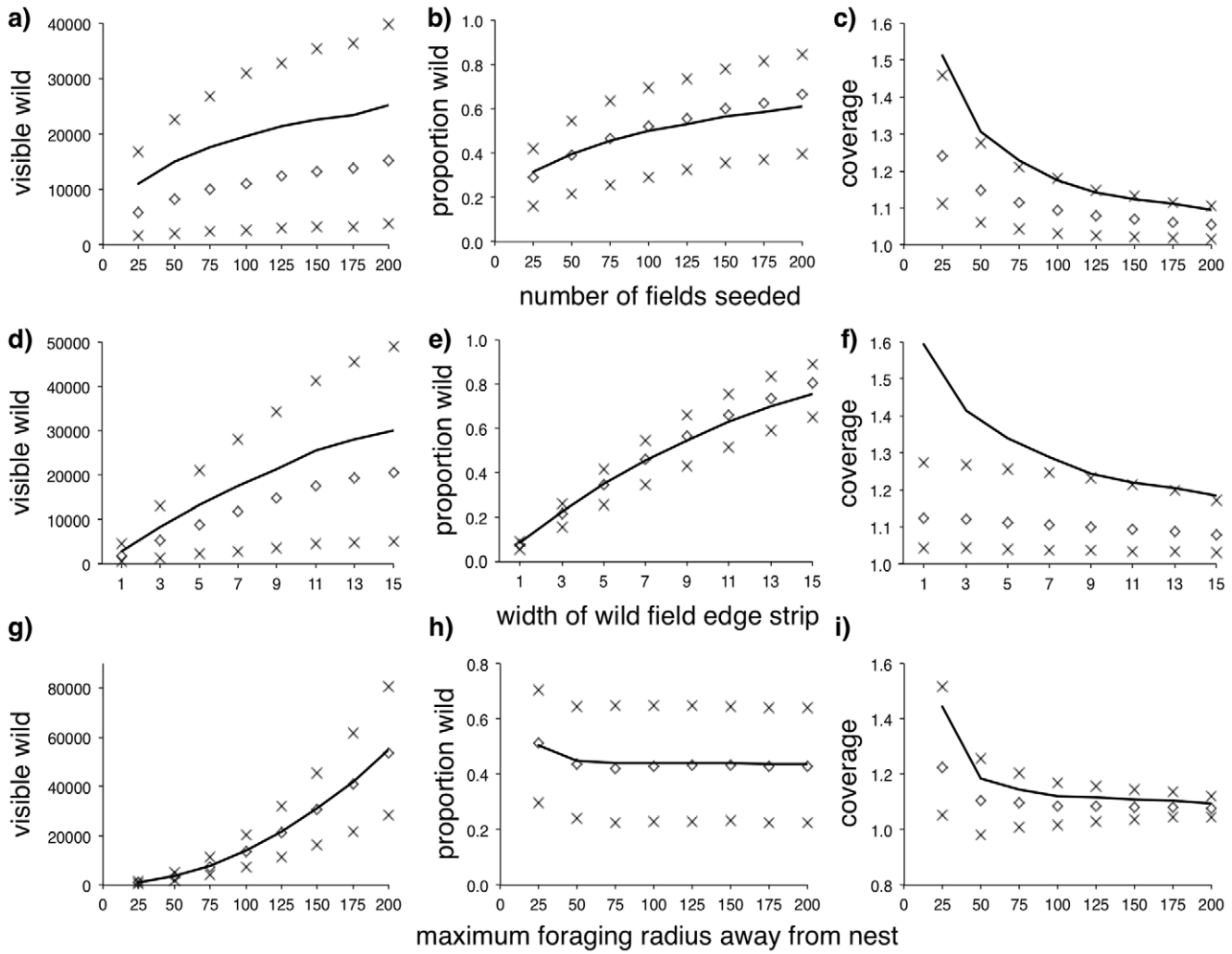

Figure 2. Wild forage available within Voronoi-like randomised fields. Solid black line gives mean values and symbols give the 25%, median and 75% interquartile values for the mean number of visible wild field edge cells ('visible wild', panels *a*, *d* and *g*) and the proportion of wild field-edge cells to cultivated field cells within the foraging radius ('proportion wild', panels *b*, *e* and *h*), and the ratio of the proportion of field edge cells visible within the foraging distance of the nest compared with the overall proportion of edge to field cells within the simulated arena ('coverage', panels *c*, *f* and *i*), where the number of fields seeded (panels *a*, *b*, and *c*), the width of the wild field edge strip (panels *d*, *e*, and *f*), or the radius of the foraging distance around the nest (panels *g*, *h*, and *i*) are systematically altered.
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considered separately were significant (Table 1). All the interactions between the terms were also significant (Table 1), and the trends revealed by these interactions closely followed the trends for individual parameters (Figure S1), with no differences in the qualitative patterns that emerged.

British landscape

For both the natural environment and those where the field margins were expanded by one, two or three units (Figs. 3*a*-*d*), there is a similar relationship shown to the Voronoi-like results for foraging distance manipulation (Fig. 2*h*): only foragers travelling very small distances away from the nest are likely to see a large amount of wild habitat in which to forage. Once foragers are able to travel more than *c*. 50 units from the nest (corresponding to a real-world distance of about 125 m), the proportion of wild habitat available to them essentially becomes scale-free. The panels in Figure 3 show a slight increase for very large foraging distances, but this is more likely to be an artefact of the small number of samples that were possible for assessing these larger distances.

Increasing edge width within the natural environments led to an increase in the proportion of wild habitat available to the forager, where field edges that were supplemented by three units showed the greatest proportion (Fig. 3*d*). This corresponds to the increase in the proportion of wild habitat available within Voronoi fields when the edge strip was widened (Fig. 2*e*). This is also visible when we directly compare the proportion of field edge available after manipulation with what is originally available (Fig. 4), where increasing width by a unit gives a corresponding increase in the extra proportion of wild space visible to a forager. Note also that this figure demonstrates the scale-free effect for foragers travelling more than about 50 units from the nest (and again, the noise for large foraging distances is likely to be a result of the small number of samples available).

Discussion

Our models demonstrate that enhancing field margins should lead to a corresponding increase in the availability of forage to

Table 1. Interactions between the three parameters considered in the Voronoi-like field generation model.

	degrees of freedom	visible wild	proportion wild	coverage
number of fields seeded (n)	7,101888	171934.85	56482.05	4045.19
width of edge strip (w)	7,101888	809334.96	307115.60	138.79
foraging radius (r)	7,101888	2251036.27	1632.33	2729.75
n × w	49,101888	4269.28	1375.74	2.00
n × r	49,101888	17354.86	179.16	558.71
w × r	49,101888	78643.72	37.09	15.14
n × w × r	343,101888	436.27	6.36	2.66

The table presents the *F* values, all of which are significant ($p<0.001$).
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bees and other beneficial invertebrates that nest within the landscape. This was true for both the randomly-generated Voronoi-like fields, and for the landscapes extracted from the British data. With the exception of species that only forage within a very short range of their nest (less than 125 m), the effects of a given amount of field margin manipulation should enhance the proportion of land available to a pollinator for foraging regardless of the distance over which it normally travels to find food. Therefore, field edge manipulations should be beneficial for both longer-distance foragers such as honeybees, and short distance foragers such as solitary bees. Supplementing the resources available to the latter may well be essential for ensuring their survival within the agricultural environment, as it has been demonstrated that their ability to provision their brood declines as the distance they have to travel to find food increases [58]. Most species forage in an area greater than that bounded by the critical range estimate of 125m [47], but there may conceivably be a few short-ranging species that do not benefit from edge manipulations. For example, the threatened solitary mining bee *Andrena hattorfiana* has been in decline within the UK and Europe over recent decades [59,60], and has a recorded maximum foraging distance of 130m from its nest [61]. Field edge manipulations would not be sufficient for this species if it did only forage within such a small area, and other forms of intervention would be required (in this particular case, perhaps targeting the environmental availability of this oligolectic species' principal foraging plant, field scabious *Knautia arvensis* [61]). This prediction of a critical distance is partly dependent upon the used British landscape data accurately representing what actually exists, and we would suggest that more detailed explorations are carried out with landscapes that accurately represent the foraging environment of species (such as *A. hattorfiana*), which would consider the availability of specific resources (such as field scabious) in the environment rather than just a general bank of 'wild' forage.

Here, we considered landscapes in two ways: using a randomly generated process, and extracted from existing landscape data. Although the two forms of landscape gave qualitatively similar predictions about changes in resources available to foraging pollinators, we need to be careful in considering how similar these two approaches are. Being able to randomly generate landscapes is a useful tool for considering the general effects of land use changes. Well-established techniques exist for modelling general landscape structure [62,63], with some applied specifically to generating mosaic-like landscapes (*e.g.* [64–66]). Le Ber *et al.* [67] describe a platform that generates randomised field structures based on both rectangular and Voronoi-like tessellation processes, and demonstrated that neither technique perfectly simulates fields with a similar landscape structure to comparable French agricultural landscapes. How these generation processes match with other agricultural landscapes (such as the British case study used here) would need to be tested, but being able to easily generate landscapes to test different land use manipulations within is a useful tool for understanding landscape processes [67], and gives a simple tool for exploring how landscape structure may influence the behaviour of individuals [68,69]. Although [67] suggests that the Voronoi-like fields are unlikely to match the exact landscape structure of any given environment, being able to generate any kind of field mosaic gives a means of exploring different environmental manipulations provided we acknowledge the limitations that may be caused by the lack of realism. We would suggest that the qualitative trends generated by this technique give us at the very least an indication of the direction of change of the processes we are interested in (as would the regular rectangular lattice arrangement we described in [49]).

This model, and especially the results using landscape structure derived from British maps, classified land as either wild or cultivated. Crops within cultivated agricultural fields may well provide valuable foraging resources to the forager as well, but are likely to only be available during a small timeframe within the year. Field margins should provide a diversity of resources that are available when crops are not. Of course, the model treats all wild land as being of equal worth, and maybe finer-scale differentiation for habitats such as stream edges and wooded habitat would give us insights about finer details of field edge manipulations, as habitats like these could offer different (and possibly richer) arthropod assemblages to hedgerows [70]. Furthermore, no differentiation was made for the presence of domestic gardens, which are increasingly seen as highly beneficial to foraging bees [71], and which were most probably present within the British landscapes used in this model. The presence of floral resource availability within the environment is absolutely critical to enhancing bee population size [72], and it could be argued that adding any form of wild land to the available foraging environment will therefore be seen as advantageous, although consideration may also need to be given to the general heterogeneity of the landscape [73].

Landscape structures may also have effects upon how pollinators forage through the environment, where hedges act as barriers for dispersal. Our model does not consider how field margins could act to impede forager dispersal here, but we do note that potential barriers such as thick forest may have little effect upon the ability of bees to move to foraging patches [39]. Nor do we consider how field edges may act as corridors [74], as we assume that bees will be scouting for food within the entire area around the nest, and constantly altering their foraging patterns to account for new sources [75].

Here, we specifically consider how changes in field edge structure could impact on the British landscape, which encom-

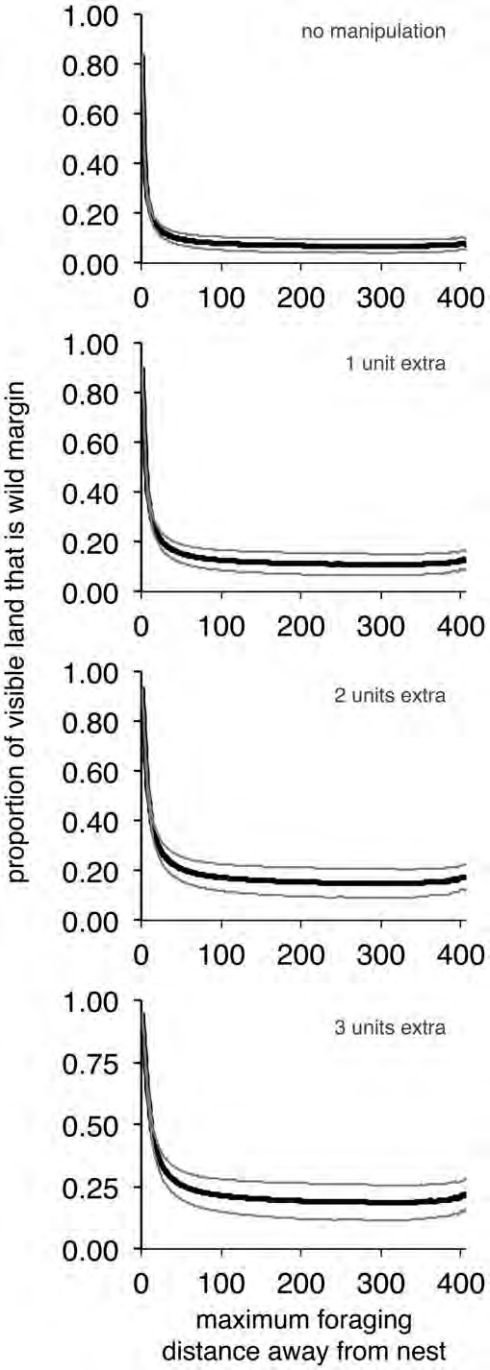

Figure 3. Results from the British landscape datasets. These panels show mean proportion (± s.d.) of wild field edges visible according to the foraging radius away from a nest, for (top to bottom) unmanipulated fields, and fields with an extension of 1, 2 and 3 units in their edge margin.
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passes just a few of the many forms of agricultural environment found within Europe [76–79], many of which are becoming more fragmented with continued urbanisation [80]. Enhancing field edges is feasible within a heterogeneous agricultural landscape that consists of fields interspersed with hedges, but the applicability of these results to any agricultural landscape will depend upon the structure of the wild land within agricultural systems. Internationally, many landscapes do involve similar interconnected refuge areas [77–79,81–85], and it may be fruitful to use the techniques described here to explore how their structure influences forage availability to native bees and other beneficial organisms that are constrained to return to a fixed point within the landscape. In the example we consider here, we took a heavily simplified approach to extract information about the availability of uncultivated areas within agricultural landscapes, and manipulated this to explore how resources could change with regard to simple changes in land use. We suggest that similar approaches could be used with more detailed landscape data (such as that extracted from land cover databases [76]). Making simple assumptions about changes in land use policy demonstrated that we could potentially consider the effects that regional policy could have upon pollinators with different foraging behaviours, and we would suggest that the techniques we develop here could be adapted to target both individual species (where the foraging biology is known) and individual locations. Furthermore, regardless of the amount of detail necessary to consider more specific cases, demonstrating that landscape manipulations are equally beneficial to nesting foragers that provide valuable ecosystem services regardless of their foraging geometry is an important consideration when justifying land being set aside from agricultural requirement.

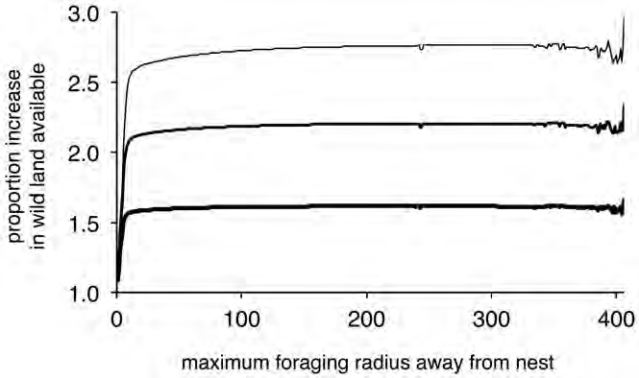

Figure 4. Increased availability of wild forage as a proportion of the 'initial' amount. Results for fields with edges manipulated by one (bottom), two (middle) or three (top) units, given as a proportion of the non-manipulated edge results.
doi:10.1371/journal.pone.0025971.g004

Supporting Information

Figure S1 Two-way Interactions between parameters used in Voronoi-like field models. Lines show the mean values of '*visible wild*', '*proportion wild*' and '*coverage*', all as defined for Figure 2. '*n*' represents the number of fields seeded, '*w*' represents the width of the edge strip, and '*r*' the foraging radius. The arrows give an indication of the direction of change for the parameter whose change is represented by the separate lines within each panel.
(PDF)

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Author Contributions

Conceived and designed the experiments: SAR HMW. Performed the experiments: SAR. Analyzed the data: SAR. Wrote the paper: SAR HMW.

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Review

Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibians and Reptiles

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Abstract: *Terrestrial habitats surrounding wetlands are critical to the management of natural resources. Although the protection of water resources from human activities such as agriculture, silviculture, and urban development is obvious, it is also apparent that terrestrial areas surrounding wetlands are core habitats for many semiaquatic species that depend on mesic ecotones to complete their life cycle. For purposes of conservation and management, it is important to define core habitats used by local breeding populations surrounding wetlands. Our objective was to provide an estimate of the biologically relevant size of core habitats surrounding wetlands for amphibians and reptiles. We summarize data from the literature on the use of terrestrial habitats by amphibians and reptiles associated with wetlands (19 frog and 13 salamander species representing 1363 individuals; 5 snake and 28 turtle species representing more than 2245 individuals). Core terrestrial habitat ranged from 159 to 290 m for amphibians and from 127 to 289 m for reptiles from the edge of the aquatic site. Data from these studies also indicated the importance of terrestrial habitats for feeding, overwintering, and nesting, and, thus, the biological interdependence between aquatic and terrestrial habitats that is essential for the persistence of populations. The minimum and maximum values for core habitats, depending on the level of protection needed, can be used to set biologically meaningful buffers for wetland and riparian habitats. These results indicate that large areas of terrestrial habitat surrounding wetlands are critical for maintaining biodiversity.*

Criterios Biológicos para Zonas de Amortiguamiento Alrededor de Hábitats de Humedales y Riparios para Anfibios y Reptiles

Resumen: *Los hábitats terrestres que rodean humedales son críticos para el manejo de recursos naturales. Aunque la protección de recursos acuáticos contra actividades humanas como agricultura, silvicultura y desarrollo urbano es obvia, también es aparente que las áreas terrestres que rodean a humedales son hábitat núcleo para muchas especies semiacuáticas que dependen de los ecotonos mésicos para completar sus ciclos de vida. Para propósitos de conservación y manejo, es importante definir los hábitats núcleo utilizados por las poblaciones reproductivas locales alrededor de humedales. Nuestro objetivo fue proporcionar una estimación del tamaño biológicamente relevante de los hábitats núcleo alrededor de humedales para anfibios y reptiles. Resumimos datos de la literatura sobre el uso de hábitats terrestres por anfibios y reptiles asociados con humedales (19 especies de ranas y 13 de salamandras, representando a 1363 individuos; 5 especies de serpientes y 28 de tortugas representando a más de 2245 individuos). Los hábitats núcleo terrestres variaron de 159 a 290 m para anfibios y de 127 a 289 para reptiles desde el borde del sitio acuático. Datos de estos estudios también indicaron la importancia de los hábitats terrestres para alimentación, hibernación y anidación, y, por lo tanto, que la interdependencia biológica entre hábitats acuáticos y terrestres es esencial para la persistencia de poblaciones. Dependiendo del nivel de protección requerida, se pueden utilizar los valores mínimos y máximos de hábitats núcleo para definir amortiguamientos biológicamente significativos para hábitats de humedales y riparios. Estos resultados indican que extensas áreas de hábitats terrestres que rodean humedales son críticas para el mantenimiento de la biodiversidad.*

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Introduction

Terrestrial habitats surrounding wetlands are critical for the management of water and wildlife resources. It is well established that these terrestrial habitats are the sites of physical and chemical filtration processes that protect water resources (e.g., drinking water, fisheries) from siltation, chemical pollution, and increases in water temperature caused by human activities such as agriculture, silviculture, and urban development (e.g., Lowrance et al. 1984; Forsythe & Roelle 1990). It is generally acknowledged that terrestrial buffers or riparian strips 30–60 m wide will effectively protect water resources (e.g., Lee & Samuel 1976; Phillips 1989; Hartman & Scrivener 1990; Davies & Nelson 1994; Brosofske et al. 1997).

However, terrestrial habitats surrounding wetlands are important to more than just the protection of water resources. They are also essential to the conservation and management of semiaquatic species. In the last few years, a number of studies have documented the use of terrestrial habitats adjacent to wetlands by a broad range of taxa, including mammals, birds, reptiles, and amphibians (e.g., Rudolph & Dickson 1990; McComb et al. 1993; Darveau et al. 1995; Spackman & Hughes 1995; Hodges & Krementz 1996; Semlitsch 1998; Bodie 2001; Darveau et al. 2001). These studies have shown the close dependence of semiaquatic species, such as amphibians and reptiles, on terrestrial habitats for critical life-history functions. For example, amphibians, such as frogs and salamanders, breed and lay eggs in wetlands during short breeding seasons lasting only a few days or weeks and during the remainder of the year emigrate to terrestrial habitats to forage and overwinter (e.g., Madison 1997; Richter et al. 2001). Reptiles, such as turtles and snakes, often live and forage in aquatic habitats most of the year but emigrate to upland habitats to nest or overwinter (e.g., Gibbons et al. 1977; Semlitsch et al. 1988; Burke & Gibbons 1995; Bodie 2001).

The biological importance of these habitats in maintaining biodiversity is obvious, yet criteria by which to define habitats and regulations to protect them are ambiguous or lacking (Semlitsch & Bodie 1998; Semlitsch & Jensen 2001). More importantly, a serious gap is created in biodiversity protection when regulations or ordinances, especially those of local or state governments, have been set based on criteria to protect water resources alone, without considering habitats critical to wildlife species. Further, the aquatic and terrestrial habitats needed to carry out life-history functions are essential and are defined here as "core habitats." No summaries of habitat use by amphibians and reptiles exist to estimate the biologically relevant size of core habitats surrounding wetlands that are needed to protect biodiversity.

For conservation and management, it is important to define and distinguish core habitats used by local breeding populations surrounding wetlands. For example, adult frogs, salamanders, and turtles are generally philopatric to individual wetlands and migrate annually between aquatic and terrestrial habitats to forage, reproduce, and overwinter (e.g., Burke & Gibbons 1995; Semlitsch 1998). The amount of terrestrial habitats used during migrations to and from wetlands and for foraging defines the terrestrial core habitat of a population. This aggregation of breeding adults constitutes a local population centered on a single wetland or wetland complex. Local populations are connected by dispersal and are part of a larger metapopulation, which extends across the landscape (Pulliam 1988; Marsh & Trenham 2001).

Annual migrations centered on a single wetland or wetland complex are biologically different than dispersal to new breeding sites. It is thought that dispersal among populations is achieved primarily by juveniles for amphibians (e.g., Gill 1978; Breden 1987; Berven & Grudzien 1990) or by males for turtles (e.g., Morreale et al. 1984). Dispersal by juvenile amphibians tends to be unidirectional and longer in distance than the annual migratory movements of breeding adults (e.g., Breden 1987; Seburn et al. 1997). Thus, habitats adjacent to wetlands can serve as stopping points and corridors for dispersal to other nearby wetlands. Ultimately, conservation and management plans must consider both local and landscape dynamics (Semlitsch 2000), but core habitats for local populations need to be defined before issues of connectivity at the metapopulation level are considered.

Literature Review

We summarize data from the literature on the use of terrestrial habitats by amphibians and reptiles associated with wetlands. We define wetlands as both lentic (pond) and lotic (stream) habitats that are either permanent or temporary (Cowardin et al. 1979). Also, we use the term riparian in the broadest sense of encompassing the shore, bank, or edge of any wetland. We used data from studies that define habitat use mainly by the adult population and report a mean, mode, or range of distance of migrations from the outer edge of wetlands (Appendices 1 & 2). We used these values to calculate a grand mean for major taxa (Table 1). Rather than calculating a 95% confidence limit, which depends on knowing the distribution of migration distances, and because some studies did not report means, we calculated a mean minimum and maximum distance for amphibians and reptiles from the distance values reported for species in each study (Table 1). These minimum and maximum values likely encompass a large portion of populations and adequately represent the majority of species. We did not use observations of individuals of unknown origin, especially juveniles, found at some distance from a wet-

Table 1. Mean minimum and maximum core terrestrial habitat for amphibians and reptiles.*

Group	Mean minimum (m)	Mean maximum (m)
Frogs	205	368
Salamanders	117	218
Amphibians	159	290
Snakes	168	304
Turtles	123	287
Reptiles	127	289
Herpetofauna	142	289

**Values represent mean linear radii extending outward from the edge of aquatic habitats compiled from summary data in Appendices 1 and 2.*

land. Such anecdotal observations are relevant to maximum dispersal distances and the probability of recolonization and connectivity for species (Pulliam 1988) but are misleading for the calculation of core terrestrial habitat for the maintenance of local populations. The data we report reflect the size of terrestrial habitats that are biologically necessary for the conservation of amphibian and reptile diversity at individual wetlands. Further, we discuss the use of core habitat sizes in conjunction with a buffer zone and how land-use practices in the surrounding landscape matrix may modify the amount of habitat needed for adequate protection.

Amphibian Core Habitat

Amphibians constitute an important and diverse fauna associated with both isolated wetlands (e.g., Texas, 15 species [Wiest 1982]; Florida, 16 species [Dodd 1992]; South Carolina, 27 species [Semlitsch et al. 1996]; Tennessee, 19 species [Scott & Bufalino 1997]) and stream or river floodplains (e.g., Virginia, 21 species [Buhlmann et al. 1993]; California, 4 species [Panik & Barrett 1994]; Illinois, 14 species [Burbrink et al. 1998]). The studies we reviewed indicate that amphibians use a wide range of terrestrial habitats adjacent to wetlands and streams. Most of these habitats are related to foraging, refuge, or overwintering sites and typically consist of leaf litter, coarse woody debris, boulders, small mammal burrows, cracks in rocks, spring-seeps, and rocky pools. Data on emigration distances from wetlands were found for 19 species of frogs and 13 species of salamanders representing 1363 individuals (Appendix 1).

Patterns of variation in distances traveled appear related to life-history differences between major taxonomic groups. In general, the plethodontid stream salamanders (e.g., *Desmognathus fuscus, Eurycea bislineata, Eurycea longicauda*), although migratory at some stage of their life cycle, remain close to the edges of ponds and streams and seldom move more than 20–30 m from aquatic habitats. Alternatively, some species of frogs, toads, and newts are highly vagile and move 1000–1600 m (e.g., *Bufo bufo, Rana catesbeiana, Notophthalmus viridescens*). The majority of the remaining species use intermediate distances, where they emigrate to find suitable terrestrial habitats. The overall core terrestrial habitat for amphibians ranged from 159 to 290 m from the edge of the aquatic site (Table 1).

Reptile Core Habitat

We summarized data for five snake and 28 turtle species from 25 U.S. states and five countries (Appendix 2). We gathered migration distances from studies of known sample size (total $n = 2245$ individuals) and from those of unknown sample size. Relatively few studies have been conducted on terrestrial migrations of hydrophilic snakes. Snakes migrated into adjacent uplands for the purpose of aestivating, basking, hibernating, or nesting. Although most studies of terrestrial migrations by turtles have focused on nesting, turtles also migrated for the purposes of aestivating, feeding, and hibernating.

Similar to that of amphibians, variation in reptile migration distances appears related to taxon-specific differences in life-history patterns. Some colubrid snakes (e.g., *Nerodia* sp., *Opheodrys aestivus*), trionychid turtles (e.g., *Apalone* sp.), some emydid turtles (e.g., *Graptemys geographica*, *Sternotherus* sp.), and one chelydrid turtle (i.e., *Macroclemys temminckii*) rarely migrate >30 m from aquatic habitats. In contrast, one colubrid snake (i.e., *Coluber constrictor*), viperid snakes (e.g., *Crotalus horridus*, *Sistrurus catenatus*), many kinosternid turtles (e.g., *Kinosternum leucostomum*, *K. subrubrum*), and several emydid turtles (e.g., *Chrysemys picta*, *Clemmys* sp., *Emydoidea blandingi*, *Trachemys scripta*) routinely migrate >100 m. The length of time spent in the terrestrial habitat ranges from <1 hour (e.g., nesting *Chelydra serpentina*; Punzo 1975) to 88% of recorded activity (e.g., *Nerodia sipedon*; Tiebout & Cary 1987). Some migrations into terrestrial habitats occurred following significant rainfall or stream flooding when uplands were temporarily inundated with water (e.g., *Graptemys pseudogeographica* foraging in flooded forest; Bodie & Semlitsch 2000). The overall core terrestrial habitat for reptiles ranged from 127 to 289 m from the edge of the aquatic site (Table 1).

Protection and Management of Terrestrial Habitat

It is not surprising that the terrestrial ecology of semiaquatic species is often underappreciated or overlooked by managers and conservation planners. Some semiaquatic reptiles make only brief visits to terrestrial habitats when nesting, and hibernacula are rarely observed. Additionally, many pond-breeding amphibians are fosso-

rial and are also rarely observed in terrestrial habitats. Surveys and studies of these animals are consequently concentrated within stream and wetland sites, where they are found seasonally, rather than in terrestrial habitats, where detection is extremely difficult but where much of their life history occurs. Aquatic habitats may not be used by semiaquatic species for extended periods of their lives, including between breeding seasons and during droughts. For example, a population of striped newts (*Notophthalmus perstriatus*) in northern Florida was relegated to predominantly terrestrial activity during a 5-year drought (Dodd 1993). Eastern mud turtles (*Kinosternon subrubrum*) in South Carolina often leave aquatic sites after mating in late spring and do not return until the following spring (Bennett et al. 1970). In both cases, the upland forest habitat had obvious importance as a reservoir for adults of these species until breeding and reproduction again occurred.

Although wetlands vary in many characteristics related to type, region, topography, climate, and land-use surrounding them, the data we compiled suggest that a single all-encompassing value for the size of core habitats can be used effectively. Maximum values generated from a taxon with the greatest need for terrestrial habitat—that is, the largest core area or home range (Table 1)—would likely encompass all other taxa and could be used more broadly. On public lands or reserve systems, where first priority is given to conserving biodiversity, this maximum value can facilitate management objectives. On private lands or areas, however, where sustainable land use is the priority, a stratified system of protection zones can minimize impacts on wildlife and support desired land uses. For example, for streams in managed forests in North America, it is recommended by deMaynadier and Hunter (1995) that criteria be adjusted for stream attributes such as width, intensity of logging, and slope adjacent to the stream. Further, the authors recommend a two-tiered approach in which the terrestrial habitat closest to the water is fully protected and a second, outer area provides limited protection (e.g., the forestry practice of light partial cutting and removal of no more than 25% of the basal area).

We propose that stratification should include three terrestrial zones adjacent to core aquatic and wetland habitats (Fig. 1): (1) a first terrestrial zone immediately adjacent to the aquatic habitat, which is restricted from use and designed to buffer the core aquatic habitat and protect water resources; (2) starting again from the wetland edge and overlapping with the first zone, a second terrestrial zone that encompasses the core terrestrial habitat defined by semiaquatic focal-group use (e.g., amphibians 159–290 m; Table 1); and (3) a third zone, outside the second zone, that serves to buffer the core terrestrial habitat from edge effects from surrounding land use (e.g., 50 m; Murcia 1995).

All things being equal, these zones of protection should extend outward from the edge of wetlands far enough to encompass all species populations. However, the habitats used by various species or at different life-history stages are probably not evenly distributed. To protect those habitats essential for species functions, we need to know more about species requirements at each

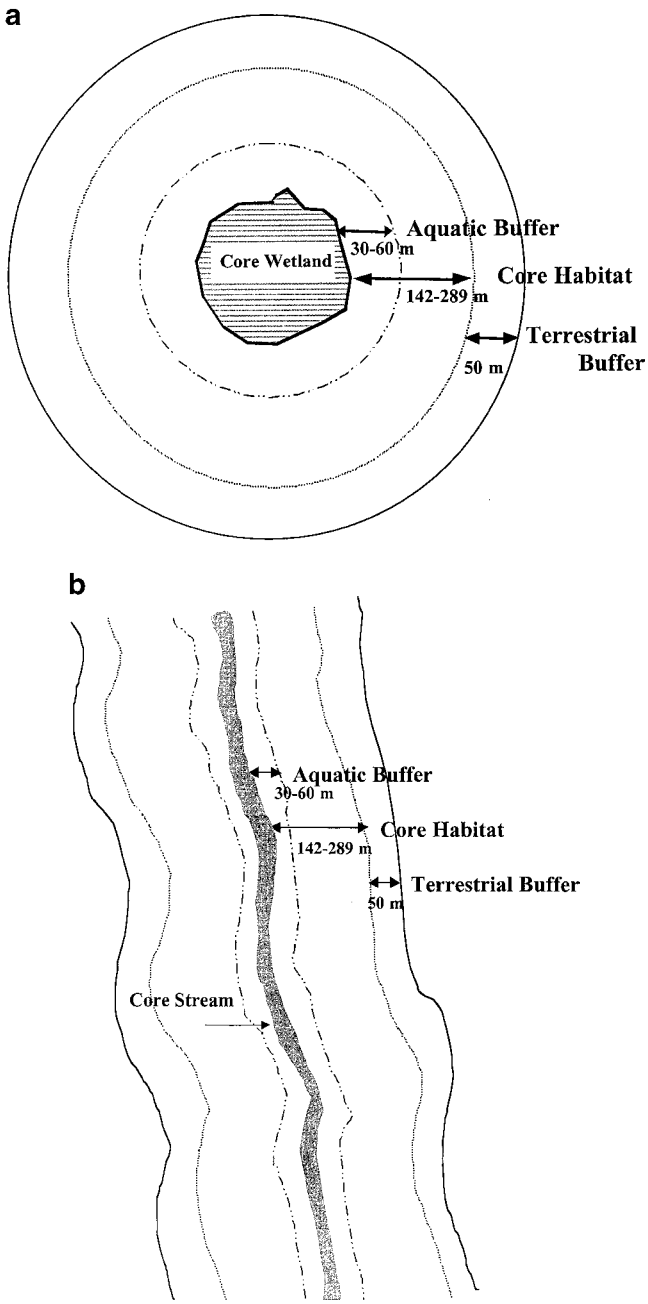

Figure 1. Proposed zones of protection of (a) wetlands and (b) streams. Both core habitat and aquatic buffer requirements are met within the second zone, which may range from 142 to 289 m for amphibians and reptiles (see Table 1 for taxon-specific values). An additional 50-m buffer is recommended to protect core habitat from edge effects (Murcia 1995).

life-history stage and season of the year. We know that special habitats are required by some species, such as the presence of highly aerated pools along small streams or caves for thermal refuges (e.g., overwintering sites for green frogs [*Rana clamitans*; Lamoureux & Madison 1999; Birchfield & Semlitsch unpublished data], yellow-legged frogs [*Rana muscosa*; Matthews & Pope 1999], and pickerel frogs [*Rana palustris*; R.D.S., personal observation]) and mammal burrows for thermal and predatory refuges (e.g., gopher frog [*Rana sevosa*; Richter et al. 2001]), and must be included within protective zones. Habitat generalists probably use whatever habitat is available, and land use such as silviculture may be compatible with maintaining their populations. Little is known, however, about habitat requirements for even common species such as the American toad (*Bufo americanus*), often used as an example of a generalist but which may not be a generalist during all life stages. Newly metamorphosed *B. americanus* exhibit strong selection for forest habitat in the summer in Missouri (Rothermel & Semlitsch 2002). Adjusting the size of terrestrial zones, such as the core habitat, could be done on the basis of protecting different portions of the population (e.g., for turtles 50–90% [Burke & Gibbons 1995]; for ambystomatid salamanders 50–95% [Semlitsch 1998]). It is not known, however, how protecting different amounts of terrestrial habitat affects the population persistence of any species or how habitat quality (e.g., density of mammal burrows; Loredo et al. 1996) might influence that decision.

Decisions about how restrictive each zone might be to land-use practices would depend on management goals and species of concern. Although little data are available on how various amphibians and reptiles might respond to major land-use practices (e.g., logging, farming, residential development), it is reasonable to assume that some activities (e.g., hiking, bicycling), especially those not destroying essential habitats (e.g., for amphibians, vegetation canopy for shade, coarse woody debris and a litter layer used for refuge and food sources), could be conducted in this outer zone of protection and be compatible with the goal of protecting biodiversity. In applying these criteria and bolstering the biological values of core terrestrial habitats, policymakers could develop stratified habitat zones that guide associated protection or management intensity, resulting in more effective conservation of biodiversity along with sustainable land use.

Conclusions

We provide biologically based estimates for the protection of terrestrial habitats surrounding wetlands. Our data clearly indicate that buffers of 15–30 m, used to protect wetland species in many states, are inadequate for amphibians and reptiles. Further, we emphasize that our estimates are derived from the core terrestrial habitats used by amphibians and reptiles and therefore are not buffers per se but necessary habitat. Additional area of terrestrial habitat is needed to fully protect core habitats and minimize edge effects (Fig. 1). For maximum protection, this may be more land than managers can provide, although we do not believe that our estimates are excessive biologically. And we are not naïve enough to believe that all terrestrial land-use activities around wetlands must be excluded. It is our intent, however, to ensure that managers and conservation biologists recognize that both aquatic and terrestrial habitats are essential for maintaining biodiversity and that they must be managed as an integral unit to protect biodiversity. Further, we want managers to know that little is known about the effects of land-use practices on amphibians and reptiles and that without further research it cannot be known whether any such practices used within the core habitat are potentially harmful to their long-term persistence. We hope this discussion generates more research on the effects of land-use practices on plants and animals and that biologists begin testing the effectiveness of various criteria for protecting the core habitats of species. A sustainable balance between continuing economic development and protecting natural resources depends on knowing and responding to species' biological requirements and knowing how tradeoffs affect the maintenance of biodiversity.

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Appendix 1. **Summary of terrestrial migration distances from aquatic breeding sites for amphibians.**

Species and location	Distance in m (sample size)	*Data source*
Frogs		
Acris crepitans, Illinois	range 8–22 (189)	O'Neil 2001[a]
Bufo americanus, Ontario	range 23–480 (176)	Oldham 1966[a]
Bufo boreas, Colorado	mode = 900	Campbell 1970[b]
Wyoming	maximum = 101	Carpenter 1954[a]
Bufo bufo, Germany	mode 70–760, maximum = 1600	Sinsch 1988[a]
Bufo hemiophrys, Minnesota	range 23–35 (6)	Breckenridge & Tester 1961[b]
Bufo japonicus formosus, Japan	mean = 98.5, range 27–260 (19)	Kusano et al. 1995[c]
Bufo marinus, New Guinea	mean = 150	Zug & Zug 1979[a]
Bufo valliceps, Texas	range 31–72	Blair 1953[a]
Hyla andersoni, New Jersey	mean = 70, maximum = 106 (8)	Freda & Gonzalez 1986[b]
Hyla regilla, Oregon	mode = 92, maximum = 240	Jameson 1956[a]
Pseudacris ornata, Florida	maximum = 55	Ashton & Ashton 1977[b]
Pseudacris triseriata, Indiana	mean = 75, maximum = 213 (9)	Kramer 1973[b]
Rana capito, Florida	range 280–480	Greenberg 2001[a]
Rana catesbeiana, New York	mean = 406, mode = 1046 (22)	Ingram & Raney 1943[a]
Rana clamitans, Ontario	mean = 137, maximum 457	Oldham 1967[a]
New York	mean = 121, maximum = 360	Lamoureux & Madison 1999[c]
Missouri	mean = 485, range 321–570 (6)	Birchfield & Semlitsch 2002[c]
Rana muscosa, California	range 66–142 (81)	Matthews & Pope 1999[a]
Rana pretiosa, Montana	range 41–443	Hollenbeck 1976[a]
Wyoming	maximum = 46	Carpenter 1954[a]
Wyoming	range 369–462	Turner 1960[a]
Rana sevosa , Mississippi	mean = 173, range 49–299 (12)	Richter et al. 2001[c]
Syrrhophus marnocki, Texas	mean = 213, range 114–303	Jameson 1955[a]
Salamanders		
Ambystoma californiense, California	mean = 36, range 8–129 (59)	Loredo et al. 1996[a]
California	mean = 114, maximum = 248 (11)	Trenham 2001[c]
Ambystoma jeffersonianum, Michigan	mean = 39, range 22–108 (6)	Wacasey 1961[a]
Michigan	mean = 92, range 15–231 (45)	Wacasey 1961[d]
Indiana	mean = 252, range 20–625 (86)	Williams 1973[b]
Kentucky	mean = 250 (10)	Douglas & Monroe 1981[b]
Ambystoma maculatum, Michigan	mean = 67, range 26–108 (2)	Wacasey 1961[a]
Michigan	mean = 103, range 15–200 (14)	Wacasey 1961[d]
Indiana	mean = 64, range 0–125 (7)	Williams 1973[b]
Kentucky	mean = 150, range 6–220 (8)	Douglas & Monroe 1981[b]
Michigan	mean = 192, range 157–249 (6)	Kleeberger & Werner 1983[b]
New York	mean = 118, range 15–210 (8)	Madison 1997[c]
Ambystoma opacum, Indiana	mean = 194, range 0–450 (12)	Williams 1973[b]
Kentucky	mean = 30 (6)	Douglas & Monroe 1981[b]
Ambystoma talpoideum, South Carolina	mean = 178, range 13–287 (17)	Semlitsch 1981[b]
Ambystoma texanum, Indiana	mean = 52, range 0–125 (10)	Williams 1973[b]
Ambystoma tigrinum, South Carolina	162 (1)	Semlitsch 1983[b]
South Carolina	mean = 215, range 112–450 (4)	Semlitsch et al., unpublished data[c]
New York	mean = 60, range 0–286 (27)	Madison & Farrand 1998[c]
Desmognathus fuscus, Kentucky	maximum = 17 (14)	Barbour et al. 1969[b]
Ohio	maximum = 20 (16)	Ashton 1975[b]
Eurycea bislineata, Ohio	maximum = 31 (20)	Ashton & Ashton 1978[b]
Eurycea longicauda, New Jersey	mode = 6, maximum = 31	Anderson & Martino 1966[a]
Hynobius nebulosus tokyoensis, Japan	maximum = 100 (48)	Kusano & Miyashita 1984[a]
Notophthalmus viridescens, Massachusetts	mode = 800 (383)	Healy 1975[a]
Taricha torosa granulosa, Oregon	mode = 185	Pimentel 1960[a]

[a] *Uniquely marked individuals.*
[b] *Radioactive tags.*
[c] *Radiotransmitters.*
[d] *Unmarked individuals.*

Appendix 2. Summary of terrestrial migration distances from aquatic sites for reptiles.

Species and location	*Distance in m (sample size)*	*Data source*
Snakes		
Crotalus horridus, New Jersey	maximum = 700 (15)	Reinert & Zappalorti 1988[a]
Nerodia harteri, Texas	mean = 2.1, range 0–15 (8)	Whiting et al. 1997[a]
Nerodia sipedon, Wisconsin	maximum = 6 (10)	Tiebout & Cary 1987[a]
Opheodrys aestivus, Arkansas	mode = 3, range 0–5 (31)	Plummer 1981[b]
Sistrurus catenatus, Pennsylvania	mode = 200 (25)	Reinert & Kodrich 1982[a]
Turtles		
Apalone ferox, Florida	22.9 (1)	Goff & Goff 1935[c]
Apalone mutica, Iowa	range 3–18	Muller 1921[c]
Iowa	range 2–8	Goldsmith 1945[c]
Kansas	mean = 38.2, range 4–90 (104)	Fitch & Plummer 1975[c]
Apalone spinifera, Arkansas	mean = 2.5, range 2–3 (4)	Plummer et al. 1997[b]
Indiana	mode = 2	Newman 1906[c]
Minnesota	0.3 (1)	Hedrick & Holmes 1956[c]
Nebraska	4.5 (1)	Gehlbach & Collette 1959[c]
Chelydra serpentina, Florida	mean = 93.7, range 38–141 (7)	Punzo 1975[c]
Michigan	mean = 37.2, range 1–183 (210)	Congdon et al. 1987[b]
Nebraska	mode = 25, maximum =100	Iverson et al. 1997[b,c]
New York	mean = 27.4, range 1–89	Petokas & Alexander 1980[b]
Chrysemys picta, Idaho	mode = 200, maximum = 600	Lindeman 1992[b]
Michigan	mean = 60.4, range 1–164 (185)	Congdon & Gatten 1989[b]
Quebec, Canada	mean = 90.4, range 1–621 (51)	Christens & Bider 1986[a,b]
Clemmys guttata, Connecticut	range = 3–265 (9)	Perillo 1997[a]
Michigan	maximum = 150	Harding & Bloomer 1979[b]
Pennsylvania	range 60–250 (207)	Ernst 1976[b]
Clemmys insculpta, Canada	mean = 27, range 0–500 (10)	Foscarini & Brooks 1993[b]
Pennsylvania	mode = 300, maximum = 600 (50)	Kaufmann 1992[a,b]
New Hampshire	mean = 60.3 (9)	Tuttle & Carroll 1997[a]
New York	maximum = 200 (189)	Carroll & Ehrenfeld 1978[b]
Clemmys marmorata, California	mean = 168, range 39–423 (19)	Reese 1996[a]
Deirochelys reticularia, Texas	30 (1)	David 1975[c]
Virginia	mean = 95, range 32–192 (4)	Buhlmann 1995[a]
Emydoidea blandingi, Illinois	mean = 815, range 650–900 (3)	Rowe & Moll 1991[a]
Michigan	mean = 135, range 2–1115 (105)	Congdon et al. 1983[b]
Wisconsin	mean = 168 (16)	Ross & Anderson 1990[a,b]
Graptemys barbouri, Florida	200 (1)	Ewert & Jackson 1994[c]
Graptemys ernsti, Alabama	range 3–15	Shealy 1976[b]
Graptemys flavimaculata, Mississippi	mode = 100 (20)	Jones 1996[a]
Graptemys geographica, Quebec, Canada	mean = 2.3, range 2–3 (3)	Gordon & MacCulloch 1980[b]
Graptemys oculifera, Mississippi	range 7–17	Jones 1991[c]
Graptemys pseudogeographica, Missouri	mean = 353, range 0–1133 (15)	Bodie & Semlitsch 2000[a]
Kinosternon baurii, Florida	mean = 15.6, range 1–49 (23)	Wygoda 1979[b]
Kinosternon flavescens, Iowa	range 100–450	Christiansen et al. 1985[a]
Nebraska	range 21–191 (33)	Iverson 1990[a]
Kinosternon leucostomum, Mexico	mean = 275, range 0–600 (14)	Morales-Verdeja & Vogt 1997[a]
Kinosternon subrubrum, South Carolina	mean = 103.4, range 1–600 (20)	Bennett et al. 1970[d]
South Carolina	mean = 200, range 100–300 (2)	Bennett 1972[d]
South Carolina	mean = 49.3, range 17–90 (25)	Burke et al. 1994[a]
South Carolina	mean = 61.6, range 18–135 (115)	Burke 1995[a]
Macroclemys temminicki, Florida	mean = 12.2, range 3–22 (12)	Ewert 1976[c]
Florida	maximum = 200 (106)	Ewert & Jackson 1994[c]
Malaclemys terrapin, New Jersey	mode = 150 (40)	Burger & Montevecchi 1975[c]
Podocnemis unifilis, Venezuela	mean = 38.3, range 21–80 (422)	Escalona & Fa 1998[c]
Pseudemys floridana, South Carolina	mean = 106.7, range 62–286 (19)	Burke 1995[a]
Pseudemys rubriventris, Massachusetts	range 10-250	Ernst et al. 1994[b]
Sternotherus depressus, Alabama	6.5 (1)	Dodd 1988[c]
Sternotherus odoratus, Pennsylvania	mean = 6.6, range 3–11 (27)	Ernst 1986[c]
Trachemys scripta, Florida	mode = 180	Carr 1952[c]
Louisiana	maximum = 1600	Cagle 1950[c]
Missouri	mean = 348, range 0–1394 (11)	Bodie & Semlitsch 2000[a]
Panama	mean = 50, range 2–320 (139)	Moll & Legler 1971[b]
South Carolina	mean = 86.5, range 23–299 (11)	Burke 1995[a]

[a] *Radiotransmitters.*
[b] *Uniquely marked individuals.*
[c] *Unmarked individuals.*
[d] *Radioactive tags.*

Specialist Bee Pollinators of Showy Vernal Pool Flowers

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ABSTRACT. Bees of the family Andrenidae often specialize on a narrow range of flowering plants as pollen sources. This host specificity for pollen (oligolecty) involves close synchrony in space and time between the bees and their host plants. Plants of four genera, *Blennosperma*, *Downingia*, *Lasthenia*, and *Limnanthes*, produce showy floral displays often considered characteristic of California vernal pools and the pollinator guilds of each contain oligolectic andrenid bees that are likely to contribute significantly to plant reproduction. These bees nest in the uplands and forage for pollen from plants growing in the pools, thus ecologically linking the uplands and vernal pools together. In this paper we update several aspects of the biology of the andrenid bees that are oligolectic on vernal pool plants. The geographic distributions of these bees are within, but do not totally cover the geographic distributions of their pollen host-plant genera. The lack of geographic congruence may in part be due to our incomplete knowledge of the systematics of the bees. In preliminary transplant studies, adult bees were refrigerated for sufficient time for transport to and release at another site and mark-recapture of foraging females indicated that some colonization had occurred at the new site. Preliminary lists of floral visitor guilds of the four plant genera include many generalist bees and other insects in addition to the oligolectic bees. Many generalist flower visitors also live and nest outside the margins of the pools. Interactions between upland and pool biota have important implications for vernal pool conservation. To restore or create new pools as mitigation for destruction of existing pools, suitable habitat for flower visitors must also be restored or provided if we hope to have viable, long lasting vernal pool communities.

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INTRODUCTION

California vernal pool ecosystems are often characterized by populations of annual plants that bloom in the early spring. These plants have common names such as Yellow Carpet (*Blennosperma*), Meadowfoam (*Limnanthes*), Goldfield (*Lasthenia*), and Skyblue (*Downingia*), that elegantly describe their showy displays of dense and abundant flowers. Many solitary bees of the family Andrenidae specialize on these flowering taxa for collecting pollen and in some areas may be their principal pollinators (Thorp, 1990). For example, Leong (1994) in her studies of *Blennosperma nanum* (Hook.) S. F. Blake var. *nanum* at Jepson Prairie Preserve suggests that its oligolege, *Andrena* (*Diandrena*) *blennospermatis* Thorp, can be the predominant visitor.

While these specialist bees forage in the flora-rich pool basins, they nest in the upland areas near the vernal pools. Therefore, they link the lower lying aquatic with the upland terrestrial microhabitats within the vernal pool ecosystem. Since these bees are likely to be important in the reproduction of many vernal pool plant species, the quality of upland habitat needs to be considered in addition to vernal pools proper when evaluating the viability of created and/or restored vernal pool habitats.

Mitigation projects for loss of vernal pools may involve creation of pools in new areas some distance from the original pools. Seeds of vernal pool plants, and eggs and cysts of invertebrates of special concern can easily be obtained by vacuuming or carefully removing surface materials from dried pool areas. This matter from pools to be destroyed can be used to inoculate newly created pools. If the hydrologic conditions are adequate, the addition of water in the form of winter rains should

suffice to initiate germination and development of seeds, eggs, and cysts in the created pools. Specialist (= oligolectic) bees may colonize the new site if the upland habitat is suitable for their nesting requirements. This is best facilitated if newly created pools are on-site and if the original upland habitats are leveled or destroyed well after the time the flowering plants bloom and native specialist bees emerge. If these conditions are not met, the plants will be forced to rely upon generalist pollinators already established in the new habitat to pollinate their flowers.

The general life cycles and floral associations of vernal pool oligolectic bees have been discussed in previous papers (Thorp, 1969; 1976; 1990; Rust, 1976; Leong, 1994; Leong et al., 1995; Thorp and Leong, 1995) and will only be summarized here. The vernal pool oligoleges discussed in this paper are all members of the bee family, Andrenidae. They are solitary, ground nesting bees. They have only one generation per year, like their pollen host plants. Adult activities (mating, nest construction, foraging, brood cell provisioning, and egg laying) are limited primarily to the bloom period of their pollen host plants. Most of the annual life cycle of the bees is spent underground as immatures in the brood cell, feeding and growing as larvae in spring, resting through the summer as post-defecating larvae followed by a brief spurt of pupation in early autumn, and finally resting overwinter as adults in their natal cells. In this way they are ready to emerge quickly as the spring bloom of their pollen host plants begin. The males tend to emerge first (protandry) and mating occurs with or just before initial bloom. Females construct shallow nests in upland soils in the vicinity of host plant populations. These oligolectic bees are K-selected in contrast to most insect species, in that they produce very few offspring per female (ca <30), but invest heavily in provisioning for their young. Where present, they often tend to be the most abundant visitors in the guilds of potential pollinators of their pollen host plants. Females tend to return to the same flower patches during successive foraging bouts and to forage over restricted areas, usually visiting a near-neighbor of the flower previously visited, which restricts gene flow that occurs via pollen dispersal.

Our primary focus here is to provide a summary of our current understanding of the geographic distributions of oligolectic bees in relation to their pollen host plants in vernal pool habitats, and to document the guilds of specialist and generalist flower visitors, with emphasis on outcrossing vernal pool species of the genera *Blennosperma*, *Lasthenia*, *Downingia*, and *Limnanthes.* As gaps in our knowledge of these bees exist, we also discuss potential difficulties associated with their poorly documented geographic distributions. Additionally, we report results of preliminary field tests that were conducted to evaluate the potential for transplanting oligolectic bees to newly created vernal pool habitats for mitigation projects.

METHODS

Geographic distributions

Field data on the ecology and systematics of vernal pool plant pollinators have been accumulated by one of us (RWT) on a casual basis since about 1960, with periods of intensive field studies in the 1970's, and by both of us in the 1990's as funding has become available. Species of principal interest have been oligolectic (pollen host specific) bees of the genus *Andrena* including: *A.* (*Diandrena*) *blennospermatis* Thorp, *A.* (*D.*) *submoesta* Viereck, and *A.* (*D.*) *puthua* (Cockerell); *A.* (*Hesperandrena*) *limnanthis* Timberlake, *A.* (*H.*) *duboisi* Timberlake, *A.* (*H.*) *lativentris* Timberlake and other undescribed species (Thorp, 1969; 1976; 1990; Thorp and Leong, 1995; Leong, 1994; Leong et al., 1995). Also of interest were *Panurginus occidentalis* (Crawford), and *P. atriceps* (Cresson) (Rust, 1976; Thorp, 1976; 1990).

Distributions of specialist bees relative to their pollen host plant taxa presented herein are based on our own field collections, other museum specimens, and literature records. Maps of the currently known distributions of major oligolectic bee species have been constructed and superimposed on the currently known distributions of their pollen host taxa according to the most recent revisions of: *Blennosperma* (Ornduff, 1964); *Downingia* (Weiler, 1962); *Lasthenia* (Ornduff, 1966); and *Limnanthes* (Mason, 1952).

Transplantation

Due to the potential importance of oligolectic bees to the reproduction of their pollen host plants, the desirability for transplanting oligolectic bees to new habitats was explored. Nests of these andrenids are not easy to locate. Adult females after they emerge, mate, establish nests, and begin foraging are the easiest stage to collect. Therefore, emphasis was placed on two aspects of transplanting female bees. First we tested the survival and longevity ("shelf life") of bees kept under cold storage for transportation between sites and secondly we performed a mark-release-recapture study of transplanted females.

Cold storage survival. Twenty-one female bees were collected while foraging for pollen at host flowers at several sites: Merced Co. on *Downingia* (6); Sonoma County on *Downingia* (6); Solano County on *Downingia* (2) and on *Lasthenia* (7). They were transferred to small plastic vials containing some of the host flowers. The vials were placed in a cooler with blue ice and returned to the Davis campus. The vials were then stored in a refrigerator at about 4°C. The vials were removed periodically and brought to room temperature (ca 25 °C) to check for mortality. Specimens were categorized as: "Alive" if they were able to right themselves and actively crawl around the vial; "Twitching" if there was any perceptable movement of legs or

antennae after 10 minutes warming; or "Dead" if no movement or response to probing after 10 minutes warming. Dead bees were removed and pinned as vouchers. Most alive bees became active within a couple of minutes at room temperature. Bees that were alive or exhibited some twitching response were returned to refrigeration. These observations continued for up to 4 weeks.

Mark-recapture study. This involved capture of 91 nesting *Andrena* females while they were gathering pollen from *Lasthenia* south of Olcott Lake, Jepson Prairie Preserve, Solano County, CA on 18 April 1994. The females were transferred to plastic vials and placed in an ice chest on blue ice. They were transported to Davis. That evening they were categorized by size, identified, and marked with an orange paint spot on the middle of the thoracic dorsum and placed in 10.5x5.5x2.5 cm cardboard slide boxes. The next morning (07:35 am) they were transported on ice and released at the same Preserve in an area with good bloom of *Lasthenia*, but about one mile north of the capture site (to minimize the chances of the bees returning to their original foraging site). The slide boxes containing the bees were placed on a larger cardboard box weighted with rocks to prevent being blown over. The slide boxes were opened partially so that the bees could escape and yet be protected from bird predation while still groggy. As soon as the boxes were opened, bees began crawling out and up their sides. The boxes were first checked that afternoon (13:05 pm) to evaluate the success of release. Subsequent surveys to determine the presence of the marked bees at the release site and at the site of original capture one mile south were made three and eight days after release. Bees were netted at flowers, examined for the mark, and released.

Flower Visitor Guilds

Our field collections provide us with data to document guilds of potential pollinators of the four major showy vernal pool flowering taxa. We have examined these to determine the specialist and generalist visitors to the various vernal pool plant taxa. Sampling/monitoring flower visitor guilds primarily involved field collection by insect nets, accompanied by visual observations; this was more recently augmented by pan-trap sampling (Leong and Thorp, 1995).

RESULTS

Geographic Distributions

The geographic distributions of specialist bees tend to be well within the ranges of their pollen host plant genera, and tend to conform most closely to distributions of their outcrossing host species (Figures 1-4). For example, *Panurginus occidentalis* and *Andrena limnanthis* are found throughout most of the ranges of *Limnanthes douglasii*, *L. alba*, *L. montana*, *L. striata*, and the endangered *L. vinculans*, all outcrossing species. However, they have not been found in association with *L. douglasii* ssp. *sulphurea* at Point Reyes National Seashore. They occur with *L. floccosa*, a selfer, only where it is sympatric with *L. alba* and are not found with the selfing populations of *L. gracilis* in southern Oregon or in San Diego County, California.

Blennosperma. New distribution records of *Andrena* (*Diandrena*) *blennospermatis* Thorp (Figure 1) more than double the area of distribution as published by Thorp (1969). However, it covers only a small (northern) portion of the distribution of *Blennosperma nanum* var. *nanum*. One of us (RWT) has briefly sampled populations of *Blennosperma nanum* in Butte County (east of Durham) and Fresno County (Ford Table) without finding the *Diandrena* oligolege. Females of this bee collect pollen from both *B. nanum* var. *nanum* and the endangered *B. bakeri*. [See note added in proof.]

Lasthenia. New geographical records of *Andrena* (*Diandrena*) *submoesta* Viereck and *A.* (*D.*) *puthua* (Cockerell) fill some gaps, but do not greatly extend the distribution records published by Thorp (1969) (Figure 2, Appendix I). These two species of *Diandrena* collect pollen only from flowers of the genus

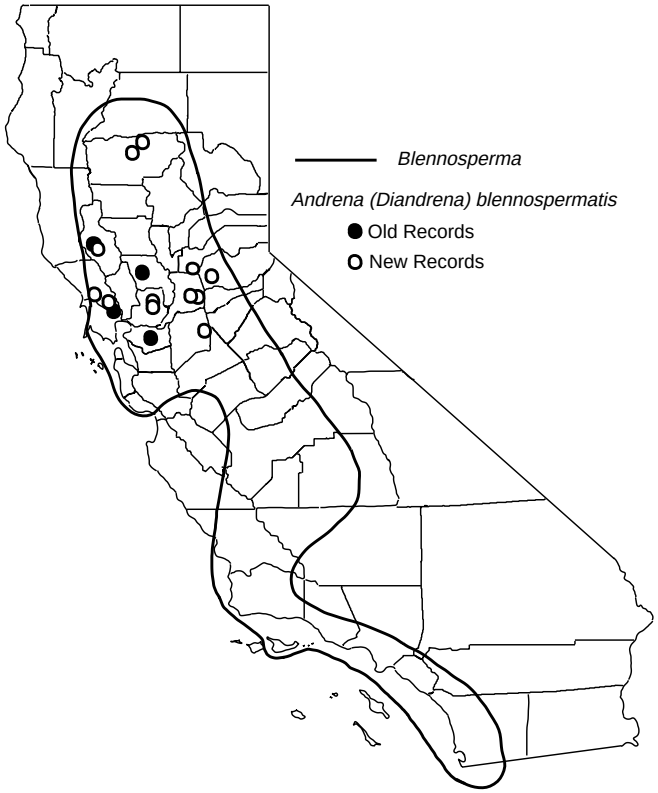

FIGURE 1. Geographic distribution of the outcrossing species of *Blennosperma* (bounded by the black line) and its oligolege, *Andrena* (*Diandrena*) *blennospermatis* (closed circles are records published by Thorp (1969), open circles are new records).

Lasthenia. They overlap considerably in space and time and share floral resources (Thorp, 1969). Their distribution areas cover most of the central range of the genus *Lasthenia*, especially of the widespread *L. californica*. *A. puthua* is more prominent in the Transverse Ranges of southern California and extends further south into Baja California, while *A. submoesta* is more prominent north of the San Francisco Bay area and in the southern Sacramento Valley (Figure 2).

Most species of *Hesperandrena*, especially *A.* (*H.*) *baeriae* Timberlake, *A.* (*H.*) *duboisi* Timberlake, *A.* (*H.*) *lativentris* Timberlake, and several undescribed species, collect pollen from flowers of *Lasthenia*. Some overlap in space and time and share the same floral resource both with each other and with *A.* (*Diandrena*) *submoesta* and *A.* (*D.*) *puthua* (Figure 2).

Limnanthes. The distribution of *Panurginus occidentalis* (Crawford), an oligolege of *Limnanthes*, tends to be quite similar to that of *A.* (*Hesperandrena*) *limnanthis* and frequently the two occur sympatrically (Figure 3, Appendix I). Females of these bees collect pollen primarily from *L. douglasii* subspecies *douglasii*, *nivea*, and *rosea*, and to a lesser degree from *L. alba*, *L. montana*, *L. striata*, and the endangered *L. vinculans*.

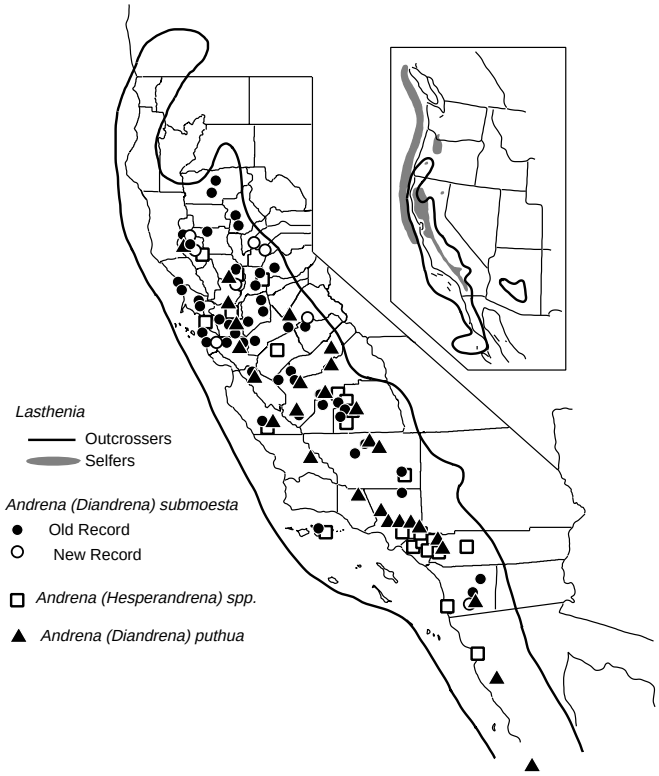

FIGURE 2. Geographic distribution of *Lasthenia* in North America (selfing and outcrossing species shown on inset, solid line encloses outcrossers) and its oligolectic bees: *Andrena* (*Diandrena*) *submoesta* (closed circles are records published by Thorp 1969, open circles are new records), *A.* (*D.*) *puthua* (solid triangles) and *A.* (*Hesperandrena*) spp. (including: *A. baeriae*, *A. duboisi*, *A. lativentris* and several undescribed species, open squares).

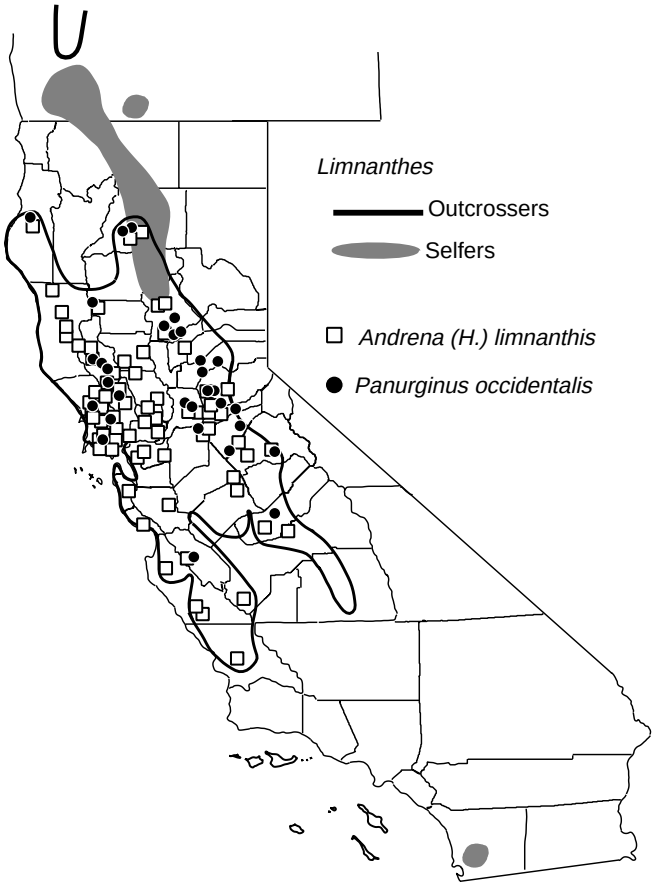

FIGURE 3. Geographic distribution of *Limnanthes* (gray areas are selfing species, black line bounds outcrossers) and its oligolectic bees: *Andrena* (*Hesperandrena*) *limnanthis* (open squares) and *Panurginus occidentalis* (closed circles).

Downingia. The known distribution of *Panurginus atriceps* (Cresson), the putative oligolege of *Downingia*, is based entirely on our own collections on the host plant, since there is confusion over the correct nomenclature of this bee species as judged by examinations of determined specimens in museum collections. Our current validated records for the bee flower relationship are well within the generic distribution of *Downingia* (Figure 4). Females of this bee collect pollen primarily from outcrossing species that have a short anther tube: *D. bicornuta*, *D. concolor*, *D. cuspidata*, *D. ornatissima*, and *D. pulchella*.

Specific locality records for all these oligolectic bees are given in Appendix I. For the three species of *Diandrena*, only new records since Thorp (1969) are listed.

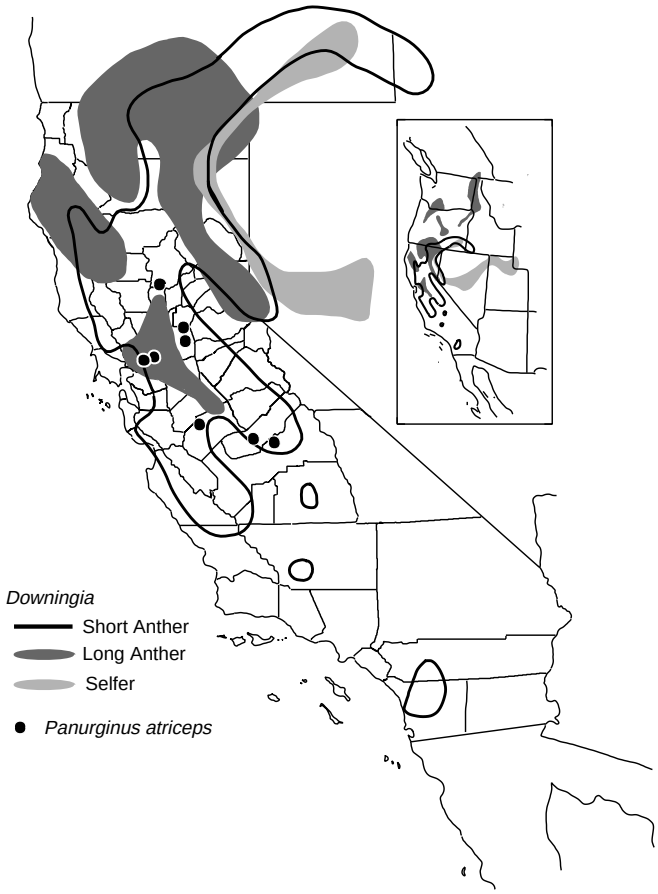

FIGURE 4. Geographic distribution of the North American species of *Downingia* (gray grid = selfer; black = outcrossing species with long anther tubes; black line bounds outcrossers with short anther tubes) and their oligolege, *Panurginus atriceps* (closed circles).

Transplantation

In studies to test the feasibility of transplanting foraging female oligolectic bees, considerable variation was shown in survivorship of bees stored under refrigeration in the laboratory. Some mortality occurred within the first two days, but 66.7% of the 21 bees were alive after one week and nearly 43% of the bees were still alive after two weeks of storage. Maximum length of survival in cold storage was 26 days.

In the mark-recapture study, 91 marked bees were returned the next morning to Jepson Prairie Preserve and released one mile north of the site of their capture. Five marked bees were found dead in the release boxes 5.5 hours after release; no dead bees were found in the vicinity of the release box. Thus, we assume that 86 marked bees were released. No marked bees were recaptured on the day of release among 132 bees sampled at the release site and 75 at the original collection site. Three days after release, one marked bee out of 37 bees surveyed was observed collecting pollen at *Lasthenia* at the release site. By the 8th day, when most of the *Lasthenia* flower heads were spent, 12 bees were observed at the release site, but none were marked.

Flower Visitor Guilds

Guilds of both specialist and generalist bees and other generalist visitors tend to be most diverse in association with *Lasthenia* and *Limnanthes* and least diverse in association with *Blennosperma* and *Downingia* (Appendix II). The greatest number of oligolectic species, including complexes of sympatric, and thus potentially competing species, are also associated with *Lasthenia*. Within the genus *Limnanthes*, the most diverse generalist visitor guilds are associated with *L. douglasii* ssp. *sulphurea* and *L. striata*.

Our lists record all species observed and do not distinguish rare versus common occurrences nor visit frequencies by each visitor species. Individuals of the oligolectic bee species are often the most abundant flower visitors, followed by generalist bees, flies of the families Anthomyiidae, Bombyliidae, Syrphidae, and Empididae, and pollen feeding beetles of the families Dasytidae, Melyridae, and Dermestidae. Although they may obtain part of their food resources from vernal pool flowers, none of these generalist guild members are restricted to vernal pool habitats.

DISCUSSION

In general, geographic distributions of oligolectic bees that pollinate showy vernal pool flowers tend to be well within the central part of the ranges of the outcrossing species of their pollen host plant genera (Figures 1-4). These bees collect pollen only from plants of their preferred hosts. They are not restricted to single host plant species, but they do not visit all species in their host genera. However, our knowledge of their geographic distributions in vernal pool habitats remains incomplete.

Blennosperma blooms earliest (February-March), when the weather is rainy and least conducive for entomologists to be collecting. The fact that we were able to double the distribution records for *A. blennospermatis* suggests that the limits of its distribution are yet to be established. *Lasthenia* and *Limnanthes* both attract the greatest diversity of visitors (Appendix II) and bloom during a time when weather is sunnier and entomologists are more likely to be in the field. *Downingia* attracts relatively fewer visitors due to its specialized flower form; and being a small "belly flower" does not attract the attention of many entomologists. Thus, our knowledge of geographic distributions of oligolectic bees in vernal pool habitats is probably most complete for bees associated with *Lasthenia* and *Limnanthes*.

The incomplete nature of many of our distribution records is in part also due to our insufficient knowledge of the systematics of the bee taxa. Identification of oligolectic bees in vernal pool habitats is problematic for many species due to insufficient systematic literature. Only for *Andrena* (*Diandrena*) is there a systematic revision with keys, descriptions, ecological data, and distribution records to identify the bees (Thorp, 1969). And even in this subgenus, we were able to make some significant additions to the distribution records of the vernal pool species. The paucity of information is illustrated by the two oligoleges of *Limnanthes*. *Andrena* (*Hesperandrena*) *limnanthis* and *Panurginus occidentalis* are the most distinctive and recognizable in their respective taxa, but detailed information on distribution records to augment our own field collections had to be ferreted out from mostly undetermined material in museum collections. Until further field associations are made and a revision of the genus *Panurginus* is completed, the nomenclature, distribution, and floral specificity of the principal pollinator of *Downingia* will remain an enigma. At this juncture, it appears that the species currently referred to as *P. atriceps* is actually a complex of at least two species (Thorp unpublished data): a widespread species that visits *Ceanothus* and other chaparral shrubs (Dobson, 1993) and another that visits only *Downingia* (Rust, 1976). There are also several undescribed species of *Andrena* (*Hesperandrena*) associated with *Lasthenia* and a revision of the subgenus is needed before they can be identified or studied with certainty.

Our limited experiments have demonstrated some potential for transplanting specialist bees. Field-collected foraging females that had mated and established initial nests could be held under refrigeration for up to one week with 66.7% survival. This is sufficient time to transport and release them at distant sites, and to allow for several days of inclement weather that would delay bee releases. Of course, in any attempts to transplant adult bees, it is important to determine the success of colonization after release. Bees should be marked for ease of identification after release. Even if nests cannot be located, the occurrence of marked females collecting pollen on their host plants is a good indication that they have established nests in the release area.

In our transplantation studies, we selected foraging females that had established nests, because of availability and ease of collection. Transplantation of freshly emerged adult bees, both males and females, may yield higher colonization success, since the primary time for dispersal to new habitats is likely to be prior to the time of mating, nest establishment, and initiation of pollen foraging. Successful colonization would then depend on the suitability of the new site in providing proper resources such as pollen host plants and nesting habitat. However, the window of opportunity to collect these freshly emerged bees is very small. Another approach is to transplant progeny in their brood nests. We have not yet explored methods for this, but difficulties could arise from the fact that these bees tend not to be highly gregarious making it rare to find groups of more than 12 nests in a nest site area. If sufficient nests could be located, they might be excavated during the summer when the larvae are resting after having completed their feeding, or in the autumn/winter when they have pupated and are in the overwinter resting adult stage. In either case, methods would need to be devised for transplanting soil cores for temporary storage prior to transplanting to ensure that the brood cells remained intact and were not physically damaged. Methods for successfully transplanting progeny in soil nests have been developed for the solitary, but highly gregarious nests of the alkali bee, *Nomia melanderi* Cockerell, (Stephen, 1960).

At best, transplanting these oligolectic ground nesting bees either as immatures or as emerged adults, is a challenging endeavor. Availability of adequate numbers of bees, narrow windows of time suitable for bee collection and/or transfer, and the likelihood that the bees may leave the release site if not all conditions are perceived as suitable compound the difficulty. Also, since vernal pool habitats contain other specialist and many generalist bees, accurate identification of desired target species for transplantion is important. Accurate identification or confirmation of initial identifications of most of these bees will require the aid of an expert. These bees are especially difficult to identify in the field. Collection of samples for examination and comparison with collections in a museum is usually required and voucher specimens should be deposited in a public entomology museum. There are published keys to the genera of bees (Michener et al., 1994), the subgenera of *Andrena* (LaBerge, 1986), and the species of *Diandrena* (Thorp, 1969). However, the latter two are difficult for the inexperienced to use. There are no keys available for *Andrena* (*Hesperandrena*) or *Panurginus* and since neither of these taxa have been revised they contain many undescribed species.

Although our focus here is on oligolectic bees, the guilds of visitors to the major showy vernal pool flower genera are diverse and usually contain many species of generalist bees, flies, and beetles in addition to oligolectic bees. The visitor guilds of *Blennosperma* and *Downingia* exhibit the least diversity. *Blennosperma* is the earliest blooming when fewer insect species are available. *Downingia*, although the latest blooming species, has the most specialized flower morphology. Visitor guilds of *Limnanthes* and especially *Lasthenia* show the greatest diversity of floral visitors. *Lasthenia* also has greatest number of oligoleges, including many sympatric species, as members of its visitor guilds. Our lists of guild memberships are biased in that each taxon is represented equally based on an occurance without regard to the relative frequencies or abundances of individuals in each taxon. Therefore a species with only one record may appear equal to one with many individual records, from different times and localities. The lists also do not indicate the quality of the floral visit, e.g., whether the insects forage for

pollen and/or nectar or visit the flower for some more casual reason. They are meant to serve as a starting place for future studies, such as investigations of the relative pollination efficiencies of different guild members. It is crucial to establish which guild members are the main pollinators. Presence of key pollinators should be an important consideration in vernal pool habitat conservation efforts.

In summary, we know a fair bit about the specificity and seasonal synchrony of the oligolectic andrenid bees to their vernal pool pollen host-plant taxa, as well as about their annual life cycles. However, our information on their systematics (except for *Diandrena*), dispersal, nesting habitat requirements, and distributions relative to their host plants is limited and needs more attention for us to understand their role in the reproductive biology of vernal pool plants. Some particularly interesting questions that need to be addressed include: What happens to plant reproduction in areas beyond the distribution ranges of their oligoleges? Are each of the oligolectic bees the most important pollinators of their pollen host plants? If so, how do we save them and possibly transplant them to restoration/creation sites for mitigation? Furthermore, a question not often asked is are these oligolectic bees worth conserving for their own sakes? We would answer the last with a firm yes. These bees are "inhabitants" and not merely "passers through" to paraphrase M. G. Barbour, keynote speaker of this symposium. They are totally dependent on the pollen from their specific host plant genera for the production of their progeny and thus for their survival. Their populations will become extinct wherever vernal pools containing their pollen host plants and/or their upland nesting habitats are destroyed. And plants that depend on these bees for their reproduction may also decline.

Preservation of existing vernal pool habitats is the most preferable type of mitigation for loss of vernal pool habitat as long as the complex biological interactions, processes, and functions are still intact. Restoration of vernal pools is less effective, being limited by the quality of the remaining habitat values, including uplands, and our ability to recognize and successfully restore those that have been degraded or lost. Creation of vernal pools is a very challenging approach and is one that also requires consideration of surrounding upland habitat for its value as nesting sites for bees, both oligoleges and generalists, that pollinate many showy vernal pool flowers. Conservation of the interaction of pollinators with vernal pool flowers is important for maintaining the long-term viability of these plants, especially the showy outcrossing taxa.

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NOTE ADDED IN PROOF

On 14 March 1997, Carol Witham and Greg Kareofelas extended the range of *Andrena (Diandrena) blennospermatis* over 100 miles northward from Lake County to Tehama County. They collected females of this bee on *Blennosperma nanum* in the vicinity of Red Bluff. These confirm our contention in the discussion that the limits of the distribution of this bee are yet to be established.

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Appendix I. Distribution records of andrenid bees oligolectic on vernal pool flowers [for *Andrena* (*Diandrena*) spp., only new records not listed in Thorp (1969)]:

Andrena (*Diandrena*) *blennospermatis:*
CA: *El Dorado Co.*: Bass Lake, 6 mi WSW Rescue. *Lake Co*: Finley, 2 mi NW. *Sacramento Co.*: Bridgehouse, 2 mi W; Slough House, 4 mi E. *San Joaquin Co*.: Bellota, 2 mi E. *Solano Co*.: Dixon, 8 mi S; Dozier, 11 mi S Dixon (= Jepson Prairie Preserve). *Sonoma Co*.: Santa Rosa, Alton Rd.; Sebastopol, 4 mi ESE. *Tehama Co.*: Red Bluff, 3 mi E and 13 mi NNE.

Andrena (*Diandrena*) *puthua:*
CA: *San Diego Co*.: Transect 1970-72: Descanso-Alpine site. *Solano Co*.: Dixon, 11 mi S (= Jepson Prairie Preserve).

Andrena (*Diandrena*) *submoesta:*
CA: *Butte Co*.: Biggs, 6 mi NNE; Chico, 10 mi SE. *Colusa Co*.: Bear Creek; Bear Valley, 8.8 mi N Hwy 29. *El Dorado Co*.: Bass Lake, 6 mi, WSW Rescue. *Fresno Co*.: Ford Table, 10 mi, ENE Friant. *Lake Co*.: Kelseyville, 5 mi SE; Lower Lake, 5.5 mi W. *Placer Co*.: Roseville. *Sacramento Co*.: Folsom, 6.5 mi S; Mather AFB; Slough House, 4 mi E. *San Diego Co*.: Transect 1970-72: Descanso-Alpine site. *San Joaquin Co*.: Bellota, 2 mi E; Clements, 7 mi NE. *San Mateo Co*: Stanford Campus Expt. Area. *Santa Barbara Co*.: Santa Cruz Island. *Solano Co*.: Dixon, 11 mi S (= Jepson Prairie Preserve). *Tehama Co*.: Corning, 5 mi W; Red Bluff. *Tuolumne Co*.: Groveland, 6 mi E. Yuba Co.: Beale AFB, 7mi E Marysville.

Andrena (Hesperandrena) limnanthis:
CA: Alameda Co.: Oakland, (SE of). *Amador Co*.: Ione, (SW of); Plymouth, 5 mi SW. *Butte Co*.: Biggs (N of); Chico, 10 mi SE. *Calaveras Co*.: Angels Camp. *Colusa Co*.: Bear Valley, 9.7 mi N of Hwy 20; Colusa. *Contra Costa Co*.: Byron; Walnut Creek (W of). *El Dorado Co*.: Placerville; Shingle Springs. *Fresno Co*.: Coalinga, (ca 15 mi W); Ford Table, 10 mi ENE Friant. *Humboldt Co*.: Kneeland, (W of). *Lake Co*.: Finley (SE of); Lakeport (& NW & S); Lower Lake, 2 mi S; Middletown; Upper Lake (SE of). *Madera Co*.: Madera, 10 km ENE. *Marin Co*.: Fairfax; Pt. Reyes; San Geronimo. *Mendocino Co*.: Bell Springs; Laytonville; Potter Valley; Willits (& N of). *Monterey Co*.: Carmel Valley (W of); Jolon (W of & WNW of). *Napa Co*.: Calistoga (N of); Napa (S of); Pope Valley and vicinity. *Sacramento Co*.: Fair Oaks; Slough House, 2 and 4 mi E (& W of). *San Benito Co*.: Paicines (ca 11 mi S). *San Joaquin Co*.: Clements, 7 mi NE. *San Luis Obispo Co*.: Santa Margarita (ca 5 mi NW). *San Mateo Co*.: Menlo Park. *Santa Clara Co*.: Mt. Hamilton. *Santa Cruz Co*.: Felton. *Shasta Co*.: Ingot; Palo Cedro. *Solano Co*.:Dozier, 11 mi S. Dixon (= Jepson Prairie Preserve); Vacaville. *Sonoma Co*.: Agua Caliente; Forestville; Healdsburg (N of); Kenwood; Santa Rosa, Alton Rd site; Sebastopol, 4 mi ESE (& N of); Sonoma; Two Rock, 1 mi W and 2 mi N; Valley Ford and 1 mi N. *Stanislaus Co*.: Evergreen Rd, 3.2 mi W Hwy 120; La Grange (N of). *Tuolumne Co*.: Chinese Camp; Groveland; Mather, 3 and 4-5 mi S. *Yolo Co*.: Davis, 5 mi W; Rumsey; Winters. *Yuba Co*.:Beale AFB, 7 mi E Marysville.

Andrena (Hesperandrena) spp. (associated with *Lasthenia*):
MEX.: *Baja California*: Ensenada. CA: *Contra Costa Co*.: Mt. Diablo and Russleman Park; Walnut Creek. *Kern Co*.: Mojave. *Lake Co*.: Lower Lake, 5.5 mi W. *Los Angeles Co*.: Puente Hills nr. Whittier; Santa Catalina Island, Rancho Escondido. *Merced Co*.: San Luis National Wildlife Refuge, 10 mi N Los Banos. *Monterey Co*.: Lockwood, 1 mi. W. *Orange Co*.: Rancho Santa Ana. *Riverside Co*.: Albermill, 11.5 mi NW; Gavilan; Hemet Lake; Herkey Creek; Lake Mathews; Perris, 2, 3, and 4 mi W; Railroad Canyon; Riverside; Rosamond, Hills N of. *Sacramento Co*.: Bridgehouse, 2 mi W. *San Diego Co*.: San Diego. *San Francisco Co*.: San Francisco. *Santa Barbara Co*.: Santa Cruz Island. *Tulare Co*.: Earlimart; Goshen; Strathmore; Tipton, 10 mi W; Visalia. *Yolo Co*.: Davis.

Panurginus atriceps
CA: *Butte Co*.: Biggs, 6mi NNE. *Fresno Co*.: Table Mtn. *Madera Co*.: USBR Equalization Reservoir site. *Merced Co*.: Grasslands State Park, 14.2 mi N Los Banos. *Placer Co*.: Roseville. *Sacramento Co*.: Mather AFB. *Solano Co*.: Dozier, 9 mi S Dixon; Dozier, 11 mi S Dixon (= Jepson Prairie Preserve); Travis AFB.

Panurginus occidentalis:
CA: *Amador Co*.: Fiddletown, 5.6 mi E; Pioneer; Plymouth, 5 mi SW; Volcano, 5.1 mi NE. *Butte Co*.: Bangor; Biggs (vic); Oroville, 7 mi NNE; Palermo-Horcutt Rd, 2.2 mi N Central House; Table Mtn. *Calaveras Co*.: Rt. 49, 1.9 mi S Angels Camp; Sheep Ranch. *El Dorado Co*.: Diamond Springs; Shingle Springs. *Humboldt Co*.: Kneeland, 15.6 mi S. *Lake Co*.: Finley, 2 mi W; Lower Lake (vic); Middletown; Rt. 29 & Rt. 175. *Madera Co*.: Coarsegold, 8 mi S. *Marin Co*.: Forest Knolls, 3.4 mi S. *Napa Co*.: Pope Valley, 3 mi N and 3 mi S. *Nevada Co*.: 1.8 mi N County line, Rd. 49. *Placer Co*.: Auburn; Foresthill, 5 mi W. *Sacramento Co*.: Mather AFB; Rt. 16, 1.5 mi W Eagles Nest Rd. *San Benito Co*.: Rt. 25, 0.3 mi N Glora Rd. *San Joaquin Co*.: Clements. *Shasta Co*.: Ingot; Palo Cedro. *Somoma Co*.: Agua Caliente, 3 mi N; High School Rd. 0.3mi S Occidental Rd.; Rt. 12, ca 12 mi N Sonoma. *Tuolumne Co*.: Groveland; Mather.

APPENDIX II. Flower Visitor Guilds of Showy Vernal Pool Plant Taxa. * denotes oligolectic bee species.

Blennosperma

- HYMNENOPTERA
  - ANDRENIDAE
    - **Andrena (Diandrena) blennospermatis*
    - *A. (Hesperandrena) limnanthis*
    - *A. (Tylandrena) layiae*
  - ANTHOPHORIDAE
    - *Nomada* spp.
    - *Synhalonia* sp.
  - APIDAE
    - *Apis mellifera*
  - HALICTIDAE
    - *Dialictus* sp.
    - *Evylaeus* sp.
    - *Halictus* sp.
    - *Lasioglossum* sp.
    - *Sphecodes* sp.
  - MEGACHILIDAE
    - *Osmia* spp.
- DIPTERA
  - ANTHOMYIIDAE
    - *Scatophaga stercoraria*
  - BOMBYLIIDAE
  - CALLIPHORIDAE
  - CONOPIDAE
    - *Myopa* sp.
  - EMPIDIDAE
  - EPHYDRIDAE
    - *Rhamphomyia* spp.
  - RHAGIONIDAE
  - SYRPHIDAE
- COLEOPTERA
  - CANTHARIDAE
  - MELOIDAE
    - *Meloe*? sp.

Lasthenia

- HYMNENOPTERA
  - ANDRENIDAE
    - **Andrena (Diandrena) submoesta*
    - **Andrena (Diandrena) puthua*
    - **Andrena (Hesperandrena) baeriae*
    - **Andrena (Hesperandrena) duboisi*
    - **Andrena (Hesperandrena) lativentris*
    - **Andrena (Hesperandrena)* spp. (2-3 n. sp.)
    - *Andrena (Micrandrena)* sp.
    - *Andrena (Tylandrena) layiae*
    - *Panurginus* sp.
  - ANTHOPHORIDAE
    - *Nomada* spp.
  - APIDAE
    - *Apis mellifera*
  - CHRYSIDIDAE
  - COLLETIDAE
    - *Hylaeus* sp.
  - HALICTIDAE
    - *Dialictus* sp.
    - *Halictus farinosus*?
    - *Lasioglossum* sp.
    - *Sphecodes* sp.
  - ICHNEUMONIDAE
  - MEGACHILIDAE
    - *Osmia* sp.
  - SPHECIDAE
- HEMIPTERA
  - LYGAEIDAE
- DIPTERA
  - ANTHOMYIIDAE
    - *Scatophaga* sp.
  - BOMBYLIIDAE
    - *Bombylius* sp.
    - *Conophorus* sp.
  - CONOPIDAE
    - *Myopa* sp.
  - DOLICHOPODIDAE
  - EMPIDIDAE
  - MUSCIDAE
    - *Phormia* sp.
  - RHAGIONIDAE
  - SEPSIDAE
    - *Sepsis?* sp.
  - SYRPHIDAE
  - STRATIOMYIDAE
  - TEPHRITIDAE
- COLEOPTERA
  - CERAMBYCIDAE
  - COCCINELLIDAE
  - DASYTIDAE
  - DERMESTIDAE
  - MELYRIDAE
- LEPIDOPTERA
  - INCURVARIIDAE
    - *Adela* sp.
  - NOCTUIDAE
    - *Schinia* sp.

Limnanthes

- HYMNENOPTERA
  - ANDRENIDAE
    - *Andrena (Diandrena) cuneilabris*
    - *Andrena (Euandrena) caerulea*
    - **Andrena (Hesperandrena) limnanthis*
    - *Andrena (Melandrena)* sp.
    - *Andrena (Plastandrena) prunorum*
    - *Andrena (Tylandrena) layiae*
    - *Andrena* spp.
    - *Calliopsis (=Nomadopsis*) sp.
    - **Panurginus occidentalis (Crawford)*

Appendix II (continued). Flower Visitor Guilds of Showy Vernal Pool Plant Taxa. * denotes oligolectic bee species.

Panurginus sp.
Anthophoridae
Diadasia nigrifrons
Melissodes sp.
Nomada sp.
Synhalonia sp.
Xeromelecta sp.
Apidae
Apis mellifera
Bombus bifarius
B. californicus
B. caliginosus
B. edwardsii
B. occidentalis
B. sitkensis
B. vosnesenskii
Chrysididae
Eumenidae
Halictidae
Agapostemon texana
Dialictus sp.
Halictus (Seladonia) sp.
Lasioglossum sp.
Ichneumonidae
Megachilidae
Hoplitis sp.
Osmia sp.
Sphecidae
DIPTERA
Anthomyiidae
Scatophaga sp.
Bibionidae
Bombyliidae
Conopidae
Physocephala sp.
Dolichopodidae
Empididae
Muscidae
Phormia sp.
Sepsidae
Sepsis? sp.
Syrphidae
Scaeva sp.
Eristalis spp.
COLEOPTERA
Buprestidae
Cantharidae
Cerambycidae
Chrysomelidae
Coccinellidae
Dasytidae
Elateridae
Pedilidae
Scarabaeidae
HEMIPTERA
Cicadellidae
Miridae
LEPIDOPTERA
Hesperiidae
Incurvariidae
Adela sp.
Lycaenidae
Noctuidae
Schinia sp.
Satyridae

Downingia
HYMNENOPTERA
Andrenidae
**Panurginus atriceps*
Anthophoridae
Nomada spp.
Anthophora urbana
Apidae
Apis mellifera
Bombus huntii
B. vosnesenskii
Colletidae
Hylaeus sp.
Halictidae
Dialictus sp.
Evylaeus sp.
Halictus (Seladonia) sp.
Megachilidae
Osmia spp.
Pompilidae
DIPTERA
Anthomyiidae
Scatophaga sp.
Muscidae
Phormia sp.
Syrphidae
COLEOPTERA
Chrysomelidae
Coccinellidae
Dasytidae
Meloidae
Meloe sp.
LEPIDOPTERA
Incurvariidae
Adela sp.
Satyridae
HEMIPTERA
Miridae