Appendix H

Ecosystem Services of the Existing and Proposed Trees of the Palo Alto Municipal Golf Course

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Urban Ecos

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Executive Summary

The City of Palo Alto proposes renovating the Palo Alto Municipal Golf Course. The renovation will require the removal of 543 trees; 300 native trees will be planted in the new design, which will also replace approximately 40% of the turf with native grasses and shrubs, incorporate new wetlands, and significantly reduce the amount of land requiring irrigation. This study used the US Forest Service's i-Tree Streets software tool to determine the annual ecosystem services of the existing tree canopy and compare them with the services estimated to be provided by the new canopy, ten years after planting. Owing to the decrease in the number of trees, the generally smaller mature size of the proposed trees, and the early time point of the comparison, the results show a significant reduction in benefits between the existing forest and the proposed forest, ten years after planting.

- The existing forest captures approximately 1.1 million gallons of stormwater each year; ten years after planting, the proposed forest will capture 276,000 gallons (a difference valued at $3,300 annually).
- The existing forest captures 296.1 lbs of air pollutants each year; the proposed forest 52.3 lbs (an $1,800 annual difference).
- Each year the existing forest sequesters approximately 260,000 lbs of greenhouse gases; the proposed forest, at 10 years after planting, will sequester 17,000 lbs (a $2,400 annual difference).
- The total amount of greenhouse gases currently stored in the existing forest is estimated at 4.2 million lbs; after 10 years, the proposed forest will be storing a total of 126,000 lbs (a one-time difference of $41,250).
- On an advantageous note, the proposed forest will have significantly lower emissions of BVOCs, a component of smog: 50 lbs vs 4,710 lbs (an annual improvement estimated at $36,500).

Other, less quantifiable benefits will accrue from the proposed design, including greater provision of habitat, improved stormwater management, reduced water use, and heightened sense of place.

The report concludes with a discussion of possible strategies for mitigating the lost benefits, while remaining flexible to address the community's environmental values and objectives.

Introduction

The City of Palo Alto is proposing to renovate the Palo Alto Municipal Golf Course. The initial impetus for the renovation was to incorporate 7.4 acres of the golf course into a flood reduction project proposed by the San Francisquito Creek Joint Powers Authority and approved in November 2012. It was later decided to take the opportunity to remodel the entire golf course, which dated back to the 1950s, with a design more in keeping with the native landscape and the Baylands Nature Preserve, which surrounds the golf course to the east, covering nearly 2,000 acres.

To carry out the renovation, it is necessary to remove 543 trees. As a means of understanding the environmental consequences of the redesign, particularly with respect to the trees, this report describes the ecosystem services of the existing tree canopy and compares them with the services estimated to be provided by the new canopy. Where it is possible, benefits are quantified into actual units (gallons of stormwater filtered, pounds of greenhouse gases sequestered, and pounds of air pollutants captured) and associated dollar values. In other cases, the benefits are described qualitatively. Suggestions for mitigation are provided.

Methods

Ecosystem services calculations

The i-Tree Streets software program (v. 5; i-Tree 2013) was used to estimate the annual ecosystem services of the trees to be removed from the Palo Alto Municipal Golf Course and to estimate the services that will be provided by the trees in the proposed redesign 10 years after planting. The following environmental contributions were considered:

- **Annual stormwater management**: Trees capture rainwater and remove impurities, reduce the volume of water entering into sewer systems, and reduce peak stream flows. Canopy cover helps reduce erosion by reducing the impact of raindrops on bare ground. Results are presented in gallons of stormwater managed.
- **Annual air pollutant capture for ozone, nitrogen oxides, sulfur dioxide, and small particulate matter (PM_{10}):** Trees remove harmful pollutants from the air by absorbing them into their leaves or by intercepting them and allowing them to be washed away with the rain. Results are presented in total pounds of air pollutants captured.
- **Annual greenhouse gas sequestration**: Trees capture carbon dioxide from the atmosphere in the process of respiration and transform it into living matter—leaves, branches, trunks, and roots. Results are presented in pounds of carbon dioxide equivalents sequestered.
- **Total greenhouse gas storage by trees to date:** The carbon dioxide captured each year by the trees is held within them until they die, after which, in most cases, it is returned to the atmosphere as the trees decompose. Results are presented in total pounds of carbon dioxide equivalents stored.

Some species of trees also have a potentially negative impact on air pollutant emissions: they produce biogenic volatile organic compounds (BVOCs), which may combine with nitrogen oxides to produce smog. To provide the most conservative estimate of the trees' environmental contributions, **annual BVOC emissions** are also calculated.

The iTree Streets program also estimates energy conservation benefits (as well as associated air pollution mitigation and greenhouse gas avoidance associated with reduced energy use) and benefits associated with increases in property values when trees are planted around residences. These benefits were not included here because few if any of the trees shade buildings (and thus they do not reduce energy use) and, of course, they are not planted around residences and thus the property value benefits do not apply. (For a general nontechnical description of the science behind i-Tree Streets [formerly known as STRATUM], see CUFR 2005; for a more technical discussion, see the "Methodology and Procedures" section of Maco et al. 2005.)

Dollar values of ecosystem services

i-Tree Streets translates the ecosystem services above into associated dollar values using economic indicators of society's willingness to pay for the environmental benefits trees provide. With the exception of greenhouse gases, where a value of $21/ton is used in the United States as the "social cost of carbon," the dollar values are the default options used in i-Tree Streets (Table 1; for further discussion of how there were determined, see Maco et al. 2005). Air pollutant values are based on average emission reduction offset transaction costs for the San Francisco Bay area (Table 3); for stormwater values, single-family residential sewer service fees were used.

Table 1. Dollar values of ecosystem services

Ecosystem service	**Dollar value**
Reduction in greenhouse gases	$21/ton
PM_{10} interception	$11.79/pound
Nitrogen oxides absorption	$10.31/pound
Sulfur dioxide absorption	$3.67/pound
Biogenic volatile organic compound emissions	$-7.22/pound
Stormwater mitigation	$0.004/gallon

Inventory

The Tree Management Plan dated October 23, 2013, was used to identify the existing trees to be removed. Tree species and trunk diameter at breast height (DBH) were taken from an inventory done in March 2012. No adjustments were made for tree growth in the intervening 18 months.

The specifications for trees in the proposed design were communicated by team members (Richardson 2013) as taken from the Planting Plan. Species and expected sizes at planting were provided.

A critical question that arises in these cases is choosing the future time point at which the proposed forest should be assessed. The chosen point could be anywhere from immediately to 40–50 years in the future when the forest has matured. Choosing a point shortly after planting is not recommended as the sizes of the new trees should be chosen to ensure the greatest health and likelihood of success rather than to artificially increase the level of benefits. Time points too far in the future fail to account for the benefits lost between the time a mature forest is removed and the new one matures. A conservative time point of ten years was chosen here, which is also in keeping with Palo Alto's Tree Technical Manual. The Center for Urban Forest Research's Tree Carbon Calculator v. 31 (CUFR 2009), which includes growth curves, was used to estimate the sizes the proposed trees would reach in ten years time.

Results

Existing forest

Plans call for 543 trees to be removed from the golf course. Forty-one species are included, with DBHs ranging from 2 to 71 inches (Table 2). The species mix reflects popular choices at the time the golf course was built, including eleven species of eucalyptus, three ironwoods (*Casuarina* spp.), two acacias, and four pines among others. None of the existing species is native to the region and only five *trees* (four Monterey cypress [*Cupressus macrocarpa*] and one Monterey pine [*Pinus radiata*] are native to California.

Owing to the mature size of the existing canopy, the annual benefits the trees are providing are substantial (Table 3):

- 1.1 million gallons of stormwater are filtered.
- 296 pounds of air pollutants are captured.
- 260,000 pounds of greenhouse gases are sequestered.
- These benefits are valued at $9,200 annually.

The existing tree canopy also currently stores a total of 4.2 million pounds of greenhouse gases, which have been sequestered over the trees' lifetimes (total estimated value of $42,500).

Because the existing species mix includes many high BVOC emitters, the annual BVOC emissions are quite heavy at 4,710 lbs.

Table 2. Species and size distribution (DBH) of the trees to be removed from the Palo Alto Municipal Golf Course.

Species	DBH																					
	2	5	8	11	14	17	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	Total
Acacia melanoxylon					1		1															2
Acer sp.	3																					3
Casuarina cunninghamiana	1			5	1	1	2	1														11
Casuarina equisetifolia	7	25	2	11	11	9	4	2	2		1											74
Casuarina stricta					1																	1
Cupressus macrocarpa									1													1
Eucalyptus sp.				2																		2
Eucalyptus camaldulensis	1	6	5	7	6	10	11	5	3	3	3	1										61
Eucalyptus globulus		5	2	8	7	4	13	11	8	8	10	8	8	8	9	8	2	2	2	1	1	125
Eucalyptus leucoxylon		1							1													2
Eucalyptus nicholii		1	3	2	4		1															11
Eucalyptus polyanthemos	1	6	16	22	6	5	3	1	1													61
Eucalyptus rudis		1		5	5	5	2		1	1												20
Eucalyptus sideroxylon		2	10	19	12	5	2		1													51
Eucalyptus torquata		1	1	1																		3
Eucalyptus viminalis										1												1
Fraxinus sp.	1																					1
Fraxinus pennsylvanica			1	1																		2
Fraxinus uhdei			1		1																	2
Maytenus boaria			2	1																		3
Melaleuca linariifolia			1	1	1		3		1													7
Morus alba	2																					2
Myoporum laetum		6	5	6	10	3																30
Olea europaea	1	1																				2
Pinus canariensis			3	1	1																	5
Pinus halepensis				2	2		2	1	1	1	1											10
Pinus pinea	2	1	1	5	2		1		1	1												14
Pinus radiata									1													1
Populus nigra 'Italica'				1																		1
Pyrus calleryana	9	3																				12
Pyrus calleryana 'Aristocrat'	1																					1
Pyrus calleryana 'Chanticleer'	12	1																				13
Schinus molle		1																				1
Schinus terebinthifolius				1			1															2
Ulmus parvifolia			2		1																	3
Unknown	1	1																				1
Grand Total	42	62	55	101	72	42	46	21	22	15	15	9	8	8	9	8	2	2	2	1	1	543

Table 3. Annual ecosystem services provided by the existing trees and the proposed trees ten years after planting. Annual emissions of BVOCs (a component of smog) are shown as negative numbers as they are a potential environmental burden. Total storage of greenhouse gases by the existing and proposed forests is also shown.

Annual benefits	Resource units			Dollars		
	Trees to be removed	Planned forest	Difference	Trees to be removed	Planned forest	Difference
Stormwater management (gallons)	1,105,065	276,004	829,061	$4,420	$1,104	$3,316
Air quality: ozone capture (lbs)	139	24	115	$1,022	$174	$847
Air quality: nitrogen oxides capture (lbs)	61	10	51	$449	$77	$372
Air quality: PM_{10} capture (lbs)	84	16	68	$664	$128	$536
Air quality: SO_2 capture (lbs)	12	2	10	$53	$9	$44
Greenhouse gas sequestration (lbs)	259,592	17,158	242,434	$2,596	$172	$2,424
Annual total benefits				**$9,204**	**$1,663**	**$7,540**
Air quality: BVOC emissions (lbs)	-4,711	-50	-4,661	$-36,933	$-395	$-36,538
Lifetime greenhouse gas storage (lbs)	4,251,568	125,568	4,126,001	$42,516	$1,256	$41,260

Proposed forest

The new golf course will include 300 trees of four species (Table 4), all of which are native to the area. After ten years, the new trees are estimated to provide the following annual ecosystem services:

- 276,000 gallons of stormwater will be filtered.
- 52 pounds of air pollutants will be captured.
- 17,000 pounds of greenhouse gases will be sequestered.
- These benefits are valued at $1,200 annually.

Ten years after planting, the new forest will also have stored a total of 17,000 pounds of greenhouse gases (a total estimated value of $170).

The BVOC emissions of the new forest are expected to be significantly lower at 50 lbs total. They will remain significantly lower even as the trees mature as the species mix as a whole consists of far fewer heavy emitters.

Table 4. Trees to be planted in the Palo Alto Golf Course restoration.

Species	Number	Container size	DBH at planting (in)	DBH at 10 years (in)
Rhamnus californica	110	15 gallon	1	6
Myrica californica	122	24 in box	2	7
Ceanothus sp.	40	15 gallon	1	6
Quercus agrifolia	28	24 in box	2	8

Benefits comparison

The results show a significant reduction in annual benefits between the existing forest and the proposed forest, ten years after planting (Table 3).

- The proposed forest will mitigate 830,000 fewer gallons of stormwater ($3,300).
- The proposed forest will capture 244 fewer lbs of air pollutants each year ($1,800).
- The proposed forest, at 10 years after planting, will sequester 242,000 fewer lbs of greenhouse gases ($2,400).
- On an advantageous note, the proposed forest will lower emissions of BVOCs by 4,660 lbs (an improvement estimated at $36,500).

Furthermore, after 10 years, the proposed forest will have stored 4.125 million fewer lbs of greenhouse gases ($41,250).[1]

[1] It should be noted that it may not be entirely correct to count the loss of greenhouse gases stored in the existing forest as a penalty against the project. Under normal circumstances, as a tree decomposes, it returns its sequestered greenhouse gases to the atmosphere. Here, it is envisioned that the trees will be buried on site to create the desired topography and hence the

It’s important to note that, with the exception of the total stored greenhouse gases, these differences accrual *annually*.

The reasons for the differences in ecosystem services between the existing forest and the proposed design include the following:

- The number of trees. Plans call for 543 trees to be removed and 300 to be planted.
- The maturity of the existing forest. One-third of the existing forest is 20 inches or more in diameter, including 50 trees over 35 inches in diameter. The proposed trees are being assessed quite early in their lives (ten years after planting).
- The mature size and growth rate of the species. In the existing forest, only 8% of the trees would be characterized as small at maturity. In the proposed forest, in contrast, 91% would be considered small. All of the ecosystem service values are closely related to tree size. Note that although one of the species is significantly larger at maturity than the others (*Q. agrifolia*), it grows slowly in the early years and provides benefits at 10 years that are similar to the other, smaller species. The benefits provided by the oak trees would be significantly higher than the other species in later years.

Other benefits

The replacement of the existing golf course, which consists mainly of turf and nonnative trees, with the proposed design will incur additional environmental benefits beyond those described above. Currently, models do not exist to quantify these benefits, but they can be described qualitatively. The advantageous aspects of the new design include the following:

- Non-native tree species will be replaced with native tree species.
- Total area requiring irrigation will be reduced by approximately half.
- Approximately 40% of the existing managed and irrigated turf will be replaced with native grasses and shrubs.
- The current ecosystem, which might be described as a monoculture of turf and trees, will be replaced by a more diverse patchwork of areas of native grasses, shrubs, forested areas, and wetlands.

The provision of these features will enable the following environmental improvements.

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fate of the sequestered gases is not clear. Studies have shown that 97–100% of the carbon in wood *buried in landfills* remains sequestered, essentially indefinitely (Micales and Skog 1997). The extent to which conditions on the golf course will mimic the anaerobic conditions of a landfill are not clear, therefore, a conservative has been taken here and it is assumed that the greenhouse gases are returned to the atmosphere.

Habitat provision: The availability of the landscape to provide habitat for plant and animal species will be improved by replacing nonnative with native species, by moving to a more diverse ecosystem with a variety of potential habitats, and by the provision of wetland areas.

Stormwater management: Currently, stormwater runoff on site is collected in storm drains that lead to drainage ditches, then to a pumping station and eventually into the Bay. It is generally preferable to treat stormwater on site, allowing it to seep into the ground, which slows erosion, allows for filtering impurities, and recharges the groundwater. Replacing turf with native grasses and shrubs can significantly slow the movement of water, allowing it to seep through the soil rather than into storm drains.

Water usage: Water scarcity is an issue of growing concern in California. By significantly reducing the amount of land requiring irrigation, the proposed design will support the goal of using less water.

Sense of place: Often overlooked in environmental studies is the concept of "sense of place" or *genius loci*, that is, the distinctive spirit of a place that makes it memorably and uniquely itself. In a heavily urbanized and thus homogeneous area like the San Francisco Peninsula, replacing a somewhat generic golf course design with a landscape that reflects the native conditions can offer opportunities for connecting people with the natural surroundings.

Mitigation considerations

It is beyond the scope of this report to suggest a specific mitigation solution; these decisions are ultimately best made with input from the community based on local needs and values. It may be helpful however to summarize the issues involved and to describe some of the options.

It seems clear that, overall, the proposed design will be an environmental improvement over the existing golf course. There will be greater provision for wildlife, improved stormwater management, increased wetland functionality, reduced water usage, and a return to some of the structure and function of the original landscape. At the same time, the loss of certain valued ecosystem services should be acknowledged and addressed. The existing trees, owing to their numbers and large stature, are helping clean the air of air pollutants, filter water, and sequester greenhouse gases from the atmosphere, services estimated at approximately $9,200 per year, or $7,500 more than the proposed design after ten years. Although the other vegetation of the new landscape (shrubs and native grasses) will provide some of these services, no models currently exist to quantify them. In addition to these annual values, when the existing trees are removed, they will release up to $42,500 worth of greenhouse gases, of which only $1,250 will be made up for by the proposed design after ten years.

Taking the annual benefits first: There are a number of ways to conceive of mitigating the reduced benefits of the tree canopy. The simplest—but by no means necessarily best and certainly the least flexible—strategy is to replace removed trees one for one (or even some multiple thereof). In the case of the Baylands renovation project, this would have the unfortunate consequence of requiring many more trees to be planted than the native landscape would have supported. Furthermore, the available financial resources would be weighted toward tree planting, leaving less funding for other, perhaps more suitable or desired environmental remediations such as planting of native grasses and shrubs, development of wetlands, or even acquiring additional land for conservation.

It may be more worthwhile to consider a mitigation strategy that invests the dollar amount of the difference in benefits in environmental restorations that target community priorities. One practical method might be to sum the difference in benefits over a reasonable time period, for example, the time it takes the new trees of the golf course to mature, i.e., 20–25 years (= $150,000–$187,500). This funding could then be used on environmental projects selected for their ability to provide the most important ecosystem services as determined by the community and stakeholders. If, for example, habitat provision is particularly valued, the funding might be used to acquire land or to restore native flora in targeted areas with the goal of improving wildlife connectivity in the region. Alternatively, if stormwater management and greenhouse gas sequestration are considered critical, the funding might be used to support wetlands protection or restoration as wetlands are valuable for reducing flooding, improving groundwater recharge, and sequestering greenhouse gases. If air quality concerns are of the greatest concern, the money might be invested in planting trees and shrubs along major thoroughfares, particularly in areas with low canopy cover.

In addition to the question of mitigating the *annual* differences in benefits, there remains the one-time difference of $41,250 in greenhouse gas sequestration between the existing trees and the trees of the proposed golf course to be considered. As described above in footnote [1], it may not be correct to count these pounds against the project as the fate of the greenhouse gases locked in the trees is unclear if they are buried. If the most conservative mitigation strategy is desired, this funding could be combined with that above while being careful to ensure that the resulting projects have climate change benefits. These need not necessarily be straightforward sequestration; projects that seek to allow the ecosystem and the region to adapt to anticipated changes such as differences in precipitation, temperature extremes, and flooding could be considered.

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