Habitat Equivalency Analysis for Windsor Eastside Road Storage Project - DRAFT

PREPARED FOR: Craig Scott/Town of Windsor

PREPARED BY: Mark Rockel/CH2M HILL
Deborah Waller/CH2M HILL
Andrea Gardner/CH2M HILL

COPIES: Joe Green-Heffern/CH2M HILL
Dave Richardson/RMC

DATE: May 1, 2008

This Technical Memorandum (TM) provides a quantification of habitat impacts, in ecological service values, for the Eastside Road Storage Project (ERSP, or the Project). It also provides an estimate of the mitigation value of preserving onsite oak woodland. This information will support the analysis and estimated mitigation costs of the ERSP and will provide a basis for establishing mitigation during the permitting process.

This TM is organized into the following sections:

- Section 1.0 - Summary
- Section 2.0 - Site Description
- Section 3.0 - Purpose of the Habitat Equivalency Analysis
- Section 4.0 - Measuring Natural Resource Value
- Section 5.0 - Analysis of Ecological Service Losses from the Project
- Section 6.0 - Analysis of Ecological Credits Gained From Preservation Actions
- Section 7.0 - References

1.0 Summary

Total estimated impacts for the ERSP's different habitat types are shown in Table 1 of this TM. Total habitat impacts from the Project are approximately 32 acres. Approximately 139 acres of the 171-acre parcel [1] is assumed to be available for preservation as a mitigation option.

Based on the results of the Habitat Equivalency Analysis (HEA) described below, the preservation area is expected to be large enough to mitigate for (replace the loss of) the service values provided by the oak woodland that would be impacted by the Project.

The results of this analysis provide a consistent methodology to gain and accrue credit for preservation actions to offset obligations regarding habitat disturbances from construction

[1] The area within the legal property boundaries of the parcel is 168 acres. The habitat mapping done for this memorandum used a GIS base map that extends slightly beyond the parcel legal boundaries, resulting in an area of approximately 171 acres that was evaluated.

of the ERSP ponds. If a credit of 10 discounted service-acre years (DSAYs) is used, the mitigation ratio is 2.92 to 1, resulting in a preservation area of approximately 82 acres. The 82-acre preservation goal can be achieved through preservation of oak woodland on other portions of the Town parcel.

TABLE 1
Aquatic Features within the Project Parcel

Habitat	Parcel - 170.89 Acres	Impacted - 32.14 Acres
Oak Woodland (Acres)	136.69	28.07
Riparian Woodland (Acres)	2.48	0
Annual Grassland (Acres)	23.74	3.79
Coastal Scrub (Acres)	5.01	0.35
Redwood Groves (Acres)	2.07	0
Remnant Orchard (Acres)	0.3	0.13
Developed (Acres)	0.59	0.05
Wetlands (Acres)[1]	0.69	0
Drainages - Delineated (Feet)[2]	8,775 ft	7,084 ft
Drainages - Reconnaissance (Approx. Feet)[3]	9,000 ft	0 ft
Drainages Total (Approx. Feet)	17,775 ft	5,315 ft

Notes:

[1] One of the drainages (Drainage T) contains 0.015 acre of vegetated channel that could be classified as “wetland” habitat and will be impacted by the Project; however, at the time the HEA calculations were perfomed, it was classified as oak woodland habitat and is included as such in the results presented in this TM.

[2] These are drainages identified and mapped during the delineation of wetlands and waters of the U.S. performed for the Project. Impacted length includes both temporary (up to 3,455 feet) and permanent (up to 3,629 feet) impacts.

[3] These are drainages not included in the wetland delineation that were observed during reconnaissance surveys of the rest of the parcel.

2.0 Site Description

The Project area is located in the unnamed hills at the western edge of the broad, relatively flat Santa Rosa Plain. Immediately to the west of the Project area is the Russian River. To the north and east are the Mayacamas Mountains, which form the headwaters for Windsor Creek, Pool Creek, and Mark West Creek—all creeks within the Project vicinity. Pool Creek is a tributary to Windsor Creek, which flows into Mark West Creek, which is a tributary of the Russian River, which drains into the Pacific Ocean. To the south are the Laguna de Santa Rosa and the Santa Rosa Plain. The Project site is situated in an incised canyon. The canyon supports an unnamed intermittent creek, referred to in this document as Drainage T.

Vegetation Types found on the Project parcel are summarized in Table 1.

2.1 Mixed Oak Woodland

The mixed oak woodland vegetation on the Project parcel corresponds to the Holland-type Coast Live Oak Forest (Holland, 1986), based on the dominance by coast live oak and the closed canopy which, in Holland's system, distinguishes oak forests from the more open oak woodlands. The equivalent for the Sawyer and Keeler-Wolf (1995) classification system is the coast live oak series.

Mixed oak woodland is the predominant vegetation community on the Project parcel, occupying approximately 137 acres (or 80 percent). Oak woodlands within the range from open savannah-like conditions, where oaks are scattered through grassland areas, to very densely treed areas, particularly on steep slopes.

The 2007 Town of Windsor Protected Tree Inventory (Horticultural Associates, 2007) indicates that coast live oak is the predominant tree within the Project parcel's oak woodlands, representing over 80 percent of the 5,608 trees inventoried. Other species protected under the Town of Windsor tree ordinance present on the Project parcel include black oak (*Quercus kelloggii*), valley oak (*Quercus lobata*), blue oak (*Quercus douglasii*), Coast live oak (*Quercus agrifolia*), California bay (*Umbellularia californica*), and California buckeye (*Aesculus californica*). Trees occurring within the oak woodlands on the Project parcel, but not designated as Town of Windsor-protected trees, include madrone, Douglas firs (*Pseudotsuga menziesii*), Oregon ash (*Fraxinus latifolia*), big leaf maple (*Acer macrophyllum*), and redwood (*Sequoia sempervirens*). These species represent only a minor portion of trees onsite. Some cherry plums (*Prunus cerasifera*) trees, a non-native invasive species, are also present.

Understory vegetation in the oak woodlands varies in density, depending on canopy cover. In most areas, the canopy is densely shaded and understory vegetation is relatively sparse. Understory species include poison oak (*Toxicodendron diversilobum*), wild rose (*Rosa californica*), bracken fern (*Pteridium aqualinum*), and sword fern (*Polystichum munitum*). Non-native invasive understory species include periwinkle (*Vinca major*).

2.2 Annual Grassland

Annual grassland on the Project parcel corresponds to the Annual Grassland type of Holland (1986) and is equivalent to the California annual grassland series of Sawyer and Keeler-Wolf (1995).

Annual grasslands comprise approximately 24 acres (14 percent) of the Project parcel. Annual grassland in the Project parcel is largely dominated by disturbance response non-native annual grasses. Common non-native grasses include slender wild oat (*Avena barbata*), velvet grass, rip-gut brome (*Bromus diandrus*), hedgehog dogtail (*Cynosurus echinatus*), and big quaking grass (*Briza maxima*). Some of the grassland areas support native perennial grasses that are patchily distributed throughout the annual grasslands. These native species generally represent a minor component of the non-native annual grassland. Native grasses include: blue wildrye (*Elymus glaucus*), California oatgrass (*Danthonia californica*), and purple needlegrass (*Nassella pulchra*). Many species of non-native forbs, including narrow-leaved plantain (*Plantago lanceolata*), Klamathweed (*Hypericum perforatum*), common vetch (*Vicia sativa*), broadleaf filaree (*Erodium botrys*), bristly ox-tongue (*Picris echioides*), and cut-leaf geranium (*Geranium dissectum*), occur throughout the annual grassland within the Project parcel. Many native wildflowers also are present, including soap plant (*Chlorogalum pomeridianum*), miniature lupine (*Lupinus bicolor*), California buttercup (*Ranunculus californicus*), white yarrow (*Achillea millefolium*), and crown brodiaea (*Brodiaea coronaria*). The annual grasslands also contain several species designated as invasive by the California Exotic Pest Control Council. A selection of these species include medusa head (*Taeniatherum caput-medusae)*, yellow star thistle (*Centaurea solstitialis*), and fennel (*Foeniculum vulgare*) (CAL-IPC, 2006).

2.3 Coastal Scrub

Coastal scrub within the Project parcel corresponds to a drier, interior form of Holland's (1986) Northern Coastal Scrub, one that is dominated by coyote brush (*Baccharis pilularis*). The equivalent series of Sawyer and Keeler-Wolf (1995) is the coyote brush series. Coastal scrub comprises approximately 5 acres (3 percent). Coastal scrub occurs along the edges of the mixed oak woodland and in scattered locations within stands of annual grassland. The dominant shrub is coyote brush, which forms dense stands in some areas. Also found in this habitat type is common manzanita (*Arctostaphylos manzanita* ssp. *manzanita*), although it is more typical of mixed oak woodland. Poison oak is another component of this form of coastal scrub. California Exotic Pest Control Council invasive species within the coastal scrub include French broom (*Genista monspessulana*) and Himalayan blackberry (*Rubus discolor*) (Cal-IPC, 2006).

2.4 Other Vegetation Communities

Several small areas support remnant vineyards and orchards; orchard trees are predominately apple (*Malus sylvestris*). Remnant vineyards and orchards comprise less than 1 percent of the Project parcel, totaling approximately 0.3 acre.

There are also several small groves (approximately 2 acres) of redwood trees on the northwest portion of the Project parcel and some areas of riparian shrub/ woodlands (approximately 3 acres) associated with intermittent drainages, as described below.

2.5 Aquatic Habitats

Aquatic habitats within the Project parcel include intermittent drainages, seasonal wetlands, and seeps.

There are several intermittent drainages, as indicated on Figure 3.2-1 of the Supplemental Environmental Impact Report. Four primary intermittent drainages were identified on the Project parcel. These include Drainage S1, Drainage S2, Drainage T, and the Eastside Road roadside drainage. In addition, a non-jurisdictional drainage runs parallel to the access road and conveys roadside runoff.

Two major seasonal wetlands and two seeps were identified on the Project parcel. Seasonal Wetland #1, approximately 0.34 acres, occurs in an open meadow/shrubland area at the toe-slope of the hills in the southwestern part of the site. Seasonal Wetland #2, approximately 0.32 acres, occurs in a low valley on a relatively level area within an open grassy meadow that is surrounded by coastal scrub and mixed oak woodland.

Seep #1 is located on a north-facing slope on the south side of Drainage S1. Vegetation within the seep is generally similar to the adjacent velvet grass/coyote brush habitat but is distinguished by a relatively dense cover of clustered field sedge. Seep #2 occurs on a south-facing slope on the north side of Drainage S. This area is characterized by relatively dense cover of brown-headed rush (*Juncus phaeocephalus*) with scattered Italian ryegrass (*Lolium multiflorum*), velvet grass, and California oat grass. The two seeps total approximately 0.03 acres.

3.0 Purpose of the Habitat Equivalency Analysis

The Town of Windsor is concerned with assuring that the loss in public value of oak woodland associated with construction of reclaimed water storage is appropriately compensated. The Town of Windsor's Tree Technical Manual specifies using the "Guide for Plant Appraisal," which includes the Trunk Formula Method (Town of Windsor, 2003). The Trunk Formula Method is an appraisal model for estimating a defined value. Value is broadly defined by the Appraisal Institute as "the current worth of future benefits." This definition considers that value is derived from utility, the "ability of a product to satisfy human wants, needs or desires," that is, to provide benefits. In actual practice, the benefits that are considered or how their worth is estimated will vary depending on a more specific definition of value. The Trunk Formula Method is a depreciated replacement cost approach to value. The cost approach considers that the utility or benefit inherent in an object is replaced or reproduced by replacing or reproducing the object. The cost of replacement or reproduction, therefore, provides an indication of value.

In applying the Trunk Formula Method, the appraiser starts with the cost to buy and install the largest reasonably available replacement tree. The appraiser then calculates a cost per unit area for such a tree and applies it to the difference in size between the replacement and appraised trees. The result is added to Installed Tree Cost to obtain Basic Tree Cost. The Basic Tree Cost is then reduced by species, condition, and location factors to reflect the difference, if any, between the cost to produce an idealized replacement for the appraised tree and the benefits the appraised tree is (or was) likely to provide. The species adjustment can be understood as functional depreciation, which considers species-related attributes such as growth characteristics, maintenance requirements, and aesthetics. The condition adjustment can best be understood as physical depreciation, which considers condition-related factors in the broad categories of structural integrity and plant health. The location adjustment considers whether or how physical characteristics of the appraised tree are (or were) likely to be enjoyed or experienced. The appraiser must remember that value is derived from the satisfaction of human wants, needs, and desires. Stated another way, there must be a beneficiary not just the ability to provide benefits.

An inherent limitation of any replacement cost approach is an assumption that its indication of value equals replacement cost. The appraiser must consider whether value might exceed or be less than replacement cost. To the extent that this is likely, the appraiser must consider any available non-cost data such as comparable sales prices or quantifiable benefits.

While this approach may be appropriate for individual or small groups of trees in an urban setting with high aesthetic values (e.g., for tree-lined sidewalks, small city parks, and residential/commercial lots), it may not fully capture the benefits and value to the public of an oak woodland. The woodland as habitat provides natural resource value, and the estimation of that value may be more appropriate.

4.0 Measuring Natural Resource Value

Economic theory suggests that natural resource services provide economic value because individuals demonstrate a willingness to expend valuable resources (i.e., time and money) to either participate in recreation activities or to preserve and/or protect natural resources to be enjoyed by them or others at a later date or for future generations. Total economic value for a natural resource comprises direct use (e.g., hunting or fishing activities) and indirect or passive use (preservation actions). This represents all aspects of a natural resource that gives rise to well-being (utility) derived by individuals.

Most valuation methods have their theoretical foundations in welfare economics, such as benefit-cost analysis, risk-benefit analysis and cost-effectiveness analysis. Each analysis's framework comes with tools and measurement methods that have their advantages and disadvantages, depending upon the decision they are intended to support and the nature of the effects they are attempting to measure. For example, the preferred metric in a benefit-cost analysis is usually dollars so as to facilitate aggregating across a wide range of effects from alternative policy actions. However, in the case of assessing morbidity or mortality benefits, other metrics, such as reduced cancer risk or statistical lives saved, are often preferred.

To assess ecological value, environmental metrics based on the flows of ecosystem services may be used.[2] Such metrics are preferred over monetary metrics to capture ecological service flows that provide indirect human use benefits. Such basic ecosystem support services are relatively difficult to quantify in dollar terms and yet can be significantly affected by human activities. This is contrast with direct human use benefits from natural resources and the environment, such as recreational fishing and hunting, wildlife observation, nature photography, etc., which are generally quantified in dollar terms using economic valuation tools that rely upon observations or verbal statements about recreation behavior. Thus, depending upon the problem and the nature of the available data, different metrics may be used to measure, compare, and value the potential benefits from human actions.

Past and present human activities at the ERSP site have affected the environment and the quality and quantity of ecological services being provided. Some of those activities, such as grazing, have resulted in a decline or decrease in ecological services, and some have resulted in an increase in ecological services through restoration actions such as habitat enhancement (e.g., cessation of grazing activities) and *de facto* preservation.

---

[2] From the Department of Interior (DOI) (1996) regulations, ..."services include provision of habitat, food and other needs of biological resources, recreation, other products or services used by humans, flood control, ground water recharge, waste assimilation, and other such functions that may be provided by natural resources.

From the Oil Pollution Act (OPA) (1996) regulations, "Services (or natural resource services) means the functions performed by a natural resource for the benefit of another natural resource and/or the public." NOAA guidance further classifies natural resource services as:

- Ecological services - the physical, chemical, or biological functions that one natural resource provides for another natural resource and thus indirectly provides value to the public. Examples include provision of food for wildlife, protection from predation, and nesting habitat, among others: and ,
- Human services - the human uses of natural resources or functions of natural resources that provide direct value to the public. Examples include fishing, hunting, nature photography, and education, among others.

Measuring these changes in services requires an understanding of how these ecological services have changed over time. Services that are produced over time are referred to as service flows. For example, humans consume the flow of services provided by their homes. That is, they consume the shelter and warmth provided by their home during the course of a year. Similarly, ecological services are provided by a habitat over the course of a year as well. Oak woodlands provide habitat for a variety of wildlife species. Barrett (1980) reports at least 60 species of mammals may use oaks in some way. Verner (1980) reports 110 species of birds observed during the breeding season in California habitats where oaks form a significant part of the canopy or subcanopy. It is these oak woodland ecological services (e.g., physical, chemical, or biological functions) that these species consume and are a part of. Hence, in order to measure the flow of coastal oak woodland ecological services, the amount and relative quality of those services as they are produced or flow over time must be understood. HEA is a method that measures ecological service flows produced by a habitat.

HEA was developed by the U.S. Fish and Wildlife Service (Unsworth and Bishop, 1994). It has been adopted by the National Oceanic and Atmospheric Administration (NOAA) and Department of the Interior as a method to scale compensatory restoration options in natural resource damage assessment (NRDA) under the Oil Pollution Act of 1990 (NOAA 1997a; 1997b). HEA has been used extensively throughout the country for NRDAs and accounts for 80 percent of the NRDAs conducted. It is also supported by the U.S. Army Corps of Engineers (Ray, 2007). HEA is based on the identical conceptual framework as other economic valuation methods, but it measures ecological services only [3] (see Jones and Pease, 1997, for technical details).

In the HEA framework, the service flows from a habitat are normalized to some baseline condition. This baseline condition can be either the condition or quality of the habitat before a selected time period (e.g., when a human activity is considered) or it can be the condition or quality of some other similar habitat nearby (e.g., a reference habitat). The HEA representation of the service flows of the habitat from some point in time t=0 when a human activity is considered in the absence of any uncertainty about future service flows is (NOAA, 1997a):

$$\left[\sum_{t=0}^{B} \rho_t \left(b^j - x_t^j\right)/b^j\right] * J \qquad (1)$$

where:

t = 0, the time when a human activity affects ecological services.

t = B, the time when the human activity's effects on ecological services are finished.

[3] This section relies heavily upon Tomasi, Theodore, Mary Jo Kealy, and Mark Rockel "Scaling Compensatory Restoration Under the 1990 Oil Pollution Act" Paper ID #265 International Oil Spill Conference, Seattle, WA. 1999.

x_t^j = the level of services per acre provided by the habitat as affected by the human activity in year t.

b^j = the baseline level of services per acre of the affected habitat.

ρ_t = discount factor where $\rho_t = 1/(1+r)^t$, and r is the discount rate, and

J = is the number of affected acres.

This HEA equation is the present value of the change in ecological services per acre (as percentage of baseline services) times the number of affected acres. Within HEA, this is done by developing indicators of the ecological service flows from the site and expressing the changes in services from the site under alternative human activities as percentage changes from a baseline or reference condition. These changes can be either positive or negative depending upon the human activity (e.g., a habitat removal action or a habitat restoration action).

In conducting a HEA, the amount of habitat potentially affected by the proposed actions at the site (usually expressed in acres) is measured. The major service flow from the site is identified, and some structural or functional indicators of the ability of the habitat to provide that service flow are then developed. A baseline or reference habitat is specified. This baseline habitat is defined as providing 100 percent of the service flows from a habitat. Using indicator(s) of service flows, the service flows under alternative human activities are compared as a percentage difference relative to the baseline.

The units of comparison are called service acre years (SAYs). One acre of oak woodland habitat operating at 100 percent of service flows generates, over a 1-year period, one SAY of services. Taking into account the acreage and the percentage differences in amount of services, the evaluated habitats provide a certain number of SAYs each year. For example, 20 acres of oak woodland habitat operating at 80 percent of reference services in a given year provide 16 SAYs in that year. Because benefits occur over time, an adjustment in service flows needs to be made using a discount rate. This yields DSAYs.

To determine the DSAYs for a habitat affected by a human activity, the following inputs are needed:

- Affected area (in acres)
- Percentage of services in each year relative to baseline
- Discount rate[4]

[4] To understand the concept of discounting, compare it with a more familiar concept, the compounding of interest on savings. Compounding takes an amount invested today and determines what it will be worth at some future date. Specifically, at six percent interest, $100 invested today will earn $6.00 in interest and will be worth $106 a year from now. In year two, the investment will earn interest of $6.36 on the $106 for a total investment value of $112.36. In twelve years the value of the investment will have doubled to $200 and it will have doubled again to $400 in twenty-four years. Discounting works in the reverse direction. It begins with an amount that will be received at some future date, say $200 twelve years from now, and computes what it is worth today. Discounting at six percent a year gives a present worth of $100. The larger the discount rate, the lower is the present worth. For example, a 10 percent discount rate applied to a $200 value 12 years from now, would be worth about $64 today.

Trustee agencies have typically used a discount rate of 3 percent. Under Department of the Interior regulations, a 3 percent real discount rate is mandated. Comments for the proposed regulations during the public comment period indicated that most professional economists agreed upon using a range of 2 to 4 percent for the real discount rate.

The first two inputs are site-specific and rely on scientific information such as an understanding of the hydrogeology of the area, extent and geomorphic and silvic characterization of the habitat, age and conditions of primary tree species, life requisites of wildlife species, and other factors that influence the quality of the habitat. The third input is a general parameter.

5.0 Analysis of Ecological Service Losses from the Project

Vegetation habitat types, including oak and other native trees, that would be temporarily or permanently impacted as a result of the ERSP are quantified in Table 1 above. The proposed Project would result in the total loss of approximately 32 acres, of which, approximately 28 acres is mixed oak woodland, a habitat type protected under the California Department of Fish and Game code (Sections 1755 and 1801). Oak woodlands within the Project parcel are also designated by the Sonoma County Agricultural Preservation Open Space District (SCAPOSD) as a Core Oak Woodland "District Focus Area," an area of interest for SCAPOSD (SCAPOSD, 2006).

Impacts to creeks are shown in linear feet, assuming an average 5-foot channel width.

It is assumed that the ground area affected by Project construction will result in the complete removal of existing habitat. Therefore, the current levels of ecological services being produced by those habitats would be lost permanently and replaced by reservoir ponds.

Annual Grassland habitat loss is 3.79 acres, Coastal Scrub habitat loss is 0.35 acre, and drainage losses are 5,315 lineal feet. Assuming the current level of ecological services produced by these habitats is normalized to 100 percent, and using a 3 percent rate of discount, the ecological service losses associated with oak woodland habitat from the Project is estimated as 819.08 DSAYs. It is assumed construction commences in 2012 and ecological services are permanently lost thereafter. Similarly, ecological service losses can be estimated by alternative for the other habitats listed as well. Table 2 shows the areas of affected habitats by alternative, as well as the estimated ecological service losses expressed in DSAYs.

6.0 Analysis of Ecological Credits Gained From Preservation Actions

The entire Project parcel is approximately 171 acres of primarily mixed oak woodland and grassland/shrub habitat, with several seasonal drainages. The potential exists for portions of the site outside of the pond areas (the northern portion of the parcel as well as upland areas surrounding the ponds) to be placed in preservation. The following discussion outlines how potential ecological credit from preservation (preventing development) on these portions of the parcel may be estimated.

The HEA allows the ecological benefits from various actions to be compared. There are at least two potential land use actions that could be made on a particular tract of land: (1) preservation of the habitat or (2) agriculture, residential, or some other type of development resulting in a disturbance to the habitat. The overall objective is to determine the value to society that the preservation action would yield. This is accomplished by determining the value of the ecological service flows over time from the natural resource ***with*** the preservation action in comparison to the value of the ecological service flows over time from the natural resource ***without*** the preservation action. The next section describes the method used to quantify the ecological services from the two actions.

TABLE 2
Affected Habitats of the Proposed Project

Habitat	Project Impacts	Discounted Service Acre Year
Mixed Oak Woodland (Acres)	28.07	819.08
Riparian Woodland (Acres)	0	0.00
Annual Grassland (Acres)	3.79	110.59
Coastal Scrub (Acres)	0.35	10.21
Redwood Groves (Acres)	0	0.00
Remnant Vineyard/Orchard (Acres)	0.13	3.79
Developed (Acres)	0.05	1.46
Wetlands (Acres)	0	0.00
Drainages –Delineated (Feet)	7,084 ft	
Drainages – Reconnaissance (Feet)	0	
Drainages Total (Feet)	7,084 ft	
Total Impacts (not including drainages)	**32.39**	

6.1 HEA and Preservation

To understand how the HEA approach can be applied to preservation, suppose that a candidate property is currently providing high-quality ecological services and that development of the property, such as agriculture or residential development, can occur at some point in time. This development will cause some level of disturbance to the habitat, resulting in fewer ecological services.

The first step of the HEA approach is to determine the service flow amounts for each potential development scenario that could occur. The analyst determines the magnitude of ecological service flows over time provided by the natural resource in its current or preserved state. These ecological service flows are measured in SAYs per year.

The relative difference in SAYs between preserved and developed habitat represents the difference in habitat quality. For the mixed oak woodland and grassland/shrub habitats, some habitat quality measures would need to be selected to evaluate quality. Then the difference in habitat quality relative to the site that is to be preserved would need to be compared. This comparison would need to be performed for that site's preserved status and developed status.

As an example, assume that the average quality of the site to be preserved provides the same service flows as the mixed oak woodland – grassland/shrub area that may be used for the ponds. Also assume that if that site were developed agriculture (much of the surrounding area is vineyards), the relative quality would diminish to 0.1 or 10 percent. Hence, 0.1 SAYs of services per acre per year occurs if the site is developed, and 1.0 SAYs of services per acre per year flow if the habitat is preserved, assuming these service flows are constant over time.[5]

Given a time horizon of 200 years, one possible outcome is that, absent preservation, the property is immediately developed. In this instance, society receives zero years of the current flow of services and 200 years of the 0.1 SAY flow of services in the developed state. Discounting at an interest rate of 3 percent, the present value of the flow of services from the developed land could be computed. Another possible outcome is that development occurs after the first year. Society enjoys 1 year of the current 1.0 SAYs of services and 199 years of the 0.1 SAY of developed land services. The present value of the services could be computed for this combination of service flows.

Naturally, there is a chance that development occurs at any of the possible dates between now and 200 years hence. So, the expectation of these combinations of service flows is taken over all the possible dates when development could occur.

The second step is to compute—conditional on development occurring on some given date, say date t—the present value of the flow of services up until t at the current level and the present value of the flow of services provided by developed land over the balance of the period between t and year 200. This calculation would be made for all possible dates when land could switch from undeveloped to developed.

However, there is only a chance that any given date of switching development status is the true outcome. The third step is to attach a probability to each possible switch date.

Step 4 computes the expected present value of services if the site is not preserved. This is accomplished by multiplying the numbers generated in Step 2, conditional on a switch date, by the probability determined in Step 3 that the hypothesized date is the true date and then summing over all possible switch dates.

Step 5 is to subtract the present value of services flowing out of the preserved state from the number computed in Step 4, the expected present value of services under no preservation.

The value of the credit-incorporating uncertainty would be implemented formally as follows. The event space for the problem corresponds to the set of dates where conversion of the site from its baseline condition to a developed state could appear. Let the event "the site is undeveloped up until date s, and then is developed at date s" be denoted by $S = s$. The unconditional probability, viewed from date zero, of this event is the probability rate for development at date s. This is $\Pi(s)$. Let $x(nd)$ and $x(d)$ be environmental service flows from the site in the undeveloped and developed states respectively. Using the notation from the HEA equation shown above, if the event $S = s$ occurs, the present-value of environmental service flows from the site is

5 These need not be constant; constant service flows were used in this example to make it simple.

$$\sum_{t<s} \rho_t [x_t(nd) - b^p]/b^j + \sum_{t\geq s} \rho_t [x_t(d) - b^p]/b^j \quad (2)$$

Thus, the expected present value of the service flows without preservation (i.e., the expected value of equation (2) over the events S = s) is

$$\sum_s \Pi(s) \{\sum_{t<s} \rho_t [x_t(nd) - b^p]/b^j + \sum_{t\geq s} \rho_t [x_t(d) - b^p]/b^j \} \quad (3)$$

The expected present value of service flows with preservation is

$$\sum_t \rho_t [x_t(nd) - b^p]/b^j \quad (4)$$

where the summation is over all dates. Subtraction of the value without preservation from the value with preservation gives the addition to value of preserving the property. Again, consider the sample path along which S = s. Subtraction of (2) from (4) gives the addition to value provided by preservation given S = s. It is

$$\sum_{t\geq s} \rho_t [x_t(nd) - b^p]/b^j - \sum_{t\geq s} \rho_t [x_t(d) - b^p]/b^j \} \quad (5)$$

Taking the expectation of (5) over possible switch dates gives the credit from preserving the site. This is

$$\sum_s \Pi(s) \{\sum_{t\geq s} \{\rho_t [x_t(nd) - x_t(d)]/b^j \} \quad (6)$$

6.2 The Simplest Case: Infinite Horizon and Constant Services and Hazard

There are many probability structures that could be estimated using data on past development to obtain the necessary inputs to the analysis. A complete overview of the possibilities is provided in *The Econometric Analysis of Transition Data* (Lancaster, 1990). For purposes of this simple example, the most widely employed and simplest probability structure based on the exponential distribution was used. For the exponential distribution with parameter $\gamma > 0$, the probability of development having occurred on a certain parcel of land as of year t is

$$\Omega(t) = 1 - \exp(-\gamma t) \quad (7)$$

This is the probability that development occurred on or before date t. Then, $[1 - \Omega(t)] = \exp(-\gamma t)$ and $\Pi = \gamma\exp(-\gamma t)$.

6.3 Preservation Value of ERSP Site

Using this simple model requires obtaining an estimate for γ, the parameter characterizing the conditional probability of development in any given year. This value can be empirically estimated by collecting data on parcels of land in the area that either were or were not developed and the timing of development.

For this analysis, it is assumed that the lands within and adjacent to the ERSP site would have some positive likelihood of development, causing habitat disturbance within the next 200 to 300 years and that the rate of development is constant and consistent with the current long-term development rate for Russian River Valley lands. It is assumed that the rate of habitat disturbance is about 1.5 percent per year based upon recent trends in agricultural land development.

Assume that the baseline service flow from the pre-preserved resource is 1.0 SAYs (i.e., it would be the same before preservation as it was after preservation) based on the habitat quality indicator discussed above. Assume the likelihood of some sort of development occurring on this site in any given year is 1.5 percent, as discussed previously.

The analysis takes a very simple form if the time horizon over which resource enhancement will be obtained is infinite and if the service flows in the two states (developed and preserved) are constant. In this case, no matter when development occurs, the present value of the SAYs is the number of SAYs divided by the percentage rate of discount.

Assuming the exponential distribution on the development process, a continuous-time version of equation (6) can be written as

$$[\gamma/r(\gamma + r)][x(nd) - x(d)]/b^j \qquad (8)$$

Letting $b^j = 1.0$, $\gamma = .015$ and $r = .03$, there is a credit of 10 DSAYs per acre for preserving the remaining parcel.

6.4 Discussion and Use of Results

Not surprisingly, these results support what most professional biologists, ecologists, and the public already knew: that preservation of habitat is a good thing and provides value. However, this analysis also provides decision-makers with a tool (HEA) to quantify different options regarding land use and to compare those options using an ecological metric.

These results are based upon a simple model with restrictive assumptions. Relaxation of these assumptions, such as not making the rate of development a constant, using multiple indexes to represent ecological service flows, and taking into account other land use decisions within the region, would serve to bolster the results from the analysis.

The results of this analysis provide a consistent methodology to gain and accrue credit for preservation actions to offset obligations regarding habitat disturbances from construction of the ERSP. If a credit of 10 DSAYs is used, the mitigation ratio is 2.92 to 1 resulting in a preservation area of approximately 82 acres. The 82-acre preservation goal can be achieved through preservation of oak woodland on other portions of the Town parcel.

7.0 References

Barrett, R. H. 1980. Mammals of California oak habitats: management implications. Pages 275-291. In T. R. Plumb, tech. coord. Ecology, management, and utilization of California oaks. U.S. Dep. Agric., For. Serv. (Berkeley, Calif.), *Gen. Tech. Rep*. PSW-44.

California Invasive Plant Inventory (Cal-IPC). 2006. Cal-IPC Publication 2006-02. California Invasive Plant Council: Berkeley, CA.

California Oak Mortality Task Force (COMFT). 2008. California Oak Mortality Task Force website. Website accessed February 27. http://nature.berkeley.edu/comtf/.

Holland, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. California Department of Fish and Game. Unpublished report.

Horticultural Associates. 2007. *Tree Inventory, Windsor Ponds S & T, Windsor, California*.

Jones, C. A., and K. A. Pease. 1997. Restoration-Based Compensation Measures In Natural Resource Liability Statutes. *Contemporary Economic Policy* 15:111–122

Lancaster, T. 1990. *The Econometric Analysis of Transition Data*. Cambridge University Press, New York.

Meserve, John. 2008. Phone conversation between John Meserve, Horticultural Associates, and Deborah Waller, CH2M HILL.

National Oceanic and Atmospheric Administration (NOAA). 1997a. *Habitat Equivalency Analysis: An Overview*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Damage Assessment and Restoration Program.

__________. 1997b. *Scaling Compensatory Restoration Actions.* U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Damage Assessment and Restoration Program.

Ray, G. L. 2007. Habitat equivalency analysis: A potential tool for estimating environmental benefits. EMRRP Technical Notes Collection (ERDC TN-EMRRP-EI-02). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Sawyer, J. and T. Keeler-Wolf. 1995. A manual of California vegetation. California Native Plant Society, Sacramento.

Sonoma County Agricultural Preservation and Open Space District (SCAPOSD). 2006. *Connecting Communities and the Land: A Long-Range Acquisition Plan*. September 29.

Tomasi, Theodore, Mary Jo Kealy and Mark Rockel "Scaling Compensatory Restoration Under the 1990 Oil Pollution Act" Paper ID #265 International Oil Spill Conference, Seattle, WA. 1999.

Town of Windsor. 2003. *Tree Technical Manual: Standards and Specifications.* October.

University of California Cooperative Extension and Sonoma County Department of Emergency Services. 2008. Sonoma County Sudden Oak Death Strategic Response Plan. January.

Unsworth, R. E. and R. Bishop. 1994. Assessing Natural Resource Damages Using Environmental Annuities. *Ecological Economics*. 11(1994) 35-41.

Verner, J. 1980. Birds of California oak habitats: management implications. Pages 246-264. In T. R. Plumb, tech. coord. Ecology, management, and utilization of California oaks. U.S. Dep. Agric., For. Serv. (Berkeley Calif.) *Gen. Tech. Rep*. PSW-44.