APPENDIX K
Fish and Wildlife Coordination Act

US Army Corps of Engineers
Corte Madera Creek Flood Risk Management Project
October 2018

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Corte Madera Flood Risk Management Project
October 2018

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Sacramento Fish and Wildlife Office
2800 Cottage Way, Suite W-2605
Sacramento, California 95825-1846

In Reply Refer to:
08ESMF00-
2018-CPA-0045-1

SEP 12 2018

Tessa Beach
Chief, Environmental A & B Sections
U.S. Army Corps of Engineers
San Francisco District
1455 Market Street
San Francisco, California 94013

Dear Ms. Beach:

The U.S. Army Corps of Engineers has requested coordination under the Fish and Wildlife Coordination Act (FWCA) for the Corte Madera Creek Flood Risk Reduction General Reevaluation Report. The proposed project would occur along Corte Madera Creek in the Town of Ross, Marin County, California. The enclosed report constitutes the U.S. Fish and Wildlife Service's draft FWCA report for the proposed project.

By electronic copy of this letter, we are inviting the National Marine Fisheries Service and California Department of Fish and Wildlife to review and provide comments on this draft report. If you have any questions or comments regarding this report, please contact Harry Kahler at (916) 414-6577.

Sincerely,

Doug Weinrich
Assistant Field Supervisor

Enclosure

ec:
Stephen Willis, COE, San Francisco, California
Karen Weiss, CDFW, Napa, California
Rick Rogers, NMFS, Santa Rosa, California

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

DRAFT
FISH AND WILDLIFE COORDINATION ACT REPORT FOR THE CORTE MADERA CREEK FLOOD RISK REDUCTION GENERAL REEVALUATION REPORT MARIN COUNTY, CALIFORNIA

PREPARED FOR:
U.S. ARMY CORPS OF ENGINEERS
SAN FRANCISCO DISTRICT
SAN FRANCISCO, CALIFORNIA

PREPARED BY:
U.S. FISH AND WILDLIFE SERVICE
SACRAMENTO FIELD OFFICE
SACRAMENTO, CALIFORNIA

SEPTEMBER 2018

INTRODUCTION

Under the authority of the Fish and Wildlife Coordination Act (48 stat. 401, as amended: 16 U.S.C. 661 et seq.), the U.S. Fish and Wildlife Service (Service) is providing this report on the Corte Madera Creek Flood Risk Management General Reevaluation Report (Corte Madera Creek FRMP). The Corps of Engineers (Corps), along with the Marin County Flood Control and Water Conservation District, the non-federal sponsor for the project, is conducting a feasibility–level investigation to determine if there is a continued federal interest in providing flood risk management improvements along the Corte Madera Creek.

Congress authorized the evaluation of possible solutions to flooding along Corte Madera Creek under the Section 11 of the Flood Control Act of 1944. The authorization for the construction of the Project is found in the Flood Control Act of 1962, Public Law 87-4, 87th Congress, 2nd Session, enacted 23 October 1962, and amended by Section 204 of Public Law 89-789, the Flood Control Act of 1966 and the Water Resources Development Act of 1986. The Marin County Flood Risk Management Project was developed and consisted of four units with the Unit 1, 2, and 3 channel modifications completed in 1971. Public concerns led to a delay in Unit 4. In 1996, Marin County requested completion of Unit 4 by the Corps, and damages incurred in flooding in December 2005 renewed public interest in finding solutions to minimize the risk of future floods. Since 1971 additional technical studies have been completed to assist in formulating new alternatives.

The Corte Madera Creek FRMP is an important component of the greater Ross Valley Flood Protection and Watershed Management Program, a regional effort led by the Marin County Flood Control and Water Conservation District with an overall objective to substantially reduce the frequency and severity of flooding throughout the Ross Valley Watershed, in an economically viable manner while prioritizing public safety and minimizing environmental impacts.

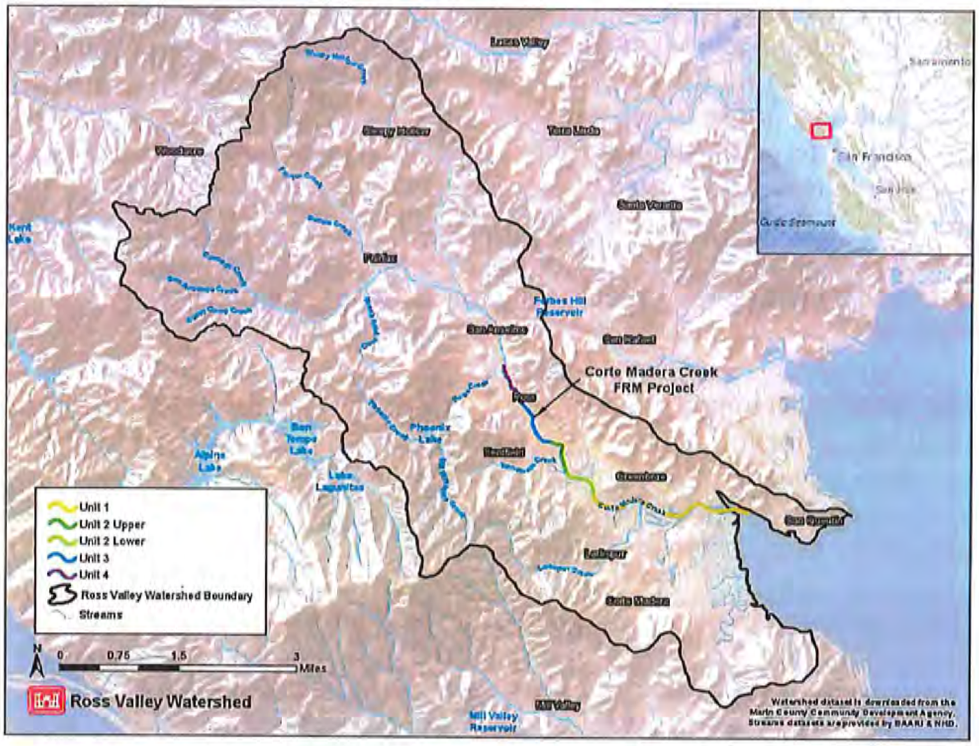
The Program's major flood reduction measures are intended to work cooperatively to reduce peak out-of-bank flows and achieve protection from a 100-year flood event (1% chance of occurring or being exceeded in any one year). Proposed flow reduction measures include detention basins, located in the upper reaches of the watershed to detain peak flows during flood events. Capacity enlargement measures include bridge replacements in Fairfax, San Anselmo and Ross to remove impediments to flows and reduce localized flooding; dredging of channels in the lower watershed; and creek improvements watershed-wide to increase capacity and handle flood flows as they move through the watershed. Flood preparation measures include coordination with local emergency officials and planners in development of local hazard mitigation plans, communication with the community on flood preparation planning and education, and working on floodplain management activities that exceed the minimum standards through the Community Rating System to help reduce flood insurance premium rates for policyholders.

Corte Madera Creek currently provides a 6-year level of flood protection (a flood that has about a 16% chance of occurring in any 1 year) in the study area. The larger Marin County flood project will be implemented in two phases. Phase 1 (2017-2027) will target a goal of 25-year flood protection (4% chance of occurring in any 1 year) currently undergoing community participatory planning and scoping for the Program environmental review (began January 2017). Phase 2 (2028- 2050, depending on flood safety priorities established within the community and securing additional funding sources such as grants) will add additional measures to achieve a target goal of 100-year flood protection.

AREA DESCRIPTION

Corte Madera Creek, within the Ross Valley watershed, is located in central eastern Marin County, California (Figure 1). The watershed contains 42 linear miles of stream channels and covers about 28 square miles, including areas of unincorporated Marin County and the towns of Corte Madera, Larkspur, Ross, San Anselmo, and Fairfax. The lower ridges and valley areas of the watershed, including areas adjacent to Corte Madera Creek, are highly developed suburban residential and commercial areas.

Figure 1. Ross Valley Watershed and Project Vicinity map

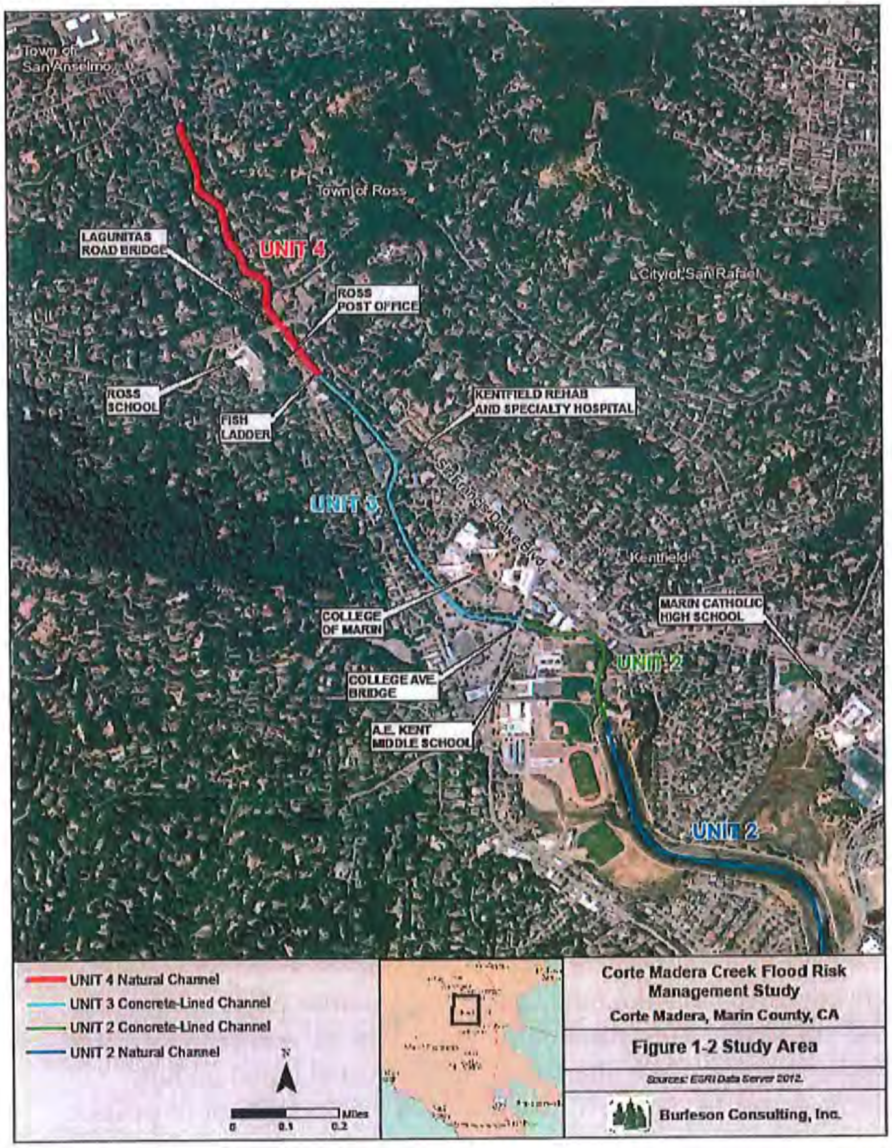


Source: U.S. Army Corps of Engineers.

The two major upstream branches of Corte Madera Creek are Fairfax Creek and San Anselmo Creek. Beginning at their confluence, the stream is known as San Anselmo Creek until it reaches Ross Creek, where it is renamed Corte Madera Creek. The tidal portion of the creek extends several miles upstream from San Francisco Bay to the Kentfield Rehabilitation Hospital Bridge. Corte Madera Creek discharges into San Francisco Bay about 9 miles north of the Golden Gate Bridge.

The general reevaluation study area consists of Units 3 and 4 and concrete-lined portion of Unit 2, along about 1.4 miles of Corte Madera Creek (see Figure 2). Unit 4 of Corte Madera extends about 0.4 mile downstream from Sir Francis Drake Boulevard and continues about 600 feet downstream of the Lagunitas Road Bridge before terminating at the Denil fish ladder. Unit 3 begins at the Denil fish ladder and is a concrete channel extending for about 0.67 mile to the College Avenue Bridge.

Figure 2. Corte Madera Creek Project Area.



Source: U.S. Army Corps of Engineers.

The upper portion of Unit 2 consists of a concrete channel that extends 0.33 mile downstream to 450 feet downstream of Stadium Avenue. The lower portion of Unit 2 is an earthen channel that then extends another 0.67 mile to the Bon Air Road Bridge, and 0.33 mile along the Tamalpais Creek tributary from its confluence.

PROJECT DESCRIPTION

The Corps and Marin County Flood Control and Water Conservation District (Project Team) looked at various ways to address flooding in Unit 4, as well as any resulting induced flooding in Unit 3, and the concrete channel section of Unit 2, caused by proposed measures in Unit 4. No measures were proposed in the earthen channel in Units 1 and 2. Measures include combinations of structural measures such as containing the flow within the channel, constructing a bypass channel, and upstream detention; as well as nonstructural measures such as flood proofing, raising structures, relocations, and warning/evacuation plans.

The following 6 non-structural and 14 structural measures were combined into alternative plans to address flood risk in the study area:

Non-Structural Measures

- Flood proof structures
- Emergency warning system
- Flood insurance
- Reduce authorized capacity
- Floodplain management
- Real estate relocation & acquisition

Structural Measures

- Widen channel at select areas where constriction exists
- Modify and armor in selected areas
- Deepen channel
- Change grade of channel to natural grade
- Floodwalls on Corte Madera Creek banks
- Setback floodwalls in certain areas where breakout is present
- Setback levees (Units 2 and 3 only)
- Obstruction removal
- Remove fish ladder, replace with smooth transition
- Bench excavation and retaining wall setback (leave concrete retaining wall)
- Raise channel retaining walls (turn into floodwalls) limit 2 feet
- Raise bridges
- Sediment removal
- Bypass culverts

The measures noted above were combined in to an initial array of alternative plans utilizing the following formulation strategies: no action, authorized conveyance, bypass, non-structural, and various potential hybrids of these strategies. Each alternative was evaluated based on how effectively it met the study objectives and on the team's best professional judgement of project costs.

Following the initial alternative evaluation and screening, the initial array of alternatives were further refined to a focused array of alternatives, evaluated, and screened down to the final array of four alternatives. To do this, the Project Team went through the following process:

Units were subdivided into separable reaches. These reaches were created because measures function independently in each reach from measures in upstream or downstream reaches. For instance, widening in Unit 4 downstream of Lagunitas Road Bridge would work as a system with top-of-bank floodwalls, widening, or setback floodwalls in Unit 4 upstream of Lagunitas Road Bridge. Thus, the alternatives for each sub-reach could be refined and evaluated individually to further narrow the array of alternatives before performing the technical hydraulic and economic analyses.

The following Reaches were delineated and are shown in Figure 3:

Reach 1 = Upstream Unit 4 – Sir Francis Drake Boulevard Bridge to Lagunitas Road Bridge

Reach 2 = Downstream Unit 4 - Lagunitas Road Bridge to existing Denil Fish Ladder

Reach 3 = Unit 2 and 3 Concrete Channel – Fish Ladder to Downstream End of Concrete Channel

Figure 3. Corte Madera Creek Flood Risk Management Project – Reach Delineation

Source: U.S. Army Corps of Engineers.

The sub-alternatives were evaluated and screened based on approximate real estate costs and a qualitative assessment of environmental impacts (Table 1).

Table 1. Remaining sub-alternatives after the initial screening process.

Sub-alternative	Description
1A	Top of bank floodwalls in Reach 1.
1B	Combination top-of-bank floodwalls along Sir Francis Drake Boulevard and partial setback floodwalls along Sylvan Lane in Reach 1.
1C	Combination top-of-bank floodwall along Sir Francis Drake Boulevard and full setback floodwalls along Sylvan Lane in Reach 1.
1D	Bypass tunnel/culvert from mid-Reach 1 to the top of Reach 3 at the fish ladder. The goal of this sub-alternative is for the culvert to replace the need for floodwalls in Reaches 1 and 2.
2A	Top of Bank floodwalls in Reach 2.
3A	Top of bank floodwalls and select setback barriers around the Kentfield Middle School ball fields in Reach 3.
3B*	Top of bank floodwalls, lowered bike path and select setback barriers around College of Marin parking lots in Reach 3.
3C	Concrete channel removal and creation of Allen Park Riparian Corridor in the portion of Reach 3 on Town of Ross property between the fish ladder and the Kentfield Rehab Center.
4	Nonstructural - Raise/flood proof structures in the study area having greatest risk of damages after removal of fish ladder and replacement with smooth transition and modifications to fish resting pools to address impacts to listed species.

*3B: During the plan formulation process, after the sub-alternatives were identified, the Project Team conducted a focused evaluation of sub-alternative 3B after concerns were raised by the non-federal sponsor and the land owners (College of Marin and Kent School District). Concerns were related to public safety (flooding of College of Marin's parking lot) and high real estate cost. A real estate analysis (conducted by USACE staff in 2018) yielded a real estate cost averaging $60 per square foot for the affected parcels (including a 40% contingency). If flood proofing structures (e.g. floodwall) were placed around the College of Marin parking lot, this would affect about 8.7 acres or 378,972 square feet. Real estate associated with this aspect of sub-alternative 3B has an approximate cost of $23 million. The Project Team considered the concerns of the local landowners, and the high real estate cost of implementation and chose to explore other strategies that would require less real estate expense and also appease public safety concerns. This effort led to a refined sub-alternative 3B, which has now been integrated into the plan formulation process. In lieu of flood proofing structures around College of Marin's parking lot, the "new" sub-alternative 3B proposes measures that are in close proximity to the existing channel. The concrete channel floor and right bank wall would be removed to allow for natural creek processes with low floodplain-tidal benches, and there would also be floodwalls (top-of-bank or setback) on both sides of the channel. Implementation of the new sub-alternative 3B would directly affect about 3.6 acres of land.

Source: U.S. Army Corps of Engineers.

These sub-alternatives were combined into the focused array of alternatives based on the following formulation strategies:

Alternative A: Top of Bank Floodwall – Sub-alternatives 1A+2A+3A

Alternative B: Hybrid Floodwall/Bank Excavation – Sub-alternatives 1B+2A+3B

Alternative C: Hybrid Full Sylvan Lane Setback – Sub-alternatives 1C+2A+3B

Alternative D: Hybrid Bypass – Sub-alternatives 1D+3B

Alternative E: Floodwall/Bypass – Sub-alternatives 1D+1B+2A+3A

Alternative F: Bypass/Riparian Corridor Hybrid – Sub-alternatives 1D+3C+3B

Alternative G: Floodwall/Riparian Corridor Hybrid – Sub-alternatives 1A+2A+3C+3B

Alternative H: Nonstructural Alternative – Sub-alternative 4

Alternative I: No Action

The Corps developed, in conjunction with Marin County Flood Control and Water Conservation District, four action alternatives to address the need for flood control improvements to Unit 4, including modifications to Units 2 and 3 related to proposed Unit 4 improvements. The final array of alternatives included Alternatives A, B, F, and G from the list above. Common features to all four alternatives are described below. Features are identified as located on the right or left bank of the creek, based on downstream flow. Because Corte Madera Creek flows from Unit 4 to 3, the right bank refers to the west or south side of the channel and the left bank refers to the east or north side of the channel.

Fish Ladder Removal

The Denil Fish Ladder in Unit 4 downstream from the Lagunitas Road Bridge, would be removed and replaced with a smooth transition for every action alternative. The Denil fish ladder would be replaced with a combination of natural bed material and biotechnical bank stabilization or stone protection treatments to create a smooth transition to meet fish passage criteria.

Floodwall Construction

For those portions of the action alternatives that include floodwall, the majority of the floodwall structure would be constructed using reinforced concrete. Floodwall thickness would be expected to vary from 12 to 24 inches, depending on the floodwall height, location, geotechnical data, and other design parameters and requirements that would be determined during the detailed project design phase. The floodwalls were designed to contain the water surface elevation of the 25-year event, plus an additional height for resiliency. For the current phase, the floodwalls were designed using an estimated resiliency of 3 feet. The actual additional resiliency height will be determined in a future feasibility study phase using risk and uncertainty analysis. Closure structures would be needed where floodwalls connect to bridge crossings and cross roadways or bike paths. If the elevation of the roadway is higher than the top of the floodwall design, the floodwall would connect into the roadway abutment without a closure structure because the roadway would function as a closure structure with a continuous line of protection.

College Avenue Bridge Culverts

Due to capacity limitation under the College Avenue Bridge, three underground bypass culverts are proposed across the College Avenue Bridge for Alternatives A, B, F, and G. The reinforced concrete box culverts would be constructed from 10-foot x 10-foot reinforced concrete material. The culverts are modeled to provide sufficient passage for excess flow coming from the upstream portion of the project. Two of the culverts are proposed on the right side of the bridge, and one culvert is proposed on the left side of the bridge. To accommodate the culverts, both banks would require some type of grading and benching or trenching.

Associated Activities

Project activities associated with floodwall construction would include general grade changes, tree removal, clearing and grubbing, and other site preparation work as needed throughout.

Non-structural Components

All alternatives may also include flood warning systems, floodproofing measures, and floodplain management (risk communication, emergency action plan, training, flood preparedness, evacuation routes, and response).

The Project Team reformulated flood risk management measures featured in Alternative F, given that it was the alternative within the Final Array which showed the most promise. The reformulation sought to minimize project cost by including the measures that were cost efficient and helped the plan capture relatively higher net benefits. The reformulation yielded a new plan, the Allen Park Riparian Corridor/Bypass Plan (or Scaled Alternative F) (Figure 4).

Figure 4. Bypass/Allen Park Riparian Corridor/Floodwalls Plan.

Source: U.S. Army Corps of Engineers

The Bypass/Allen Park Riparian Corridor/Floodwalls Plan would utilize a combination of floodwalls, an underground bypass (along Sir Francis Drake Blvd.), and the creation of Allen Park Riparian Corridor. The underground bypass would alleviate the need to construct any floodwalls in Unit 4, allowing the creek within Unit 4 to remain a natural channel.

Unit 4 Bypass

An underground bypass, starting on the left bank near the Corte Madera Creek and Ross Creek confluence in Unit 4, would (mostly) run under Sir Francis Drake Boulevard, and would re-enter the stream channel at the Allen Park Riparian Corridor (Unit 3). The bypass would be constructed using two parallel box culverts, each 12-feet wide by 7-feet high with a length of about 2,200 feet. Construction activities would include trenching portions of Sir Francis Drake Boulevard up to 20 feet deep by 30 feet wide for installation of the prefabricated box culverts. Although site preparation work would still be necessary, Scaled Alternative F would require minimal riparian vegetation removal because the majority of work would occur along an existing roadway.

Fish Ladder Removal

The Denil Fish Ladder, located at the downstream end of Unit 4 about 580 feet downstream of Lagunitas Road Bridge, would be removed and replaced with a smooth transition. The Denil fish ladder would be replaced with a combination of natural bed material and biotechnical bank stabilization or stone protection treatments to create a smooth transition to meet fish passage criteria.

Fish Passage Transition

As a result of removing the fish ladder, channel modifications would be necessary to accommodate the change in flow dynamics, and also create the need to modify and lower the channel floor elevations to allow for a smooth transition and geomorphological sustainable channel bed. The channel bed modification would extend from the fish ladder to about 110 feet upstream of Lagunitas Bridge. A portion of the natural channel in Unit 4, extending a length of about 115 feet, within the reach between Lagunitas Road Bridge and the fish ladder, would be widened to increase hydraulic conveyance capacity. The existing concrete channel downstream of the existing fish ladder, starting at its upstream limit at the beginning of Unit 3, would be demolished and removed. The demolition and removal of the concrete channel would continue downstream for about 900 feet. Additional improvements include 900 feet of realigned natural gravel creek bed, the lowering of the southwest side of the new creek channel in Allen Park to restore a historic floodplain and to increase flow capacity. At the downstream end of Allen Park, Corte Madera Creek will enter a new smooth transition to guide flow into the remaining existing concrete channel upstream of the Kentfield Rehabilitation Hospital.

Allen Park Riparian Corridor

Allen Park Riparian Corridor would extend a length of about 900 feet and encompass about 2 acres. The riparian corridor would include a widened, native substrate channel that allows higher flows to spread over a larger area and include floodwalls on both banks to a maximum height of 2 feet. At the upstream end of the left bank, the concrete channel wall would be raised to create a floodwall where real estate parcels are particularly constrained and there is not an existing bike path that provides an opportunity to widen the channel.

Floodwalls

Floodwalls will be constructed in three main areas within the project: along both banks of Allen Park Riparian Corridor (mentioned above), in close proximity to Granton Park, and adjacent to College Avenue.

The Granton Park floodwall would be constructed along the left bank and extend about 1,050 feet terminating at the western boundary of the College of Marin campus. The height of the Granton Park floodwall would vary. At its upstream end, it is estimated that that the wall height would be 2 feet and gradually increase to a floodwall height of 6 feet at the downstream termination point. The new floodwall would be installed as a separate wall offset from the existing concrete wall.

Scaled Alternative F would also construct a short wingwall upstream of College Avenue Bridge (about 75 feet in length) and a longer floodwall downstream of College Avenue Bridge extending about 950 feet in length. The College Avenue floodwall would be constructed along the left bank and at its upstream limit have a maximum height of 4 feet and gradually taper down to a height of 2 feet at its terminating point downstream.

EXISTING BIOLOGICAL RESOURCES

Vegetation

Riparian woodland and ornamental habitats encompass a large portion of the study area. The primary vegetation community upstream of the existing wooden Denil fish ladder is riparian woodland. Riparian woodland is a structurally complex and productive terrestrial community that provides a variety of wildlife species with abundant food, cover, and nesting habitat. Riparian corridors also facilitate wildlife movement (i.e., dispersal, seasonal migration, and local movements within home ranges) and are recognized as centers of biodiversity and corridors of dispersal of plants and animals in the landscape (Grenfell 1988). It also provides leaf litter to instream food webs, large woody debris, and shading for fish. The riparian woodland in the project area fragmented by encroaching urbanization including houses, streets, bridges, and landscaping. Typical vegetation in the riparian habitat upstream of the fish ladder include eucalyptus, as well as willow, alder, bay, ash, maple, oak, and fir along the stream banks (Fluvial Geomorphology Consulting et al. 2006).

Downstream of the fish ladder, the concrete channels restrict establishment of riparian vegetation. Native tree species remain along the creek outside the concrete walls, but are often relicts of riparian woodland. Landscaping tree and shrubs species have been installed in many area as installed as part of urban development.

Wildlife

Riparian habitats are extremely productive and have diverse values for wildlife species. Historically, these communities provided habitat for a rich diversity of terrestrial and wetland plant and animal species. Terrestrial mammals, such as mule deer (*Odocoileus hemionus*) use the cover of the riparian forests and woodlands for protection from predators as they move between foraging areas. Similarly, amphibians and reptiles use the protective cover of this habitat as they disperse from their aquatic breeding sites. Migratory waterfowl use the waters and wetlands for their food supplies during their seasonal migration, mallards (*Anas platyrhynchos*) and wood ducks (*Aix sponsa*) were observed in Corte Madera Creek study area. Avian species typically found in the riparian habitats along Corte Madera Creek include: Bewick's wren (*Thryomanes bewickii*), spotted towhee (*Pipilo maculatus*), warbling vireo (*Vireo gilvus*), black-headed grosbeak (*Pheucticus melanocephalus*) and tree swallow (*Tachycineta bicolor*). Mammals of Corte Madera Creek riparian areas may include the brush rabbit (*Sylvilagus bachmani*), deer mice (*Peromyscus maniculatus*), dusky footed woodrat (*Neotoma fuscipes*), and raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and western gray squirrel (*Sciurus griseus*). Amphibians of Corte Madera Creek may include the Pacific tree frog (*Hyla regilla*), foothill yellow-legged frog (*Rana boylii*), California slender salamander (*Batrachoseps attenuatus*) and arboreal salamander (*Aneides lugubris*). Many of these species rely on the availability of food, cover, breeding, resting sites, and the migration corridor provided by the riparian habitat on Corte Madera Creek.

Fisheries

Corte Madera Creek Watershed and its tributaries are among the few streams flowing into San Francisco Bay that retain a steelhead trout population. Corte Madera Creek is highly channelized as a result of various activities such as concrete channel construction to reduce flood risk in urban areas and placement of retaining walls to prevent erosion by individual landowners. Currently the concrete flood control channel serves only as a migration route for the anadromous steelhead trout. The area above the concrete channel consists of lateral scour pools alternating with riffle areas, habitat used by a variety of fish species, although none in great abundance. Osmundson (2011) observed that the study area in Corte Madera Creek generally supports moderate to low quality steelhead habitat, much of which is presumed to function as migratory habitat. Rich and Associates (2000) conducted fish population surveys during the low-flow season (dry months) and observed five native species in the watershed: rainbow/steelhead trout (*Oncorhynchus mykiss irideus*), threespine stickleback (*Gasterosteus aculeatus*), California roach (*Hesperoleucus symmetricus*), sculpin species (*Cottus* spp.), and Sacramento sucker (*Catostomas occidentalis*). Roach, stickleback and sucker were the predominant species observed in Corte Madera Creek (Rich and Associates 2000). Striped bass (*Morone saxatilis*), a non-native species, was observed in the tidally influenced portion of Unit 3 during a site visit by Service staff in June 2018. Chinook salmon (*O. tshawytscha*) occasionally are observed in the watershed and historically coho salmon (*O. kisutch*) utilized the watershed.

Endangered Species

Based on a review of the likelihood of species occurrences and completion of field surveys, one federally-listed species is known to occur in the Corte Madera Creek Study action area, the federally-threatened Central California Coastal steelhead. The California red-legged frog (*Rana draytonii*) is known to occur in Corte Madera Creek Watershed, yet it has been determined that suitable habitat for the California red-legged frog does not exist in the project area, including the riparian corridor where work activities are proposed to occur.

Corte Madera Creek lies within the critical habitat designated under the ESA for the Central California Coastal steelhead and Coho salmon. In addition, the Corte Madera Creek watershed is designated under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) as Essential Fish Habitat (EFH) for Chinook and Coho salmon managed under the Pacific Coast Salmon Fishery Management Plan. As defined in the MSFCMA, the term "essential fish habitat" means those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.

Under the ESA, federal agencies are required to consult with the Service or National Marine Fisheries Service (NMFS) with respect to any action that may affect federally-listed species or designated critical habitat. The Service has jurisdiction over terrestrial species and inland fishes, while NMFS has jurisdiction over anadromous fishes and marine species. In addition, under the MSFCMA, federal agencies are required to consult with the NMFS with respect to any action proposed to be authorized, funded, or undertaken, that may adversely affect EFH.

Under the California Endangered Species Act, the California Department of Fish and Wildlife (CDFW) has responsibility for State listed species and species of concern. A summary report from CDFW's California Natural Diversity Data Base (August 21, 2018) was retrieved specifically for Marin County. A total of 24 species which are either State listed as endangered or threatened were evaluated for their potential to occur in the Ross Valley Watershed. Of these, 21 are unlikely to occur, and the remaining 3 have low potential to occur in Ross Valley Watershed: California freshwater shrimp (*Syncaris pacifica*), central California coast Coho salmon (*Oncorhynchus kisutch*), and

Swainson's hawk (*Buteo swainsoni*). Additionally, the foothill yellow-legged frog, a candidate for State listing as threatened, has limited potential to occur in the Ross Valley Watershed.

FUTURE CONDITIONS WITHOUT THE PROJECT

Vegetation

Land use in the study area is expected to maintain the current mix of residential, retail, municipal, and industrial uses with the no project action scenario. Aquatic and riparian habitats along Corte Madera Creek would likely be maintained at their current conditions given the current operations and maintenance of the channel. Some bank sloughing may occur where banks are over-steepened and riparian vegetation has been lost or removed. In the absence of vegetation management plans, the riparian vegetation cover is expected to remain in its current ecological state throughout the life of the project.

Wildlife

Because little change is expected to occur to the vegetation throughout Corte Madera Creek, no change to existing terrestrial wildlife conditions is expected with the No Action Alternative. Minimal changes in land use outside of the riparian corridor are expected to occur as it is already largely developed.

Fisheries

The aquatic resources of Corte Madera Creek area are not expected to change significantly from existing conditions. Resident and migratory fishes would continue to use the area as they do currently. The effects of climate change and its subsequent change is the timing and duration of storm events is not clear.

FUTURE CONDITIONS WITH THE PROJECT

Vegetation

Construction of the tentatively selected plan (Scaled Alternative F) would require the removal of riparian habitat at the entrance and exit of the underground bypass constructed mainly beneath Sir Francis Drake Boulevard starting on the left bank near the confluence of Corte Madera Creek and Ross Creek (Unit 4) and where it swings back and re-enters the stream channel at Allen Park Riparian Corridor (Unit 3). There may be some minimal vegetation impacts, mostly ornamental, along Sir Francis Drake Boulevard associated with excavating the roadway for placement of the box culverts.

The removal of the Denil Fish Ladder, located at the downstream end of Unit 4, about 580 feet downstream of Lagunitas Road Bridge, is not expected to impact woody riparian vegetation as the work will be confined to the channel bottom and the existing woody riparian habitat is mostly on the bank slopes. As a result of removing the fish ladder, channel modifications would be necessary to accommodate the change in flow dynamics, and also create the need to modify and lower the channel floor elevations to allow for a smooth transition and geomorphological sustainable channel bed. The channel bed modification will extend from the fish ladder to about 110 feet upstream of Lagunitas Road Bridge (685 total feet of modification). A portion of the natural channel in Unit 4, extending a length of about 115 feet, within the reach between Lagunitas Road Bridge and the fish ladder, will be widened to increase hydraulic conveyance capacity. This modification is not expected to impact woody riparian vegetation as it will be confined to the existing channel bottom.

The existing concrete channel downstream of the existing fish ladder, starting at its upstream limit at the beginning of Unit 3, would be demolished and removed. The demolition and removal of the concrete channel would continue downstream for about 900 feet. Additional improvements include

750 feet of realigned natural gravel creek bed, the lowering of the southwest side of the new creek channel in Allen Park to restore a historic floodplain and to increase flow capacity. At the downstream end of Allen Park, Corte Madera Creek will enter a new smooth transition to guide flow into the remaining existing concrete channel upstream of the Kentfield Rehabilitation Hospital. The widening of Allen Park (creation of the Allen Park riparian corridor) there would be a loss of remnant riparian trees, as well as ornamental plantings, due removal of the floodwall and excavation of the existing park area to increase the floodway width.

The enlarged Allen Park riparian corridor would be revegetated with appropriate native riparian species at the completion of the project.

Floodwalls would be constructed in three main areas within the project: along both banks of Allen Park riparian corridor (mentioned above), in close proximity to Granton Park, and adjacent to College Avenue.

The Granton Park floodwall would be constructed along the left bank and extend about 1,050 feet terminating at the western boundary of the College of Marin campus. The height of the Granton Park floodwall would vary. At its upstream end, it is estimated that that the wall height would be 2 feet and gradually increase to floodwall height of 6 feet at the downstream termination point. The new floodwall would be installed as a separate wall offset from the existing concrete wall.

Scaled Alternative F would also construct a short wingwall upstream of College Avenue Bridge (about 75 feet in length) and a longer floodwall downstream of College Avenue Bridge extending about 950 feet in length. The College Avenue floodwall would be constructed along the left bank and at its upstream limit have a maximum height of 4 feet and gradually taper down to a height of 2 feet at its terminating point downstream.

CORTE MADERA CREEK FRMP IMPACT ANALYSIS

The construction of floodwalls would result in the permanent loss of existing vegetation (remnant riparian trees and ornamental vegetation) the length of the new floodwall and in a vegetation free zone at minimum, 15 feet landward of the floodwall due to Corps policy (COE 2014). The vegetation free zone applies to all vegetation except grass, which is exempt.

Habitat Evaluation Procedures (HEP) was used to evaluate the potential impacts to fish and wildlife resources associated with the implementation of Corte Madera Creek tentatively selected alternative utilizing information provided by the Corps (Corps 2018). See Appendix A for the specific HEP methodology and results.

Habitat Evaluation Procedures

HEP is an accounting procedure used to derive numerical expressions of habitat value under alternative scenarios. A HEP application is an approach involving model selection, field assessment of existing (baseline) conditions, and best professional judgement of habitat area and quality at different times in the future (Target Years, or TYs) with and without a project. The basis for HEP is one or more HSI models, in which measured or anticipated habitat variables are converted into Suitability Indices (SIs) using a set of published model curves and descriptions. These SIs are then combined using other equations and rules into a single index, the HSI. The product of the HSI and the evaluation area yields "habitat units" which, when averaged over the life of a project give a single quantity (Average Annual Habitat Units, or AAHUs) which is used to compare future scenarios for various alternatives to the future without a project.

General Methodology

Acreages of existing riparian, aquatic, and urban landscape cover-types that would be altered by Corte Madera Creek FRMP were developed from information supplied by the Corps and site visits by Service staff. The HSI models were chosen by a multi-agency team because they were readily available, their variables included characteristics of the riparian cover-type and aquatic habitat that would change with project implementation, and their relative simplicity facilitated completing the HEP in a timely manner.

For consistency with HEP, a standard 0.0 to 1.0 range for each SI was used. The impact areas and SIs were measured or estimated using best professional biological judgment of the physical changes and resource responses anticipated due to the project. These were based on baseline data collected along Corte Madera Creek in September 2016. More detailed descriptions of methodology is given in the attached HEP report (Appendix A).

Table 2 summarizes the net change in average annual habitat units (AAHUs) provided by the Corte Madera Creek FRMP riparian, urban landscape, and riverine aquatic cover-type values compared to no project action. The HEP results indicate that with construction of the Corte Madera Creek FRMP there would be minimal loss of riparian woodland acreage and value with construction of the proposed bypass intake and outflow, these losses would be offset by development of the Allen Park floodplain. Urban landscape would also experience loss in value which would also be offset by development of the Allen Park floodplain. Lastly, riverine aquatic values would increase with the project as the concrete channel would be replaced with a natural channel. Appendix A contains the HEP and the assumptions used for the future with- and without-project scenarios. Over the project life, which is assumed to be 50 years after construction actions are completed, there is a net gain in riparian woodland and riverine aquatic cover-type values with the project

Table 2. Summary of cover-types, acreage impacted, net change in average annual habitat units (AAHUs) gained or lost over the life of the Corte Madera Creek FRMP.

Corte Madera Creek Flood Risk Management Plan					
Cover-Type	Acres Impacted	AAHUs W/O Project	AAHUs W/Project	Net Change in AAHUs	Compensation Need[1]
Riparian Woodland	0.11	0.05	0.00	-0.05	----
Riverine Aquatic	1.36	0.63	1.31	0.68	----
Urban Landscape	2.56	1.46	1.67	0.21	----

1. The loss of riparian woodland values is offset by the conversion of the urban landscape cover-type (development of the Allen Park riparian corridor) to riparian woodland. Overall there is a net gain of 0.16 AAHUs with the project.

Wildlife

Effects of Corte Madera Creek FRMP construction activities on wildlife include disturbance from construction activity, removal of vegetated cover, project maintenance and noise. Birds and mammals typically respond to this type of activity by leaving the construction area. Construction and maintenance would include vehicle trips, human activity, vegetation clearing, excavation, grading, and installation of project features. These activities have potential to disturb wildlife in and around each sub-reach where project activities are performed. Birds in the project areas could potentially be impacted through vegetation clearing as well as noise and other human disturbance. Bird species that may nest in riparian habitats along Corte Madera Creek have the potential to be impacted through temporary habitat loss and through direct impacts to nests during restoration activities. Birds and other wildlife that generally use the riparian corridor for foraging also may be temporarily affected by the loss of habitat during project activities. However, suitable habitat would still exist along the creek outside of the study area.

Due to the proposed revegetation efforts, the quality of the riparian habitat that many wildlife species depend on would be expected to return, and possibly improved due to the expanded floodway, relative to the static riparian habitat currently present.

Aquatic Resources

The initial construction and restoration activities within each sub-reach are likely to cause localized temporary affects to existing aquatic habitat. Potential temporary effects to aquatic habitat from the construction and associated maintenance activities could result in increases to turbidity and suspended particulates, water temperatures and changes to dissolved oxygen. However, these impacts are expected to be short-term, minimal, and are expected to return back to base-line conditions shortly after construction.

Over the long-term, the Corte Madera Creek FRMP should have beneficial effects to aquatic riverine habitat by improving fish passage near the downstream end of Unit 4 and restoring the quality and area of the habitat along 900 feet of what is now a concrete lined flood channel to natural streambed. Grading and widening the creek's associated floodplain at Allen Park would provide additional cover and flood refuge for native fish species. In addition, the benefits to Corte Madera Creek fisheries of improved habitat complexity, increased availability of invertebrate production, and an introduction of sediment and nutrients would all result from project implementation.

Service Mitigation Policy

The recommendations provided herein for the protection of fish and wildlife resources are in accordance with the Service's Mitigation Policy as published in the Federal Register (46:15; January 23, 1981).

The Mitigation Policy provides Service personnel with guidance in making recommendations to protect or conserve fish and wildlife resources. The policy helps ensure consistent and effective Service recommendations, while allowing agencies and developers to anticipate Service recommendations and plan early for mitigation needs. The intent of the policy is to ensure protection and conservation of the most important and valuable fish and wildlife resources, while allowing reasonable and balanced use of the Nation's natural resources.

Under the Mitigation Policy, resources are assigned to one of four distinct Resource Categories, each having a mitigation planning goal which is consistent with the fish and wildlife values involved. The Resource Categories cover a range of habitat values from those considered to be unique and irreplaceable to those believed to be much more common and of relatively lesser value to fish and wildlife. However, the Mitigation Policy does not apply to threatened and endangered species, Service recommendations for completed federal projects or projects permitted or licensed prior to enactment of Service authorities, or Service recommendations related to the enhancement of fish and wildlife resources.

In applying the Mitigation Policy during an impact assessment, the Service first identifies each specific habitat or cover-type that may be impacted by the project. Evaluation species[a] which utilize

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a Note: Evaluation species used for Resource Category determinations may or may not be the same evaluation each habitat or cover-type are then selected for Resource Category analysis. Selection of evaluation species can be based on several rationale, as follows: (1) species known to be sensitive to specific land- and water-use actions; (2) species that play a key role in nutrient cycling or energy flow; (3) species that utilize a common environmental resource; or (4) species that are associated with Important Resource Problems, such as anadromous fish and migratory birds, as designated by the Director or Regional Directors of the Fish and Wildlife Service. Based on the relative importance of each specific habitat to its selected evaluation species, and the habitat's relative abundance, the appropriate Resource Category and associated mitigation planning goal are determined.

Mitigation planning goals range from "no loss of existing habitat value" (i.e., Resource Category 1) to "minimize loss of habitat value" (i.e., Resource Category 4). The planning goal of Resource Category 2 is "no net loss of in-kind habitat value;" to achieve this goal, any unavoidable losses would need to be replaced in-kind. "In-kind replacement" means providing or managing substitute resources to replace the habitat value of the resources lost, where such substitute resources are physically and biologically the same or closely approximate those lost.

In addition to mitigation planning goals based on habitat values, Region 8 of the Service, which includes California, has a mitigation planning goal of no net loss of acreage and value for wetland habitat. This goal is applied in all impact analyses.

In recommending mitigation for adverse impacts to fish and wildlife habitat, the Service uses the same sequential mitigation steps recommended in the Council on Environmental Quality's regulations. These mitigation steps (in order of preference) are: avoidance, minimization, rectification of measures, measures to reduce or eliminate impacts over time, and compensation.

Four fish and/or wildlife habitats were identified in the project area which had potential for impacts from the project: riparian woodland, riverine aquatic, and "other." The resource categories, evaluation species, and mitigation planning goal for the habitats impacted by the project are summarized in Table 3.

Table 3. Resource categories, evaluation species, and mitigation planning goal for the habitats possibly impacted by the proposed Corte Madera Creek FRMP, Marin County, California.

COVER-TYPE	EVALUATION SPECIES	RESOURCE CATEGORY	MITIGATION GOAL
Riparian woodland	Yellow warbler Deer	2	No net loss of in-kind habitat value or acreage.
Riverine aquatic	Rainbow trout	2	No net loss of in-kind habitat value or acreage.
Urban landscape	Warbling vireo	4	Minimize loss of habitat value.
Other	None	4	Minimize loss of habitat value.

species used in a HEP application, if one is conducted.

The evaluation species selected for the riparian woodland that would be impacted are yellow warbler and mule deer. Yellow warblers utilize riparian woodlands for nearly all their life requisites; 90% of the warbler's annual diet consists of insects and they prefer wet areas partially covered by willows and alders (Schroeder 1982). Yellow warblers can also represent impacts to other canopy-dwelling species. Mule deer also use riparian woodlands and depend on acorns as a dietary item in the fall and spring; the abundance of acorns and other browse influence the seasonal pattern of habitat use by deer. The mule deer represent species which utilize the ground component of the habitat and has important non-consumptive human uses (i.e., viewing) in the immediate project area. Based on the high value of riparian woodland to the evaluation species, and their declining abundance, the Service has determined riparian woodland which would be affected by the project should be placed in Resource Category 2, with an associated mitigation planning goal of "no net loss of in-kind habitat value."

The evaluation species selected for the riverine aquatic cover-type is the rainbow trout, which utilizes these areas for up- and downstream migration and for foraging. This species was selected because this watershed supports one of the few remaining watersheds empting into San Francisco Bay which support anadromous rainbow trout (steelhead) and their overall high non-consumptive values (uniqueness for the area) to humans. Therefore, the Service designates the riverine aquatic cover-type in the project area as Resource Category 2. Our associated mitigation planning goal for these areas is "no net loss of in-kind habitat value."

The evaluation species selected for the urban landscape cover-type is the warbling vireo. This vireo occurs in coastal areas of California and utilizes the upper canopy of trees such as found in this cover-type. This species was selected because it represents other species which depend on the upper canopy for some life requisites, the Service's responsibility for their protection and management under the Migratory Bird Treaty Act, and their overall high non-consumptive values to humans (birdwatching). Urban landscape areas potentially impacted by the project vary in their relative values to the evaluation species, depending on the degree of human disturbance, plant species composition, and juxtaposition to other foraging and nesting areas. Therefore, the Service designates the "other" cover-type in the project area as Resource Category 4. Our associated mitigation planning goal for these areas is "minimize loss of in-kind habitat value."

No evaluation species were identified for the "other" cover-type. The "other" cover-type encompasses those areas such as gravel and paved roads, parking areas, buildings, bare ground, riprap, etc. Generally, this cover-type would not provide any significant habitat value for wildlife species. Therefore, the Service designates the "other" cover-type in the project area as Resource Category 4. Our associated mitigation planning goal for these areas is "minimize loss of in-kind habitat value."

DISCUSSION

The project area will experience an initial period of loss in riparian cover-type value due to the permanent loss of vegetation at the intake and outlet of the new underground bypass. There will also be a loss of urban landscape cover-type values associated with floodwall construction. However, these losses are offset by the development of the Allen Park riparian corridor.

Corte Madera Creek FRMP actions can increase diversity in the riparian corridor by adding structural complexities that can be used as habitat by a greater number of species in the Allen Park riparian corridor. Specifically, the physical effects of riparian processes include regulating instream temperature, filtering nutrients and chemical from runoff, stabilizing banks, facilitating sediment accretion on the floodplain and providing cooler, more humid, and less windy microclimates (Stella et al. 2001). Restoration efforts would show an eventual annual average gain in value to riparian woodland by increasing native riparian vegetation successional complexity and promoting habitat diversity for riparian associated wildlife species.

There are some opportunities to increase the value of riparian woodland and urban landscape acreage and value if a variance could be obtained from the Corps' ETL 1110-2-583 (Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment dams, and Appurtenant Structures) which requires a minimum vegetation free zone of 15 feet or distance to normal water surface if less on the waterside and minimum 15 feet on the landside of the floodwall. There is an opportunity to increase plantings on the waterside of the Allen Park riparian corridor if the minimum distance can be reduced. There are also potential opportunities in some areas on the landside of the floodwall for plantings that would benefit wildlife species. The floodwall heights for this project range from only 2-6 feet high.

The other opportunity to increase habitat values is plantings associated with the intake and outlet structures. We assumed planting would not be allowed on the soil covering this structure (particularly the outlet structure) where it runs some distance from Sir Francis Drake Boulevard before it re-enters the creek. Low growing native shrub species would provide additional values for wildlife species and aesthetic values for adjacent landowners.

In addition to the riparian habitat values modeled by HEP, plant and pollinator species have been recognized as being increasingly at risk of local and global extinction (Kearns et al. 1998). Climate change and habitat loss, including alterations in land use, have been implicated as factors leading to breakdowns in plant-pollinator relationships (Wall et al. 2003; Weiner et al. 2014). Buchmann and Nabhan (1996) have estimated that animal pollinators are needed for the reproduction of 90% of flowering plants and one third of human food crops. Corte Madera Creek FRMP floodplain widening activities can be designed to benefit local and landscape-level plant-pollinator relationships through the establishment of suitable native plant species.

Another aspect of ecosystem restoration not modelled by HEP is the potential introduction of non-native microorganisms that could be detrimental to native landscapes. Phytophthoras, or "water molds," are plant pathogens known to cause sudden oak disease in California (McPherson et al. 2005), western conifers (Hamm and Hansen 1982), as well as other related forest species. Some species of Phytophthoras are also known to effect agricultural crops (Ristaino and Johnston 1999). Phytophthoras have long been known to occur in nursery stocks (Crandall et al. 1945), and using infected stock could have considerable undesirable effects on contiguous blocks of forests (Condeso and Meentemeyer 2007). With climate change, the effects of introduced pathogens to native forests can also be expected to change, therefore increasing risks to future planning and management decisions (Sturrock et al. 2011).

Aquatic Resources

The Corte Madera Creek FRMP is designed to reduce flood risk from the creek and improve instream passage and habitat conditions for anadromous and other fish species. Benefits to aquatic resources are expected to occur downstream of the fish ladder once it and the 750-foot-long section of concrete channel downstream of the ladder are removed and the channel restored. The benefits that will accrue from the natural channel bottom that will be installed include increased cover for fish species, improved passage, and improved conditions for the instream food web. In the assessment of benefits provided by restoration of the stream channel certain assumptions were made as to how the channel would look after restoration. These included constructing pools covering 35-65% of the reach, installing boulder clusters and anchored woody debris to achieve at least 15%

instream cover during the late season low water period. Large woody debris is widely important to fish and under unimpaired conditions, very long lived. Large woody debris has key roles in physical habitat formation, sediment and organic-matter storage, and in maintaining both essential habitat complexity and refugia (USFWS 2004). Losses or lack of large woody debris are known to reduce both habitat quality and carrying capacity.

There may be some water temperature improvements as well in the restored section compared to the existing concrete channel condition. However, the most suitable habitat for salmonids was higher up in the watershed which should be more accessible for anadromous species with the fish passage improvements. Rich and Associates (2000) found that despite potentially thermally stressful conditions in many areas of the watershed, there were thermal refuge areas where trout could reside during the hotter summer months. They also observed that if fish emigrated out of the system by May, water temperatures should not become thermally stressful.

Lastly, the proposed project leaves a remaining section of concrete lined channel downstream of the proposed channel restoration to where reaches the natural channel bottom in the lower portion of Unit 2.

RECOMMENDATIONS

The Service has the following recommendations if the Corps implements the Corte Madera FRMP:

1) Avoid additional impacts to woody vegetation to the maximum extent possible by fencing all areas of woody vegetation to be retained within, and immediately adjacent, to the construction right-of-way with orange construction fencing, and providing written and oral instruction to all contractors not to disturb these areas, outside of invasive plant removal activities.

2) Avoid impacts to migratory birds by completing vegetation removal outside of the nesting season for migratory birds. If this is not possible, a qualified biologist should conduct a pre-construction survey no more than 1 week prior to ground disturbing activities to identify any nesting migratory birds present within 50 feet (or nesting raptors within 300 feet) of project restoration activities, including all construction and staging areas. Appropriate buffers should be designated and maintained in the event nesting migratory birds are encountered. If nesting birds are unavoidable, the Service and CDFW should be contacted prior to disturbance.

3) Minimize impacts to riparian woodland by leaving large trees and standing snags. The hairy woodpecker HSI model indicates that leaving at least 4 standing snags (standing dead trees measuring at least 10 inches dbh and at least 6 feet in height, with at least 50% of its branches fallen, or are present, but no longer bear foliage) per acre (within or near the impacted area) will minimize potential impacts to cavity nesting species. Leaving larger trees will not only minimize impacts to the riparian cover-type and riparian associated species, but may also improve the success of the native transplants.

4) Minimize impacts to riparian habitat by completing revegetation of impacted areas within 1 year post construction.

5) Minimize the impacts to riparian woodland/urban landscape by seeking a variance from Corps policy (ETL 110-2-583) which requires a minimum 15-foot vegetation free zone

or distance to the edge of normal water surface, if less, on the waterside of floodwalls and a minimum 15-foot vegetation free zone on the landside of a floodwall.

6) Maximize benefits to restoring riverine aquatic habitat in the old concrete channel section by constructing riffle-run-pool sequences and incorporating boulder clusters and large woody debris into the design.

7) Where practicable, trees removed for construction should be salvaged and incorporated as large woody debris in the restored riverine channel section of the project (the transition zone and former concrete channel areas).

8) Develop and implement a vegetation monitoring program as part of the adaptive management, monitoring and evaluation for the Corte Madera Creek FRMP to monitor for ecological success post construction. Monitoring should continue until ecological success is determined. Monitoring the riparian restoration effort should focus on recording tree and shrub survival rates, the quantification of improved habitat values for wildlife (primarily bird species) by measuring factors such as percent tree and riparian scrub cover, average height of overstory trees, canopy layering, and total woody riparian vegetation, and developing recommendations for alternative methods of riparian restoration should initial efforts fail. All phases of the vegetation monitoring program for this project should be coordinated with the Service and NMFS. The Corps document titled, *Memorandum for Commanders, Major Subordinate Commands, Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 – Monitoring Ecosystem Restoration,* should be referenced for additional monitoring guidance.

9) Restoration plantings should include species used by and beneficial for native pollinating species. The Service is available to help establish a list of species that are beneficial to native pollinators. Suitable pollinator plant references can be found online at:
   http://pollinator.org/guides_code
   http://www.pollinator.org/PDFs/Guides/CalifCoastalStepperx4FINAL.pdf
   http://www.pollinator.org/PDFs/SierranSteppe.rx3.pdf

10) Reduce potential for deleterious effects resulting from the unintended introduction of Phytophthoras to riparian cover by consulting the website www.calphytos.org for guidance during various aspects of restoration.

11) Consult with NMFS regarding impacts to federally-listed fish species for potential impacts to anadromous fish and marine species under NMFS's jurisdiction

12) Coordinate with the CDFW regarding impacts to wildlife and fish species for potential impacts to species listed under the California Endangered Species Act.

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APPENDIX A

HABITAT EVALUATION PROCEDURES

CORTE MADERA CREEK FLOOD RISK REDUCTION GENERAL REEVALUATION REPORT

AUGUST 2018

INTRODUCTION

This application of Habitat Evaluation Procedures (HEP) is intended to quantify the anticipated impacts and benefits to fish and wildlife resources that would occur with the proposed Corte Madera Creek Flood Risk Reduction General Reevalutation Report (Corte Madera Creek FRMP) in Marin County, California. In particular, this HEP analyzes the effects on aquatic and terrestrial wildlife habitat within of the Tentatively Selected Plan (TSP), as identified by the U.S. Army Corps of Engineers (Corps) and the Marin County Flood Control and Water Conservation District (Marin County FCWCD). The goal of the Corte Madera FRMP through the implementation of the TSP is to reduce flood risk to areas along Corte Madera Creek, as well as to improve fish passage through reaches of Corte Madera Creek for anadromous and other fish species.

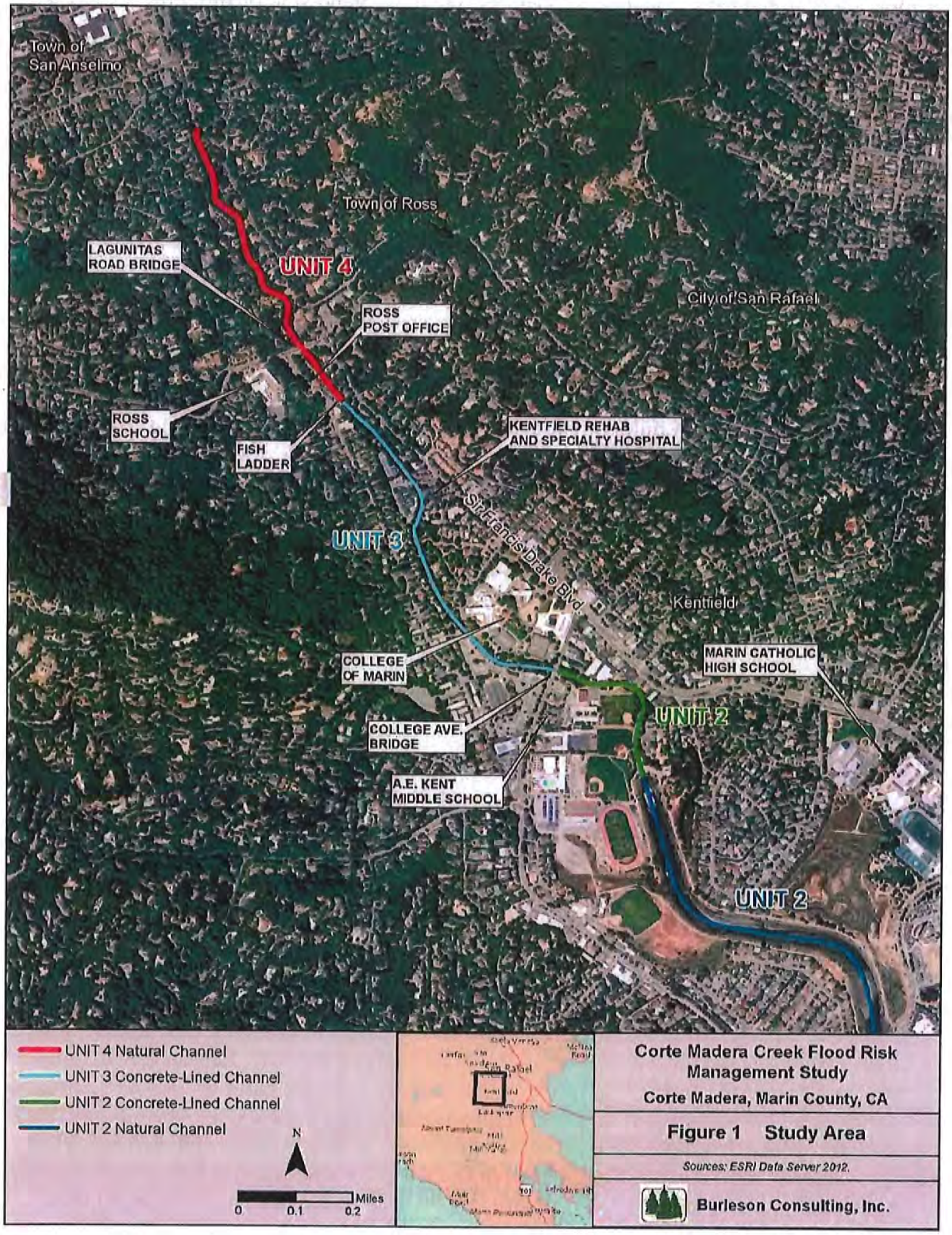
PROJECT DESCRIPTION

In coordination with the Marin County FCWCD, the Corps has put forth the Corte Madera Creek FRMP to improve floodwater conveyance and implement ecosystem restoration efforts along Corte Madera Creek in the Town of Ross, Marin County, California (Corps 2018). The TSP considers improvements along about 1.4 miles of Corte Madera Creek, including Units 3, 4, and concrete-lined portion of Unit 2 (Figure 1). Over a project life of 50 years, objectives of the Corte Madera Creek FRMP are to reduce flood risk in the Town of Ross, and to develop and implement environmental features that are consistent with the natural geomorphic processes and ecological functions of the project area. The TSP consists primarily of a combination of floodwalls, an underground channel overflow bypass along Sir Francis Drake Boulevard, and a floodplain along the riparian corridor at Allen Park. The TSP also includes the removal of the Denil fish ladder separating Units 3 and 4.

Opening on the left, downstream bank in Unit 4 near the confluence of Corte Madera Creek with Ross Creek, a bypass channel would be constructed to flow mainly below Sir Francis Drake Boulevard before it re-enters the main channel creek downstream of the Denil Fish ladder. The bypass channel would consist of two parallel box culverts, each 12-feet wide by 7-feet high, and extending for a length of about 2,200 feet. With the removal of the fish ladder, a smooth transition zone would be designed and constructed from a point beginning in Unit 4 about 110 linear feet upstream of the Lagunitas Road Bridge and continuing downstream about 580 linear feet to the current fish ladder location. Downstream from the fish ladder, for about 750 linear feet the concrete lined channel would be demolished and realigned with a natural creek bed to complete the smooth transition. Along the floodplain, the right bank would be graded and planted with native vegetation.

Downstream of the fish ladder, the Allen Park riparian floodplain corridor would extend about 900 linear feet and encompass about 2 acres on the right, downstream bank of Corte Madera Creek. The corridor would include a widened, native substrate channel to accommodate higher flows, and floodwalls would be raised to a maximum of 2 feet throughout the area. Further downstream, a Granton Park floodwall would extend about 1,050 feet along the left bank of Unit 3 to a point near the footbridge by Laurel Science and Math Building of the College of Marin. The Granton Park floodwall would be offset from the existing concrete wall and would increase flood capacity above existing conditions from a maximum of 2 feet at the upstream end to about 6 feet by the footbridge. An additional floodwall along the left bank of Unit 2 would be constructed from the College Avenue Bridge downstream for about 950 linear feet, and upstream for an additional 75 linear feet. The maximum height of the floodwall would taper from a maximum height of 4 feet near the College Avenue Bridge to a maximum height of 2 feet at the downstream end.

Figure 1. Corte Madera Creek Flood Risk Reduction General Reevalutation Report Study Units, Town of Ross, Marin County, California.



HEP OVERVIEW

The HEP is an impact assessment methodology developed by the Fish and Wildlife Service (Service) and other State and Federal resources agencies which can be used to document the quality and quantity of available habitat for selected wildlife species. HEP provides information for two general types of wildlife habitat comparisons: 1) the relative value of different areas at the same point in time, and 2) the relative value of the same areas at future points in time. By combining the two types of comparisons, the impacts of proposed or anticipated land and water-use changes on wildlife habitat can be quantified. In a similar manner, any compensation needs (in terms of acreage) for the project can also be quantified.

A HEP application is based on the assumption that habitat for selected wildlife species or communities can be described by a model which produces a Habitat Suitability Index (HSI). The HSI, a value from 0.0 to 1.0, is assumed to relate directly to the carrying capacity of the habitat being evaluated. The HSI is multiplied by the area of available habitat to obtain Habitat Units (HUs). The Average Annual Habitat Units (AAHUs) over the life of the project are then used in the comparisons described above. Species, guild, or a suite of models can be used, depending on mitigation objectives.

HSI values are quantified at several points in time over the life of the project. These points in time are known as Target Years (TYs) and are selected for years in which habitat conditions are expected to change and can be reasonably defined. In every HEP analysis, there must be a Target Year 0 (TY0) which represents the baseline conditions, Target Year 1 (TY1) which is the first year habitat conditions are expected to deviate from baseline conditions, and an ending Target Year, which defines the period of analysis. The period of analysis consists of the life of the project, plus the period of construction. The baseline year, in addition to the period of construction and life of the Corte Madera FRMP, totals 51 years.

When using HEP, it is necessary to determine HSIs for each evaluation element at selected target years for both with-project and without-project scenarios. Because it is not possible to empirically determine habitat quality and quantity for future years, future HSI values are projected. This is accomplished by increasing or decreasing specific baseline variables and/or HSI values for each evaluation element based on best professional knowledge of performance at other mitigation sites, literature on plant growth, and conditions at reference sites. To predict changes in the HSI for each future scenario, it is necessary to make assumptions regarding baseline and future values within project impact and compensation areas.

The reliability of a HEP application, including the significance of HUs and AAHUs, is directly dependent on the ability of the HEP user to assign a well-defined and accurate HSI to the selected evaluation species or communities. Also, the HEP user must be able to identify and measure (or predict) the area of each distinct cover-type that is utilized by fish and wildlife within the project area. Both the HSIs and cover-type acreages must also be reasonably estimable at various future points in time. The Service has determined that these HEP criteria can be met, or at least reasonably approximated, for the Corte Madera FRMP; thus HEP was considered to be an appropriate analytical tool.

HEP TEAM PARTICIPANTS

HEP applications rely on a team approach to sampling and projecting future values. In this application, the HEP data collection team members were: Amber Aguilera, Doug Weinrich, and Julie Wolford with the Service, and Kelly Janes and Stephen Willis of the Corps.

GENERAL HEP ASSUMPTIONS

Some general assumptions are necessary to use HEP and HSI Models in the impact assessment.

Use of HEP:

- The HEP is the preferred method to evaluate the impacts of the proposed project on fish and/or wildlife resources.
- The HEP is a suitable methodology for quantifying project-induced impacts on fish and wildlife habitats.
- Quality and quantity of fish and wildlife habitat can generally be numerically described using the indices derived from the HSI models and associated habitat units.
- The HEP assessment is applicable to the habitat types being evaluated.

Use of HSI Models

- The HSI models are hypotheses based on available data.
- The HSI models are conceptual models and may not measure all ecological factors that affect the quality of a given cover-type for the evaluation species (e.g. vulnerability to predation). In some cases, The HEP Team may make assumptions and incorporate them into the analysis to account for loss of those factors not reflected by the model.

HABITAT TYPES AND PROPOSED HSI MODELS

Field visits revealed that terrestrial land cover within the Corte Madera Creek FRMP project area largely fell into two habitat types: (1) valley foothill riparian woodland (riparian), and (2) urban (Meyer and Laudenslayer 1988). Although urban cover can provide wildlife habitat, the historic, natural cover of the project area was determined to be riparian. Additionally, a principal component of the TSP involves the conversion of the Allen Park urban cover to a riparian floodplain. Therefore, the current and future habitat value of both urban and riparian cover was evaluated using HSI models that measure historic riparian cover characteristics. Two models were chosen and considered with equal weight to evaluate the riparian cover: the hairy woodpecker model (Sousa 1987) was used to evaluate the riparian cover overstory habitat; and the yellow warbler model (Schroeder 1982) was used to evaluate the riparian cover shrub layer habitat. To evaluate the conditions of the aquatic habitat, the rainbow trout model (Raleigh et al. 1984) was modified for use within the current Corte Madera Creek specific conditions (Cordone 2000). The HSI models and habitat variables measured to generate each riparian cover habitat HSI are summarized in Table 1.

Prior to field data collection, the HSI models were selected to evaluate the riparian vegetation cover. The HSI models used in this study are mechanistic models. The term "mechanistic" means that the models define a specific mathematical relationship between measured habitat parameters and their value to the evaluation species. The HSI models use habitat variables that have been identified as important components of reproduction, cover, and feeding habitat. All models are in HEP Appendix B.

The hairy woodpecker and yellow warbler models were selected to evaluate riparian habitats of the project because: (1) together the models evaluate unique parameters of native riparian habitat that are assumed to effect the suitability of habitat for both foraging and breeding of both species, (2) the

Table 1. HSI models, cover-types, HSI model variables, and methods used for data collection.

HSI MODEL, COVER-TYPE AND STRATA	HSI MODEL VARIABLES	DATA COLLECTION METHOD
Hairy Woodpecker (Service 1987) - Riparian cover: Overstory	V1 – number of snags ≥ 25 cm dbh V2 – mean dbh of overstory trees V3 – mean dbh of overstory trees V4 – % canopy cover of trees V5 – % overstory pine canopy closure	visual count within polygon plot survey plot survey line intercept line intercept
Yellow Warbler (Service 1982) - Riparian cover: Shrub layer	V1 - % deciduous shrub crown cover V2 – average height of deciduous shrub canopy V3 - % of deciduous shrub canopy comprised of hydrophytic shrubs	line intercept line intercept line intercept
Modified Rainbow Trout Model (Service 2000) – Aquatic habitat: Instream conditions	V1 - % of streamside vegetation V2 - % of midday shade V3 – mean thalweg depth V4 - % of pools V5 - % of instream cover V6 - % of riffle fines	line intercept line intercept line intercept line intercept line intercept line intercept

Corte Madera Creek FRMP project area is within the breeding and migration range of both the hairy woodpecker and the yellow warbler, (3) the variables in each model can be compared with- and without the project implementation, (4) the Service had developed models for the species, and (5) the Corps' National Ecosystem Planning Center of Expertise and Headquarters had approved use of the model.

The rainbow trout model was selected for use in the project's aquatic habitat because: (1) non-anadromus rainbow trout are genetically indifferent from anadromous steelhead, (2) a goal of the Corte Madera FRMP is to improve instream conditions for steelhead that utilize the creek, (3) the modified rainbow trout model is based on parameters assumed to affect the specific habitat suitability of Corte Madera Creek for steelhead (3) the variables in the model can be compared with- and without the project, (4) the Service had developed a model for the species, and (5) the Corps' National Ecosystem Planning Center of Expertise and Headquarters had approved use of the modified model.

METHODOLOGY

The study design was developed jointly by Service and Corps, based on project designs developed with input from Marin County FCWCD. Project alternatives were put forth by the Corps in an Alternative Milestone Report for the Corte Madera Creek FRMP on May 17, 2016. Based on the project alternatives, the models were chosen and sampling methods were formed. Although many project details had not been designed, data was collected on September 14 and 15, 2016. The data was collected from transects established in areas common to all project alternatives.

Components of the Tentatively Selected Plan

The Corps provided a Tentatively Selected Plan Milestone Report Summary on June 13, 2018. With the TSP selected, the Corps provided G.I.S. shapefiles outlining planned project impact areas (Figure 2). The Service (Harry Kahler and Doug Weinrich) returned to the Corte Madera FRMP project area on June 21, 2018 to verify that data collected in 2016 was still applicable, and to collect additional information based on the TSP. Aquatic instream conditions were based on channel designs provided by the Corps and discussed in email correspondence in March, 2018. To evaluate project impacts on riparian and riverine habitats the following components of the TSP were used: the underground bypass; Allen Park riparian corridor; fish passage transition grading; and the floodwalls near Granton Park, College Avenue, and the Allen Park riparian corridor.

<u>The Underground Bypass</u>: Most of the Underground Bypass will lie underneath Sir Francis Drake Boulevard and will contain flows only during high water events. Therefore, most of the underground bypass was not analyzed in our habitat evaluation. However, the intake and outflow areas where the bypass tunnels daylight with Corte Madera Creek are assumed to contain urban cover (Meyer and Laudenslayer 1988). The area of habitat that would be removed with TSP implementation was estimated from field visits and aerial imagery.

<u>Allen Park Riparian Corridor</u>: The area of the Allen Park riparian corridor was based on the shapefile provided by the Corps as shown in Figure 2. Currently, the area consists of urban cover, but also does contain the Corte Madera Creelk corridor of aquatic habitat. Based on measurements from field visits, a channel of about 34 feet for the entire creek length was removed from the proposed riparian floodplain habitat acreage estimate.

Additionally, the installation of floodwalls would require a 15-foot zone on the landside free from woody vegetation. The area free of woody vegetation would extend the entire length of both the inside (waterside) and outside (landside) of the proposed floodwalls surrounding the Allen Park riparian floodplain. Therefore, the urban habitat within 15 feet of the proposed floodwalls was also included as part of the TSP project acreage. Figure 3 details the areas of the Allen Park riparian corridor that were analyzed in this HEP.

Because the riparian corridor would be used as a natural floodplain area with TSP implementation, the existing urban cover would be converted to a native riparian woodland habitat. Therefore, we used riparian woodland data collection methods throughout the upland areas of the Allen Park riparian corridor.

<u>Fish Passage Transition Grading</u>: Transition grading to take place upstream of the existing fish ladder will occur in aquatic habitat. Additionally, some channel widening would occur to accommodate floodwater conveyance and to allow the restoration of the historic floodplain at Allen Park. The transition grading will be designed to allow fish passage through the project area after the removal of the fish ladder.

<u>Floodwalls</u>: The installation of floodwalls would require a 15-foot zone on the landside free from woody vegetation. The area free of woody vegetation would extend the entire length of both the Granton Park and College Avenue floodwalls, as well as along the floodwalls surround the Allen Park riparian corridor zone. The floodwall along the downstream, left bank of the Allen Park riparian zone would extend about 830 feet, while floodwalls on the opposite would extend about 900 feet. Figure 4 shows the Granton Park and College Avenue floodwall components of the TSP.

Figure 2. Corte Madera FRMP, tentatively selected plan major components.

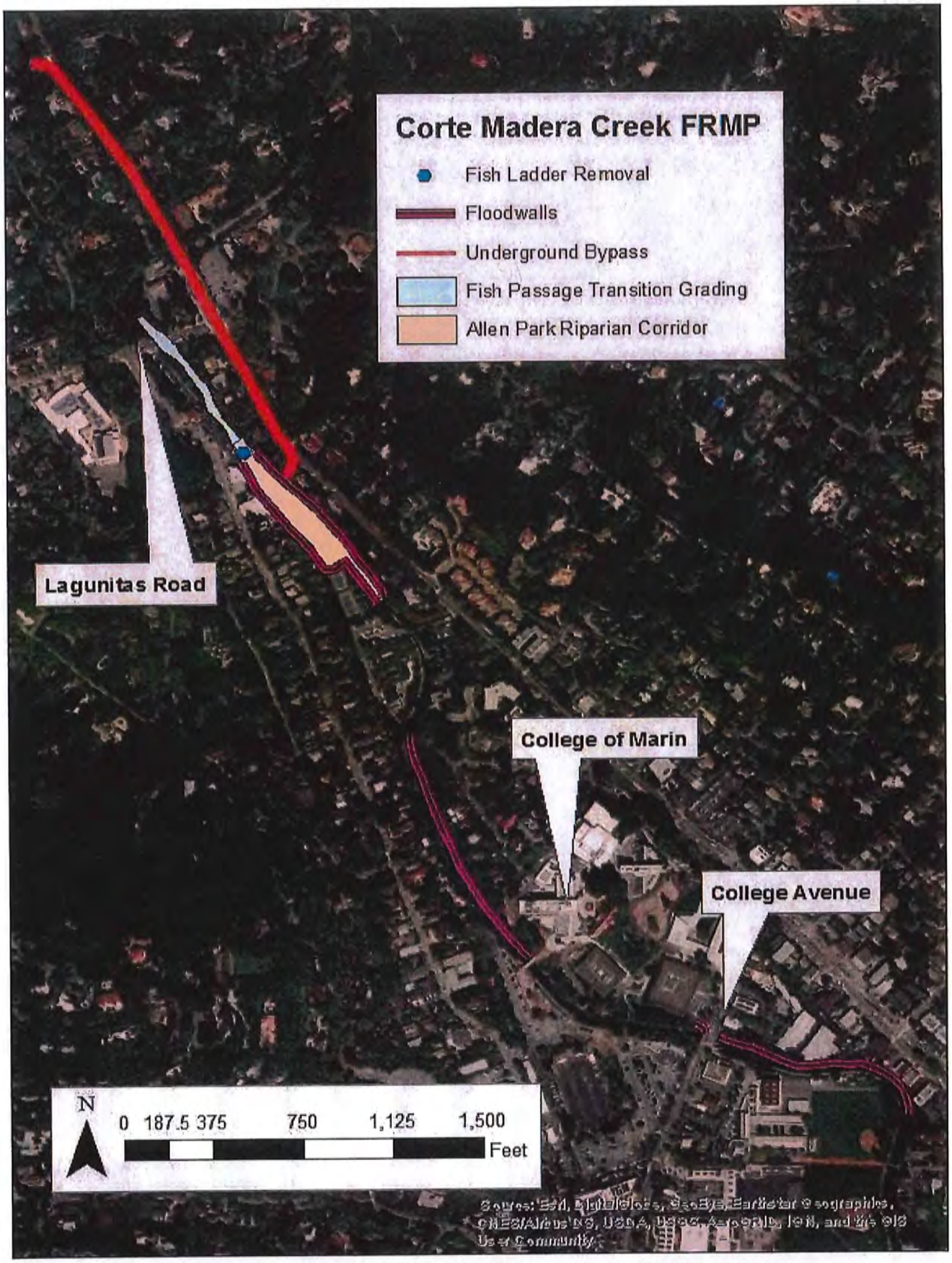


Figure 3. Areas of the Corte Madera FRMP Allen Park Riparian Corridor, as analyzed in this HEP.

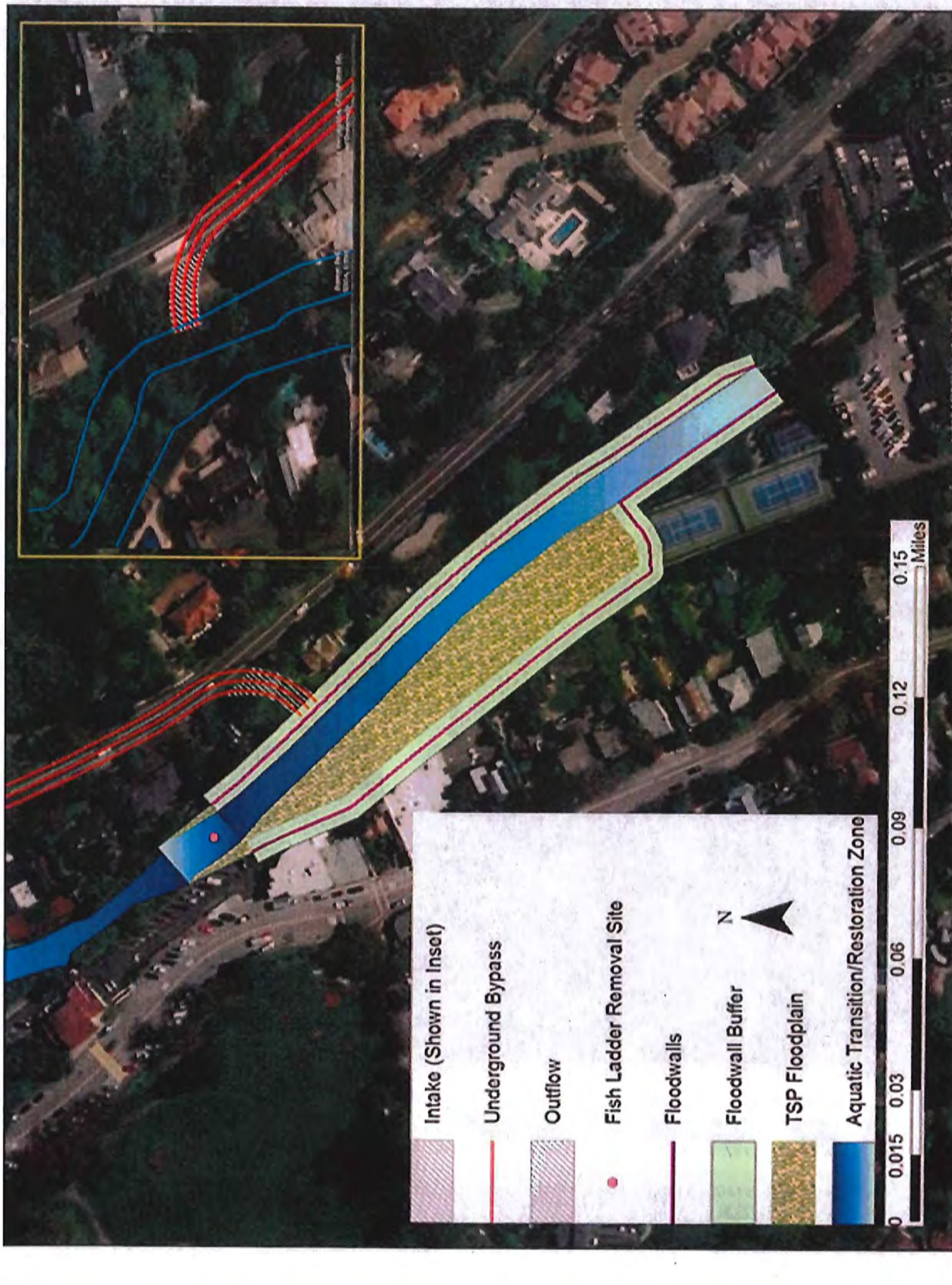


Figure 4. Areas of the Corte Madera FRMP floodwall components, as analyzed in this HEP.

The overall acreage estimates of area that would be affected with TSP implementation are shown in Table 2. The area of urban cover to be impacted is estimated as a total removed for the bypass intake and outflow areas, the Allen Park riparian corridor floodplain including landside floodwall 15-foot buffers, and the 15-foot buffers around the Granton Park and College Avenue floodwalls. Also, the area of aquatic habitat was estimated and subtracted from outlined riparian corridor outlined in Figure 2, based on the average width of the channel throughout the length of the riparian corridor. Basic HEP outputs are displayed in Appendix C.

Table 2. Estimates of existing acreage for each affected component of the Corte Madera Creek FRMP TSP.

TSP Component	Area	Current Habitat Type	Acres
Underground Bypass	Intake	Urban	0.05
	Outflow	Urban	0.06
Allen Park Riparian Corridor	Floodplain	Urban	0.84
	Floodwalls Creekside Buffer	Urban	0.42
	Floodwalls Landside Buffer	Urban	0.59
Aquatic Fish Passage	Upstream (Grading)	Aquatic	0.64
	Downstream (Bed Restoration)	Aquatic	0.72
Floodwalls	Granton Park	Urban	0.37
	College Ave	Urban	0.34

Riparian Habitat Data Collection

1. 16 transects, each 50- to 100-feet long, were laid out perpendicular to the channel. Using line intercept techniques, tree and shrub cover were recorded using a spherical densitometer at 10 foot intervals. Hydrophytic shrubs intercepted along the transect were also be recorded. Transect placement determined in the field by the HEP Team.
2. Five shrub measurements were recorded at the start, midpoint, and endpoint of the transect using a clinometer or stadia rod.
3. All overstory trees greater than 2 inches dbh: 80% of the tallest tree were measured for dbh using a Biltmore stick.

Riverine Habitat Data Collection

1. Fourteen 100- to 200-foot-long transects were placed in the channel. Streamside vegetation on both banks were recorded (trees, shrubs, grasses/forbs).
2. Canopy cover (shade at midday) was measured at 20-foot intervals from the middle of the channel along the transect using a spherical densitometer.
3. The average depth of the thalweg was measured at 10 foot intervals and the length of riffles, pools and runs will be recorded along the transects.
4. Instream cover in pool areas was estimated using ocular methods. Each pool was considered one quadrat.
5. Ocular methods were used to estimate the percent of fines in riffle run areas.

Given the assumptions used to create the models, long-term losses and gains in HUs were estimated for each model and combined equally in each future scenarios over the life of the CAP project, and then expressed as total riparian cover habitat AAHU gains or losses. To make the comparison of future TSP- and No Action-project conditions for both riparian cover habitat components, it was necessary to first develop the future No Action-project scenario for the habitat impacted within the proposed CAP Project area. This required several key assumptions that existing land uses and maintenance activities would not change in the future without the project. Given these conditions, a future No Action-project scenario was developed which was based on these assumptions: (1)

Existing habitat acreages will not change; (2) riparian habitat values will continue to develop yet overall the general ecological equilibria currently observed will be maintained; and (3) the existing hydrology will be maintained in the study area.

RESULTS AND DISCUSSION

Based on the acreage and predicted HSI values calculated over the life of the Corte Madera FRMP, AAHUs were generated for each TSP component and summarized in Appendix C. Table 3 shows the net change in AAHUs of riparian habitats resulting from the implementation of the Corte Madera FRMP TSP. Likewise, Table 4 shows the net change in AAHUs of aquatic habitats resulting from the implementation of the Corte Madera FRMP TSP. Buffer areas around floodwalls that are to be kept clear of woody vegetation were not modeled and analyzed in this HEP, other than to assess impacts of woody vegetation removal. The buffer areas should be re-seeded with natural grasses at the conclusion of the project.

Basic assumptions predict that impacted urban cover will largely be converted to natural riparian habitat cover, except in areas within 15 feet of designed floodwalls that will be maintained clear of woody vegetation. Along the Granton Park and College Avenue floodwalls, the aquatic habitat is expected to align up against the floodwalls; therefore, no creekside vegetation buffer was assumed. No maintenance of the riparian habitat cover is expected to occur. Although conditions in the riparian cover may change over the course of 50 years following TSP implementation, the overall riparian habitat value is expected to reach mature suitability levels after about 10 years of project implementation, and then be maintained through the 50-year duration. Overall, the creation of the Allen Park floodplain corridor will provide a net benefit by creating natural riparian habitats. With TSP implementation, almost all components will result in a decrease in riparian habitat value (Table 3). However, over the 50-year life of the Corte Madera FRMP, the decreases in riparian habitat value will be offset by the creation of the floodplain at Allen Park.

With the removal of the fish ladder, alterations in the streambed upstream of the existing fish ladder site will be necessary to allow for proper water flow management into the created floodplain as necessary, and to maintain suitable fish passage. However, the existing riparian vegetation cover adjacent to the wetted channel is expected to remain intact with TSP implementation. Downstream of the fish ladder for a length of about 900 feet, the aquatic habitat is expected to be restored to a condition similar to what is currently observed upstream of the existing fish ladder. Aquatic habitat conditions are expected to reach a mature state between 10 and 25 years, and then will be maintained for the duration of the 50-year life of the project. As with the riparian habitats, no maintenance of the aquatic habitats are expected with TSP implementation. Overall, upstream of the existing fish ladder no measurable difference in aquatic habitat value is expected with TSP implementation, yet aquatic habitat is expected to be improved with the restoration of a natural creek corridor for the 900-foot length downstream of the existing fish ladder.

Table 3. Net change in average annual habitat units (AAHUs) for the riparian habitats affected by the Corte Madera FRMP TSP.

TSP Component *Strata*	Area Affected (acres)	AAHUs Without Project	AAHUs With Project	Net Change in AAHUs
Bypass Intake (Total)* *Shrub* *Main Canopy*	0.05	0.02 *0.01* *0.01*	0.00 *0.00* *0.00*	-0.02
Bypass Outflow (Total)* *Shrub* *Main Canopy*	0.06	0.03 *0.02* *0.01*	0.00 *0.00* *0.00*	-0.03
Allen Park Floodplain (Total) *Shrub* *Main Canopy*	0.84	0.73 *0.23* *0.50*	1.49 *0.78* *0.71*	0.76
Allen Park Floodwall Creekside Buffer (Total) *Shrub* *Main Canopy*	0.42	0.20 *0.12* *0.08*	0.04 *0.04* *0.00*	-0.16
Allen Park Floodwall Landside Buffer (Total) *Shrub* *Main Canopy*	0.59	0.24 *0.16* *0.08*	0.06 *0.06* *0.00*	-0.18
Granton Park Floodwall (Total) *Shrub* *Main Canopy*	0.37	0.15 *0.10* *0.05*	0.04 *0.04* *0.00*	-0.11
College Ave Floodwall (Total) *Shrub* *Main Canopy*	0.34	0.14 *0.09* *0.05*	0.04 *0.04* *0.00*	-0.10
Riparian Habitat (Total) ***Shrub*** ***Main Canopy***	2.67	1.51 0.73 0.78	1.67 0.96 0.71	0.16

* The Underground Bypass Intake and Outflow areas are considered to consist of existing riparian habitat. All other terrestrial components are considered existing urban landscape that will be converted to riparian woodland cover.

Table 4. Net change in Average Annual habitat Units (AAHUs) for the aquatic habitats affected by the Corte Madera FRMP TSP.

TSP Component	Area Affected (acres)	AAHUs Without Project	AAHUs With Project	Net Change in AAHUs
Transition Grading	0.64	0.63	0.63	0.00
Natural Bed Restoration Area	0.72	0.0	0.68	0.68
Total	1.36	0.63	1.31	0.68

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APPENDIX B

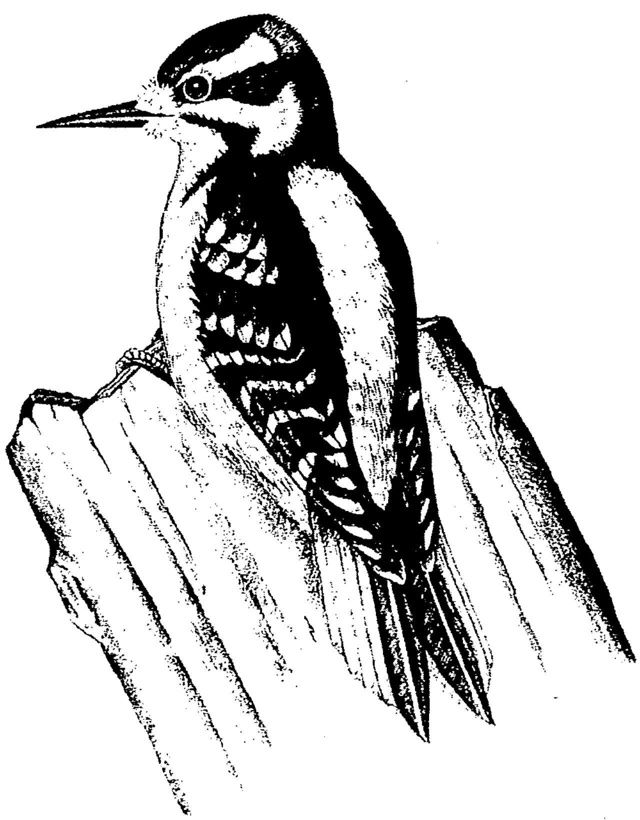
HABITAT SUITABILITY INDEX MODELS
FOR
HABITAT EVALUATION PROCEDURES

CORTE MADERA CREEK FLOOD RISK REDUCTION GENERAL REEVALUATION REPORT

AUGUST 2018

BIOLOGICAL REPORT 82(10.146)
SEPTEMBER 1987

HABITAT SUITABILITY INDEX MODELS: HAIRY WOODPECKER



Fish and Wildlife Service

U.S. Department of the Interior

MODEL EVALUATION FORM

Habitat models are designed for a wide variety of planning applications where habitat information is an important consideration in the decision process. However, it is impossible to develop a model that performs equally well in all situations. Assistance from users and researchers is an important part of the model improvement process. Each model is published individually to facilitate updating and reprinting as new information becomes available. User feedback on model performance will assist in improving habitat models for future applications. Please complete this form following application or review of the model. Feel free to include additional information that may be of use to either a model developer or model user. We also would appreciate information on model testing, modification, and application, as well as copies of modified models or test results. Please return this form to:

Habitat Evaluation Procedures Group
U.S. Fish and Wildlife Service
2627 Redwing Road, Creekside One
Fort Collins, CO 80526-2899

Thank you for your assistance.

Species ______________ Geographic Location ____________________________

Habitat or Cover Type(s) ________________________________

Type of Application: Impact Analysis ____ Management Action Analysis _____
Baseline _____ Other ______________________________________

Variables Measured or Evaluated ____________________________

____

____

____

Was the species information useful and accurate? Yes ____ No ____

If not, what corrections or improvements are needed?____________________

____

____

____

Were the variables and curves clearly defined and useful? Yes ____ No ____

If not, how were or could they be improved? ______________________________

____

____

____

Were the techniques suggested for collection of field data:

Appropriate? Yes ____ No ____

Clearly defined? Yes ____ No ____

Easily applied? Yes ____ No ____

If not, what other data collection techniques are needed? ______________

____

____

____

Were the model equations logical? Yes ____ No ____

Appropriate? Yes ____ No ____

How were or could they be improved? ______________________________

____

____

____

Other suggestions for modification or improvement (attach curves, equations, graphs, or other appropriate information) ______________

____

____

____

Additional references or information that should be included in the model:

____

____

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____

Model Evaluator or Reviewer ______________________ Date ____________

Agency ____

Address ____

____

____

Telephone Number Comm: ____________________ FTS ____________________

Biological Report 82(10.146)
September 1987

HABITAT SUITABILITY INDEX MODELS: HAIRY WOODPECKER

by

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Suggested citation:

Sousa, P.J. 1987. Habitat suitability index models: hairy woodpecker. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.146). 19 pp.

PREFACE

This document is part of the Habitat Suitability Index (HSI) model series [Biological Report 82(10)], which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. This information provides the foundation for the HSI model and may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model section documents the habitat model and includes information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The HSI Model section includes information about the geographic range and seasonal application of the model, its current verification status, and a list of the model variables with recommended measurement techniques for each variable.

The model is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts. Habitat information about wildlife species frequently is represented by scattered data sets collected during different seasons and years and from different sites throughout the range of a species. The model presents this broad data base in a formal, logical, and simplified manner. The assumptions necessary for organizing and synthesizing the species-habitat information into the model are discussed. The model should be regarded as a hypothesis of species-habitat relationships and not as a statement of proven cause and effect relationships. The model may have merit in planning wildlife habitat research studies about a species, as well as in providing an estimate of the relative suitability of habitat for that species. User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to:

Resource Evaluation and Modeling Section
U.S. Fish and Wildlife Service
National Ecology Center
2627 Redwing Road
Ft. Collins, CO 80526-2899

CONTENTS

ACKNOWLEDGMENTS

A field validation of an earlier version of the HSI model for the hairy woodpecker was conducted under the direction of Ms. L. Jean O'Neil, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. The field validation was based on habitat evaluation by the following individuals:

Dr. F.J. Alsop, III, East Tennessee State University, Johnson City

Dr. C.E. Bock, University of Colorado, Boulder

Dr. R.N. Conner, U.S. Forest Service, Nacogdoches, TX

Dr. J.A. Jackson, Box Z, Mississippi State, MS

Dr. F.C. James, Florida State University, Tallahassee

Dr. B.J. Schardien Jackson, Mississippi State, MS

Mr. J. Teaford and Dr. T. Roberts, Waterways Experiment Station, and Dr. J. Wakeley, Pennsylvania State University, assisted in the study design, data collection, data analysis, and model modification. The field validation resulted in several improvements in the model. The efforts of all of those involved in the field validation are very much appreciated.

Earlier drafts of the model were reviewed by Dr. R.N. Conner and Dr. C.E. Bock. Their review comments led to significant improvements in the model and are appreciated.

Word processing of this document was provided by C. Gulzow, D. Ibarra, P. Gillis, and E. Barstow. The cover was illustrated by J. Shoemaker.

HAIRY WOODPECKER (*Picoides villosus*)

HABITAT USE INFORMATION

General

The hairy woodpecker (*Picoides villosus*) breeds and winters throughout most of North America (American Ornithologists' Union 1983). The species is a primary cavity nester in "deciduous or coniferous forest, well-wooded towns and parks, and open situations with scattered trees ..." (American Ornithologists' Union 1983:391).

Food

Animal matter, such as beetle larvae (Coleoptera), ants (Hymenoptera), caterpillars (Lepidoptera), and adult beetles, accounted for 78% of the hairy woodpecker's annual diet, based on 382 stomachs collected throughout North America (Beal 1911). The diet is supplemented by fruit and mast (Beal 1911; Hardin and Evans 1977). Hairy woodpeckers forage extensively for seeds in winter (Jackman 1975); in Colorado, they foraged extensively during the non-reproductive season on the seeds of ponderosa pine (*Pinus ponderosa*) (Stallcup 1966). Hairy woodpeckers may concentrate in areas of insect outbreaks in response to the increased food source (Koplin 1967; Massey and Wygant 1973). The hairy woodpecker was considered to be a primary predator of the Southern pine beetle (*Dendroctonus frontalis*) in east Texas (Kroll and Fleet 1979).

Hairy woodpeckers are considered opportunistic foragers (Raphael and White 1984); they forage on a variety of substrates, including tree trunks, stumps, exposed roots (Lawrence 1966), snags, downed logs, the ground (Mannan et al. 1980), and logging debris in recent clearcuts (Conner and Crawford 1974). In California, hairy woodpeckers foraged on snags 51% of the time and on live trees 47% of the time (Raphael and White 1984). During winter, hairy woodpeckers in Virginia foraged most often on dead trees or dead parts of live trees (Conner 1980). Hairy woodpeckers in New York exhibited a sexual difference in the selection of winter foraging sites; males foraged on dead trees significantly more often than females, and females foraged significantly more often on live trees (Kisiel 1972). Both sexes used a variety of tree species for foraging sites. A variety of tree species was also used for foraging by hairy woodpeckers in Sierra Nevada forests (Raphael and White 1984). Snags used for foraging in Douglas-fir (*Pseudotsuga menziesii*) forests in Oregon averaged 61 cm dbh and ranged from 13 to 173 cm dbh (Mannan 1977). The average foraging height of hairy woodpeckers in Iowa was 8.8±1.55 m, and the average diameter of limbs used for foraging was 6.52±1.04 cm (Gamboa and Brown 1976). Hairy woodpeckers in New York typically foraged on limbs 5 to 10 cm in diameter (Kisiel 1972).

Hairy woodpeckers in southwestern Virginia foraged in "... habitats with relatively dense vegetation near the ground" (Conner 1980:121) in comparison to foraging habitat selected by other species of woodpeckers, especially the downy woodpecker (P. pubescens).

Water

No specific information on water requirements of the hairy woodpecker was found in the literature.

Cover

Hairy woodpeckers inhabit a wide variety of forest cover types. For example, they inhabit Douglas-fir forests (Mannan et al. 1980), ponderosa pine forests (Diem and Zeveloff 1980), pinyon-juniper (Pinus edulis - Juniperus spp.) woodlands (Balda and Masters 1980), eastern deciduous forests (Conner et al. 1975), and riparian communities (Stauffer and Best 1980). Winter population densities of hairy woodpeckers in Illinois were positively correlated with the number of trees >56 cm dbh and with a diversity of genera and species of large trees (Graber et al. 1977). Hairy woodpeckers in Oregon use the shrub/sapling (8 to 15 yr) and second-growth (16 to 40 yr) stages of Douglas-fir forests, but they do not nest in these younger stages (Meslow and Wight 1975). Jackman (1975) stated that hairy woodpeckers inhabit second-growth, partially thinned, and other altered forest types; however, hairy woodpeckers were reported more frequently (95% of 40 breeding bird censuses) in mature undisturbed habitats in the northern hardwoods region than in disturbed and successional habitats (43% of 30 censuses) (Noon et al. 1979).

Hairy woodpeckers use tree cavities for roosting and winter cover, as well as for nesting and rearing young (Thomas et al. 1979), and they will excavate new cavities in the fall to be used for roosting (Jackman 1975).

Reproduction

The hairy woodpecker is a primary cavity nester that is able to adapt to a wide variety of habitats (Kilham 1968). In the Pacific Northwest, hairy woodpeckers require standing dead trees and live trees with rotted heartwood (Jackman 1975). Similarly, hairy woodpeckers in Virginia exhibited a definite preference for trees with heartrot (Conner et al. 1975; Conner et al. 1976). Thomas et al. (1979), however, listed the hairy woodpecker as a species that usually excavates in sound wood. Runde and Capen (1987) found that the amount of sound wood varied widely (based on a visual estimate) in live trees used for nesting by hairy woodpeckers; 11 of 21 nests were in live trees. A possible exception to the apparently general use of live or dead trees for nest sites is that hairy woodpeckers do not nest in Engelmann spruce (Picea engelmannii) forests in the Pacific Northwest (Jackman 1975). Haapanen (1965 cited by Smith 1980:264) found that "of all the woodpeckers found in spruce-fir forests, apparently only the Northern 3-toed Woodpecker [Picoides tridactylus] is capable of making holes in the dense wood of living spruce trees." R.N. Conner (U.S. Forest Service, Nacogdoches, TX; letter dated February 19, 1986) suggests, however, that Engelmann spruce and other North American spruces are relatively soft-wooded trees (compared to oaks) that can be easily excavated by some species of woodpeckers. He suggests that the lack of use may be due to the absence of heartwood decay or to resin produced by spruce rather than to the density of the spruce wood. Whatever the reason for the observed lack of use, Conner believes that insufficient data exist to categorically classify live spruces as unsuitable for excavation by hairy woodpeckers.

Preferred nesting areas of hairy woodpeckers in east Tennessee were characterized by a large number of trees >23 cm dbh and associated high canopy biomass (Anderson and Shugart 1974). Hairy woodpeckers in Virginia apparently preferred areas with high stem density, but nested in areas with a wide range of basal areas, canopy heights, stem densities, and distances from cleared areas (Conner and Adkisson 1977). In northwestern Washington, hairy woodpecker nests were found in a variety of successional stages, though most were in, or at the edge of, old-growth forests (Zarnowitz and Manuwal 1985). Hairy woodpeckers in Washington are found in open rather than dense stands of timber (Larrison and Sonnenberg 1968), and in California's Sierra Nevada they prefer forests of low to moderate canopy closure (<70%) (Verner 1980). Both understocked and fully stocked stands in Virginia were suitable nesting areas as long as decayed trees were present (Conner et al. 1975). Hairy woodpeckers have even been reported nesting in the grass-forb stage of mixed coniferous forest regeneration by using stumps <1.5 m tall (Verner 1980).

Hairy woodpeckers require trees with a minimum dbh of 25 cm and a minimum height of 4.6 m for nesting (Thomas et al. 1979). Raphael and White (1984:24) found that "...diameter was the tree characteristic most closely correlated with nesting use" for 17 cavity-nesting birds. Conner and Adkisson (1976) found that canopy height had a greater influence on distinguishing between "possible nesting habitat" and "not nesting habitat" than did either basal area or stem density. In Vermont, no significant difference in mean tree height was detected between nest trees and adjacent non-nest trees (Runde and Capen 1987). Diameter at breast height (dbh) and diameter at nest height (dnh) were significantly greater for nest trees than non-nest trees ($\bar{x}$ dbh:27.1±1.3 cm vs. 23.9±0.7 cm, $P<0.05$; $\bar{x}$ dnh:22.4±1.1 cm vs. 13.2±9.6 cm, $P<0.01$). The probable optimum diameter range for hairy woodpecker nest trees is 25 to 35 cm dbh, and the probable optimum height range for nest trees is 6 to 12 m (Evans and Conner 1979). In Douglas-fir forests, however, hairy woodpeckers nest in older second-growth (41 to 120 yr) and mature (120+ yr) forests (Meslow and Wight 1975); these age classes are presumably taller than the optimum range suggested by Evans and Conner (1979). The average height of eight trees used for nesting in a Colorado aspen forest was 18 m, and ranged from about 11 to 21.3 m (Scott et al. 1980). Ten trees used for nesting in Virginia averaged 13.0 m tall and ranged from 4 to 26.5 m (Conner et al. 1975). The diameter of the tree at the cavity level in these 10 trees averaged 25.2 cm and ranged from 20 to 46 cm. In California, 19 nest trees averaged 13.7 m tall with an average diameter at the cavity level of 36.3±2.09 cm (Raphael and White 1984). Table 1 summarizes tree condition, nest heights, and nest tree diameter from several studies.

Table 1. Characteristics of nest sites selected by hairy woodpeckers in several study areas.

Source	Number of nests (n)	Tree condition Dead	Live	Average nest height (range)	Average nest tree dbh (range)
Lawrence (1966) (NH)	11 (n=7 for dbh)	1	10	10.5 m (4.5-14 m) 34.9 ft (15-45 ft)	28 cm (25.4-34.8 cm) 11.1 inches (10-13.7 inches)
Conner et al. (1975) (VA)	10	5	5[a]	8.8 m (2.4-19.8 m) 28.9 ft (7.9-65 ft)	40.6 cm (20-64 cm) 16 inches (7.9-25.2 inches)
Jackman (1975) (OR)	33	?	?	7.6 m (5-10 m) 24.9 ft (16.4-32.8 ft)	?
Graber et al. (1977) (IL)	17	6	11[b]	4.6-10.7 m 15-35 ft	?
Mannan (1977) (OR)	7	?	?	18.2 m (7.9-41.8 m) 59.4 ft (25.9-137.1 ft)	92 cm (48-172 cm) 36.2 inches (18.9-67.8 inches)
Scott et al. (1980) (CO)	8	2	6	10 m (6.7-15.2 m) 33 ft (22-50 ft)	38 cm (25.4-58.4 cm) 15 inches (10-23 inches)
Raphael and White (1984) (CA)	19	16	3[c]	4.9±0.69 m 16.1±2.26 ft	43.8 cm 17.2 inches
Zarnowitz and Manuwal (1985) (WA)	16	16[d]	-	13±12 m 42.6±39.4 ft	41±13 cm 16.1±5.1 inches
Runde and Capen (1987) (VT)	21	10	11[e]	17.5±1.2 m 57.4±3.9 ft	27.1±1.3 cm 10.7±0.5 inches

[a] Four of the five nests in live trees were located in dead portions of the trees; the fifth was located in a totally live oak tree with a decayed heartwood (Conner, unpubl.).

[b] About one-half of these nests were located in dead portions of the trees.

[c] Located in dead portions of live trees.

[d] All nests located in broken-top trees.

[e] All 11 cavities were drilled through live wood.

Hairy woodpeckers will excavate in both hard and soft snags (Evans and Conner 1979); however, hairy woodpecker breeding densities were significantly positively correlated ($P \leq 0.01$) with soft snags in Iowa riparian forests (Stauffer and Best 1980). The hairy woodpecker was categorized as a soft snag excavator in Sierra Nevada forests (Raphael and White 1984). Evans and Conner (1979) estimated that 200 snags were necessary in order to support the maximum population of hairy woodpeckers on 40 ha of forest. Their estimate was based on a minimum annual need of four cavities per pair, and an assumption that only 10% of the available snags would be suitable for use. Snag density requirements decreased in direct proportion to the percentage of maximum population desired; e.g., 160 snags are required to support 80% of the maximum population, and 100 snags would support 50% of the maximum population. A similar estimate for the Blue Mountains of Oregon and Washington was that 180 snags/40 ha are necessary to support maximum populations of hairy woodpeckers (Thomas et al. 1979). Raphael and White (1984) distinguished between hard and soft snags in estimating the density of snags required to support the maximum density of hairy woodpeckers. They assumed a maximum density of 16 pairs/40 ha, an annual rate of excavation of 4 cavities/pair, and a reserve of 3 suitable cavities per pair to arrive at an estimate of 192 suitable snags/40 ha to support the maximum density. They further estimated that 4 hard snags are required to produce 1 soft snag, resulting in an estimate of 768 "hard snag equivalents" (Raphael and White 1984:56) per 40 ha. Although low numbers of snags can, in theory, support low-density woodpecker populations, enough snags to support 40% of the maximum population was assumed to be the minimum that will support a self-sustaining population of hairy woodpeckers in the Pacific Northwest (Bull 1978).

Interspersion and Composition

Territory size in a mature bottomland forest in Illinois averaged 1.1 ha and ranged from 0.6 to 1.5 ha (Calef 1953 cited by Graber et al. 1977). Reported territory size of hairy woodpeckers in the Blue Mountains of Washington and Oregon averaged 2.4 to 3.6 ha (Thomas et al. 1979). Evans and Conner (1979), however, reported an average territory size of 8 ha based on available literature, whereas territories reported for two hairy woodpeckers in Kansas were 9 and 15 ha (Fitch 1958). Home range and territory size are strongly influenced by habitat quality and, therefore, can be quite variable (Conner, unpubl.).

In a study of bird use of various sized forested habitats in New Jersey, hairy woodpeckers did not occur in areas of <2 ha (Galli et al. 1976). A minimum width of riparian forest necessary to support breeding populations of hairy woodpeckers in Iowa was 40 m (Stauffer and Best 1980). Robbins (1979) compared frequency of occurrence of hairy woodpeckers at Breeding Bird Survey stops in Maryland to the amount of contiguous forested area. The greatest decrease in frequency of occurrence was recorded at 4 ha of contiguous forested habitat, and Robbins (1979) proposed this value as a preliminary estimate of the minimum area necessary to support a viable breeding population of hairy woodpeckers. Conner (unpubl.), however, believes that 4 ha may represent the minimal area that hairy woodpeckers will use, but that such a small area could not support a viable breeding population, which he considers to be a minimum of 250 pairs. He suggested a minimum habitat area of 12 ha to support several breeding pairs of hairy woodpeckers (R.N. Conner, U.S. Forest Service, Nacogdoches, TX; letter dated December 1, 1981).

Although the hairy woodpecker is considered a resident species throughout its range, altitudinal migrations between mountainous areas and lower elevations do occur (Bailey and Niedrach 1965).

Special Considerations

The hairy woodpecker has been classed as a "tolerant species" to habitat alteration in Iowa (Stauffer and Best 1980), but also has been suggested as a sensitive environmental indicator of the ponderosa pine community (Diem and Zeveloff 1980).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application within forested habitat throughout the entire range of the hairy woodpecker. Use of the model differs, however, between forests in the eastern United States and the western United States. The differences in application are described in the model.

Season. This model was developed to evaluate the year-round habitat of the hairy woodpecker.

Cover types. This model was developed to evaluate habitat in the following forested cover types: Deciduous Forest (DF), Evergreen Forest (EF), Deciduous Forested Wetland (DFW), and Evergreen Forested Wetland (EFW) (terminology follows U.S. Fish and Wildlife Service 1981).

Minimum habitat area. A minimum of 4 ha of forested habitat has been estimated to be necessary to support a viable breeding population of hairy woodpeckers (Robbins 1979), although Conner (unpubl.) believes that such a small area may represent the minimum needed to support one pair rather than a viable breeding population. Conner (unpubl.) suggested 12 ha as a reasonable estimate of the area needed to support several pairs of hairy woodpeckers. Additionally, forested riparian zones should be at least 40 m wide to be considered as potential breeding habitat for hairy woodpeckers (Stauffer and Best 1980).

Verification level. An earlier draft of the HSI model for the hairy woodpecker was used in a field evaluation of model outputs compared to expert opinion (O'Neil et al. 1988). The following species experts participated in the field evaluation:

Dr. F.J. Alsop, III, East Tennessee State University, Johnson City

Dr. C.E. Bock, University of Colorado, Boulder

Dr. R.N. Conner, U.S. Forest Service, Nacogdoches, TX

Dr. J.A. Jackson, Box Z, Mississippi State, MS

Dr. F.C. James, Florida State University, Tallahassee

Dr. B.J. Schardien Jackson, Mississippi State, MS

Initial results indicated that outputs from the earlier model were poorly correlated ($r=0.07$, $P>0.50$) with habitat ratings by experts for 40 sites in eastern Tennessee (O'Neil et al. 1988). Important habitat criteria identified by the experts were used to modify the model in an attempt to more closely mimic the procedures used by experts to rate habitats. The major changes to the model as a result of the field evaluation were (1) optimum suitability for the average diameter of overstory trees was changed from 25 to 38 cm; (2) snags were assigned greater importance than live trees for nesting; (3) the variable "percent canopy cover of pines" was added to reflect a strong negative correlation ($r=-0.91$, $P<0.001$) between this variable and habitat ratings by species authorities; (4) the mathematical function used to calculate the cover suitability index was changed from a geometric mean to a multiplicative function; and (5) the suitability relationship for tree canopy closure was changed from a preference for moderate canopy closure to a preference for dense forest canopy. Correlation of outputs from the modified model to habitat ratings by species authorities improved considerably ($r=0.82$, $P<0.001$) (O'Neil et al. 1988).

All of the changes to the model as a result of the field evaluation were based on input from species experts and reflect hairy woodpecker ecology in forests in the eastern United States. The variable "percent canopy cover of pines" is not recommended as an appropriate variable in western forests; use of the model in western vs. eastern forests is described below. The current model is the direct result of the field evaluation; it has not been field tested.

Model Description

Overview. The hairy woodpecker can satisfy all of its habitat requirements within any one of the forested cover types listed above. Reproductive and cover needs are evaluated in this model. Although sufficient food is an obvious life requisite of the hairy woodpecker, I assume in this model that food will never be more limiting than cover and reproductive requirements and that water is not a limiting factor.

The following sections identify important habitat variables, describe suitability levels of the variables, and describe the relationships between variables.

Reproduction component. The hairy woodpecker is able to adapt to a variety of habitats, but suitable reproductive habitats must (1) be dominated by trees of sufficient size and decay for nesting, (2) have adequate snag densities, or (3) have some combination of the two.

The number of snags ≥25.4 cm dbh necessary to support maximum densities of hairy woodpeckers has been estimated to range from 180/40 ha (Thomas et al. 1979) to 200/40 ha (Evans and Conner 1979), or 4.5 to 5 snags/ha; a snag density of 5/ha is assumed to represent optimal conditions for reproduction (Figure 1a). This estimate refers specifically to nesting and roosting requirements and may not adequately satisfy foraging needs (Conner, unpubl.). Potential population density is assumed to decrease proportionally with a decrease in snag density. Although I assume in this model that low snag densities will support low woodpecker densities, Bull (1978) assumed that snag densities <40% of those needed for maximum population density would not support a self-sustaining population.

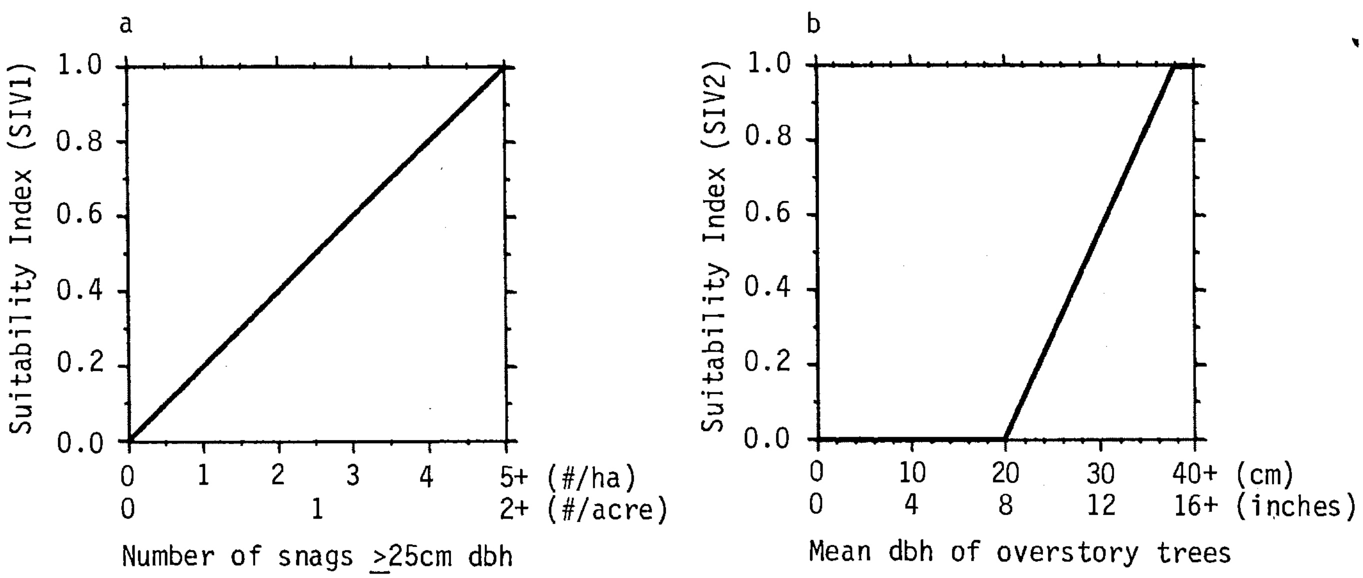

Figure 1. Relationships between variables used to evaluate reproductive habitat for the hairy woodpecker and suitability levels for the variables.

Hairy woodpeckers can excavate cavities in live trees provided that heartrot is present, and thus may inhabit a forested area even in the absence of snags. Runde and Capen (1987) believed that trees >30 cm dbh would be most useful to hairy woodpeckers, downy woodpeckers, and yellow-bellied sapsuckers (Syphrapicus varius). For this model, I assume that if the average dbh of overstory trees is ≥38 cm, then trees will be of optimum size for nesting. I assume that an adequate number of available (i.e., with heartrot) live trees will be present if the average dbh of overstory trees is ≥38 cm. There is little evidence correlating tree diameter and presence of heartrot, but the alternative is to physically examine trees for heartrot; this level of detail is presumed to be too great for the typical application of this model. Use of the average dbh of overstory trees does not consider the absolute number of available live trees. I assume that if an area meets the minimum requirements to be classified as a forest and is >4 ha, then the total number of trees available for potential nesting will be optimal. Assuming that adequate numbers of trees are present, the size and condition of the trees will determine whether the nesting potential will be low or high. The minimum reported dbh of a tree used for nesting by hairy woodpeckers is 20.1 cm (Conner et al. 1975). Thus, I assume that optimal conditions for this variable exist when the average dbh of overstory trees is ≥38 cm, and that conditions are unsuitable when the average dbh of overstory trees is ≤20 cm (Figure 1b). The values defining optimum and suitable levels of this variable are based on results of the field test mentioned earlier.

Overall nesting suitability is a function of the availability of snags or live trees. In the field test, experts consistently rated habitats without snags lower than habitats with snags (O'Neil et al. 1988), presumably because hairy woodpeckers cannot excavate in undecayed trees and prefer to forage on dead snags (Conner, unpubl.). Habitat suitability ratings in habitats without snags that were otherwise suitable were generally between 0.7 and 0.8 (on a 0-1 scale). I assume, therefore, that habitats without snags (i.e., all potential nest sites are in live trees) will have a maximum suitability rating of 0.75. An overall suitability index for nesting (SIN), based on the relationships described above, can be determined with Equation 1.

$$SIN = SIV1 + (0.75 \times SIV2) \qquad (1)$$

[Note: If the value resulting from Equation 1 exceeds 1.0, it should be set to 1.0.]

Cover component. Besides having sufficient potential nest sites, at least three other habitat factors affect the overall suitability of a habitat for hairy woodpeckers. These three factors are the seral stage of a forest stand, the degree of canopy cover of the forest, and the proportion of pines in the canopy. These variables are assumed to influence food availability, foraging, nesting suitability, and cover, but are aggregated into a cover component in this model. Because these factors affect overall habitat suitability, they will be used in this model as modifiers of the reproductive value.

A measure of the seral stage of a forest is the average diameter of the overstory trees. Hairy woodpeckers may inhabit young forests, but at lower densities than in older forests. Because they do inhabit forests in a variety of seral stages, however, this habitat variable should not be strictly limiting. I assume in this model that the optimal seral stage exists when the average dbh of overstory trees is >25 cm (Figure 2a). When the average dbh of overstory trees is <15 cm, suitability is assumed to be one-half of optimum, i.e., a suitability index of 0.5.

The literature suggests that hairy woodpeckers apparently prefer forests of moderate canopy cover. Habitat ratings by species experts in the field test, however, tended to be higher in forest stands with a dense canopy, except that closed canopy stands were generally rated lower than stands with <100% canopy cover (O'Neil et al. 1988). I assume that optimal conditions for this variable occur at 85% to 90% (Figure 2b) with complete canopy cover representing less than optimal habitat. I further assume that canopy cover <15% will provide unsuitable habitat conditions. Since the definition of a forest is a cover type with at least 25% tree canopy cover, any forest will have canopy conditions of some positive suitability level for hairy woodpeckers.

Hairy woodpeckers inhabit a variety of deciduous, coniferous, and mixed deciduous-coniferous habitats. Habitat ratings by experts were negatively correlated ($r=-0.91$, $P<0.001$) with the percent canopy closure of pines; sites completely dominated by pines received relatively low habitat ratings (O'Neil et al. 1988). I assume in this model that an increase in the canopy cover of pines in a stand will generally reflect a decrease in habitat suitability for the hairy woodpecker, although a small amount of pines (≤10% canopy cover) is assumed to contribute to the diversity of cover and prey (Figure 2c). Sites completely dominated by pines are assumed to have a suitability index for this variable of 0.2. The apparent influence of pines on hairy woodpecker habitat suitability described above probably does not apply in western coniferous forests (C.E. Bock, Environmental, Population and Organismic Biology, University of Colorado, Boulder; letter dated February 24, 1986). I recommend that the variable "percent canopy cover of pines" be deleted from the model for application in western coniferous forests. It is unclear whether a similar negative relationship exists between other species of conifers in eastern forests and perceived habitat suitability for the hairy woodpecker.

Results from the field test of the earlier model indicated that the product of the suitability indices (Equation 2) for the cover component variables most closely reflected habitat ratings by species experts (O'Neil et al. 1988).

$$SIC = SIV3 \times SIV4 \times SIV5 \qquad (2)$$

As long as an area is classified as a forested type, all of the variables in Equation 2 will be greater than zero, and the index value for the cover component will likewise be greater than zero.

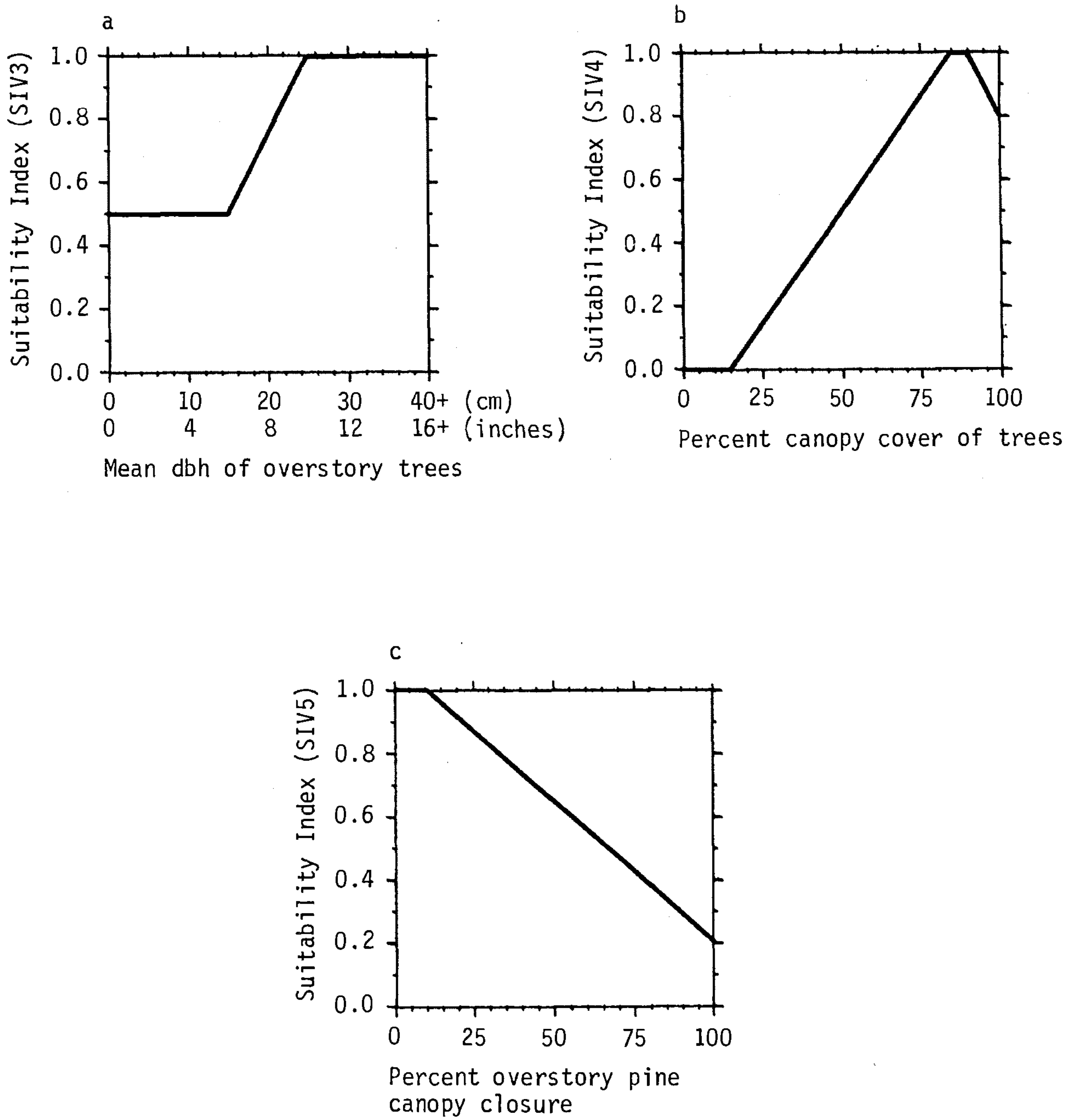

Figure 2. Relationships between variables used to evaluate cover for the hairy woodpecker and suitability levels for the variables.

HSI determination. The suitability index for the cover component is assumed to directly modify the suitability index for the reproduction component (Equation 3) to yield an overall HSI value for the hairy woodpecker in the habitat being evaluated. At optimal cover component conditions (i.e., SIC=1.0), the reproduction component will determine the habitat suitability index. If cover conditions are anything less than optimum, then the reproduction value will be reduced based on the quality of the cover conditions.

$$HSI = SIN \times SIC, \text{ or}$$

$$HSI = [SIV1 + (0.75 \times SIV2)] \times (SIV3 \times SIV4 \times SIV5) \qquad (3)$$

[Note: In instances where SIN >1.0, it should be set equal to 1.0 prior to using Equation 3.]

Application of the Model

Summary of model variables. Several habitat variables are used in this model to evaluate habitat suitability for the hairy woodpecker. The relationships between habitat variables, life requisites, cover types, and an HSI are summarized in Figure 3. The definitions and suggested measurement techniques (Hays et al. 1981) for the variables used in this model are listed in Figure 4.

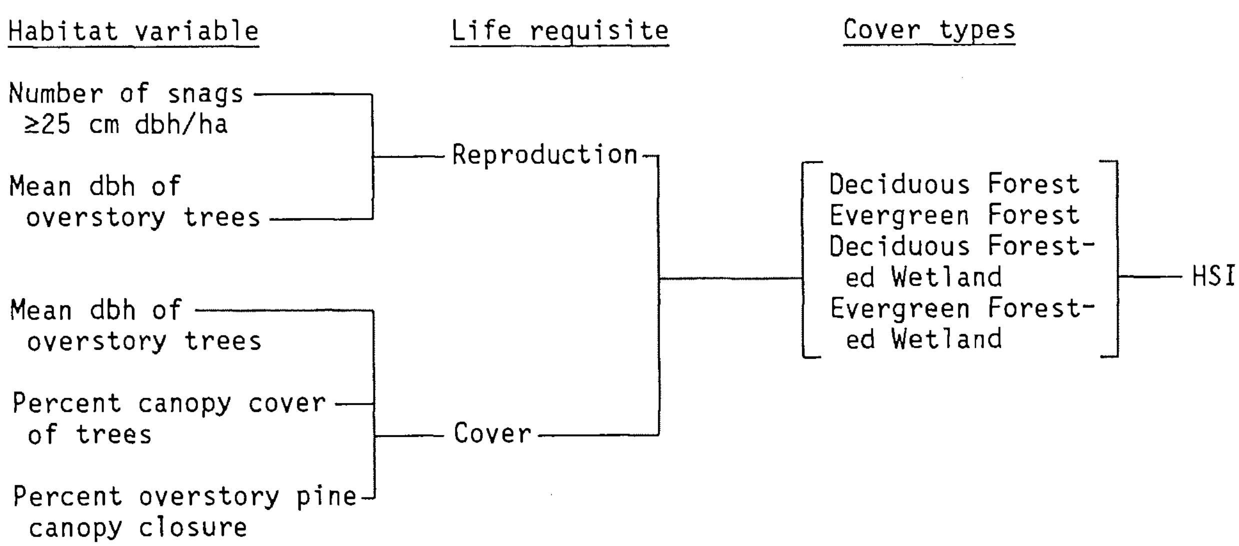

Figure 3. Relationships of habitat variables, life requisites, and cover types to the HSI for the hairy woodpecker.

Variable (definition)	Cover types	Suggested technique
Number of snags ≥25 cm dbh per ha [actual or estimated number of standing dead trees ≥25 cm dbh and ≥1.8 m tall. Trees in which ≥50% of the branches have fallen, or are present but no longer bear foliage, are to be considered snags].	DF,EF,DFW, EFW	Quadrat, remote sensing
Mean dbh of overstory trees [the mean diameter at breast height (1.4 m) above the ground of those trees that are ≥80% of the height of the tallest tree in the stand].	DF,EF,DFW, EFW	Diameter tape
Percent canopy cover of trees [the percent of the ground surface that is shaded by a vertical projection of all woody vegetation >6.0 m tall].	DF,EF,DFW, EFW	Line intercept, remote sensing
Percent overstory pine canopy closure [the percent of the ground surface that is shaded by a vertical projection of all pines (*Pinus* spp.) >6.0 m tall and ≥80% of the height of the tallest tree in the stand; recommended for use in eastern U.S. forests only (see text for explanation)].	DF,EF,DFW, EFW	Line intercept, remote sensing

Figure 4. Definitions of variables and suggested measuring techniques.

Model assumptions. A number of assumptions were made in the development of this HSI model.

1. The criteria identified for evaluation of hairy woodpecker habitat are generally assumed to be appropriate throughout the range of the species. Many of the variables and variable relationships identified in the model resulted from a field test of an earlier HSI model in eastern Tennessee. As a result, the model is probably best suited for application in the southeastern United States. No information is available to indicate the model's applicability to other parts of the United States, except there is adequate information that the presumed negative influence of pines does not apply to western U.S. forests (see number 7 below).

2. Nest sites can be provided by a combination of snags and live trees, but live trees in the absence of snags cannot provide optimal nesting habitat.

3. A measure of the average diameter at breast height of overstory trees is assumed to be an adequate estimator of the suitability of live trees for nesting. An adequate number of trees in suitable condition (i.e., with decayed heartwood) is assumed to be present as long as the cover type is classified as a forest (i.e., has ≥25% canopy cover) and tree diameter is suitable.

4. All tree species are assumed to be available for excavation by hairy woodpeckers. It is possible that some species may not typically have decayed heartwood and, therefore, will be unsuitable for excavation. It is also possible that some tree species will be unsuitable for excavation because of resins or the density of the wood. Little definitive evidence is available, however, to determine whether some tree species are absolutely unsuitable for excavation by hairy woodpeckers.

5. Hairy woodpeckers can inhabit a variety of forested habitats, but potential nesting in live trees will only be provided by older forest stands with large trees.

6. Hairy woodpeckers prefer forest stands with a dense canopy. This assumption may be valid in the southeastern United States but may be invalid in the western United States, where the forest canopy is generally less dense than in the east. The relationships described for percent canopy cover of trees and habitat suitability (Figure 2b) may need to be redefined for use in western forest habitat if the standard of comparison in such applications is intended to be the best regional habitat. Use of the model without modification will yield outputs based on a standard of comparison developed in the southeastern United States.

7. The presence of pines above a minimal level (10%) is considered to be a negative factor in habitat suitability for the hairy woodpecker in this model (Figure 2c). Pine and other coniferous forests in the western United States, however, are regularly used by hairy woodpeckers. I recommend that this variable be eliminated for application in western coniferous forests.

8. The hairy woodpecker breeds and winters throughout most of North America. I assume in this model that the year-round suitability of a habitat is a function of the habitat suitability during both the reproductive and nonreproductive seasons. Model users who wish to evaluate either of the seasons rather than both can simply use the appropriate portion of this model. Users should be aware that model outputs in such instances will refer only to a portion of the year-round needs of the hairy woodpecker.

SOURCES OF OTHER MODELS

Conner and Adkisson (1976) developed a model to distinguish between "possible nesing habitat" and "not nesting habitat" for the hairy woodpecker in oak-hickory forests of southwestern Virginia. Three variables were included in the model: basal area (m^2/ha), canopy height to crown cover (m), and stem density (number/ha). The model includes coefficients for the three variables, an aggregation function, and a linear decision scale. The model was applied to two groups, the first consisting of stands containing hairy woodpecker nests, and the second consisting of six random plots in each of five habitat types; results of the analysis were significant (P=0.02).

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16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the hairy woodpecker (Picoides villosus). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

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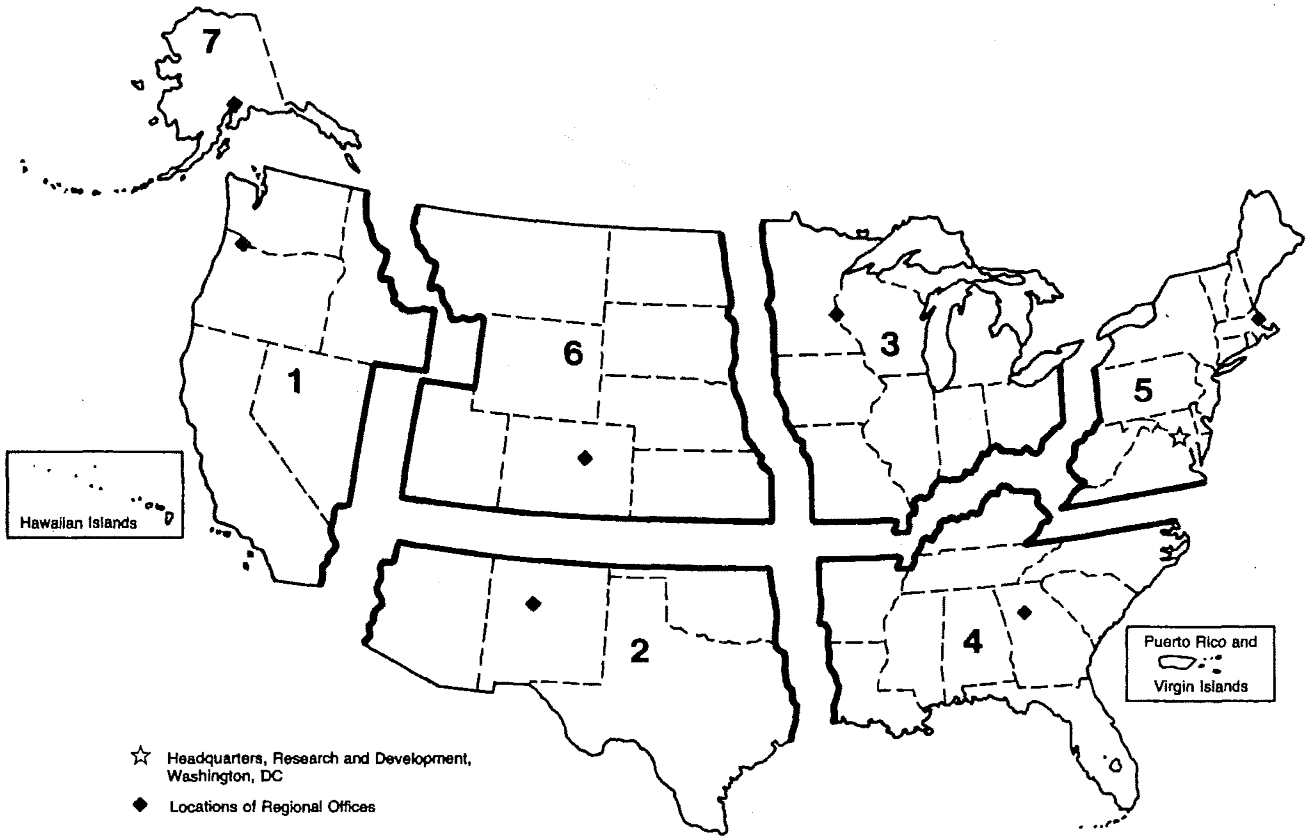

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Biological Services Program
and
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FWS/OBS-82/10.27
JULY 1982

HABITAT SUITABILITY INDEX MODELS: YELLOW WARBLER

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U.S. Department of the Interior

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The Biological Services Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams, which provide the Program's central scientific and technical expertise and arrange for contracting biological services studies with states, universities, consulting firms, and others; Regional Staffs, who provide a link to problems at the operating level; and staffs at certain Fish and Wildlife Service research facilities, who conduct in-house research studies.

This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures.

FWS/OBS-82/10.27
July 1982

HABITAT SUITABILITY INDEX MODELS: YELLOW WARBLER

by

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
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CONTENTS

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We gratefully acknowledge Douglass H. Morse for his review of this habitat model. The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Carolyn Gulzow and Dora Ibarra.

YELLOW WARBLER (*Dendroica petechia*)

HABITAT USE INFORMATION

General

The yellow warbler (*Dendroica petechia*) is a breeding bird throughout the entire United States, with the exception of parts of the Southeast (Robbins et al. 1966). Preferred habitats are wet areas with abundant shrubs or small trees (Bent 1953). Yellow warblers inhabit hedgerows, thickets, marshes, swamp edges (Starling 1978), aspen (*Populus* spp.) groves, and willow (*Salix* spp.) swamps (Salt 1957), as well as residential areas (Morse 1966).

Food

More than 90% of the food of yellow warblers is insects (Bent 1953), taken in proportion to their availability (Busby and Sealy 1979). Foraging in Maine occurred primarily on small limbs in deciduous foliage (Morse 1973).

Water

Dietary water requirements were not mentioned in the literature. Yellow warblers prefer wet habitats (Bent 1953; Morse 1966; Stauffer and Best 1980).

Cover

Cover needs of the yellow warbler are assumed to be the same as reproduction habitat needs and are discussed in the following section.

Reproduction

Preferred foraging and nesting habitats in the Northeast are wet areas, partially covered by willows and alders (*Alnus* spp.), ranging in height from 1.5 to 4 m (5 to 13.3 ft) (Morse 1966). It is unusual to find yellow warblers in extensive forests (Hebard 1961) with closed canopies (Morse 1966). Yellow warblers in small islands of mixed coniferous-deciduous growth in Maine utilized deciduous foliage far more frequently than would be expected by chance alone (Morse 1973). Coniferous areas were mostly avoided and areas of low deciduous growth preferred.

Nests are generally placed 0.9 to 2.4 m (3 to 8 ft) above the ground, and nest heights rarely exceed 9.1 to 12.2 m (30 to 40 ft) (Bent 1953). Plants used for nesting include willows, alders, and other hydrophytic shrubs and trees (Bent 1953), including box-elders (Acer negundo) and cottonwoods (Populus spp.) (Schrantz 1943). In Iowa, dense thickets were frequently occupied by yellow warblers while open thickets with widely spaced shrubs rarely contained nests (Kendeigh 1941).

Males frequently sing from exposed song perches (Kendeigh 1941; Ficken and Ficken 1965), although yellow warblers will nest in areas without elevated perches (Morse 1966).

A number of Breeding Bird Census reports (Van Velzen 1981) were summarized to determine nesting habitat needs of the yellow warbler, and a clear pattern of habitat preferences emerged. Yellow warblers nested in less than 5% of census areas comprised of extensive upland forested cover types (deciduous or coniferous) across the entire country. Approximately two-thirds of all census areas with deciduous shrub-dominated cover types were utilized, while shrub wetland types received 100% use. Wetlands dominated by shrubs had the highest average breeding densities of all cover types [2.04 males per ha (2.5 acre)]. Approximately two-thirds of the census areas comprised of forested draws and riparian forests of the western United States were used, but average densities were low [0.5 males per ha (2.5 acre)].

Interspersion

Yellow warblers in Iowa have been reported to prefer edge habitats (Kendeigh 1941; Stauffer and Best 1980). Territory size has been reported as 0.16 ha (0.4 acre) (Kendeigh 1941) and 0.15 ha (0.37 acre) (Kammeraad 1964).

Special Considerations

The yellow warbler has been on the Audubon Society's Blue List of declining birds for 9 of the last 10 years (Tate 1981).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model has been developed for application within the breeding range of the yellow warbler.

Season. This model was developed to evaluate the breeding season habitat needs of the yellow warbler.

Cover types. This model was developed to evaluate habitat in the dominant cover types used by the yellow warbler: Deciduous Shrubland (DS) and Deciduous Scrub/Shrub Wetland (DSW) (terminology follows that of U.S. Fish and Wildlife Service 1981). Yellow warblers only occasionally utilize forested habitats and reported population densities in forests are low. The habitat requirements in forested habitats are not well documented in the literature. For these reasons, this model does not consider forested cover types.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. Information on the minimum habitat area for the yellow warbler was not located in the literature. Based on reported territory sizes, it is assumed that at least 0.15 ha (0.37 acre) of suitable habitat must be available for the yellow warbler to occupy an area. If less than this amount is present, the HSI is assumed to be 0.0.

Verification level. Previous drafts of the yellow warbler habitat model were reviewed by Douglass H. Morse and specific comments were incorporated into the current model (Morse, pers. comm.).

Model Description

Overview. This model considers the quality of the reproduction (nesting) habitat needs of the yellow warbler to determine overall habitat suitability. Food, cover, and water requirements are assumed to be met by nesting needs.

The relationship between habitat variables, life requisites, cover types, and the HSI for the yellow warbler is illustrated in Figure 1.

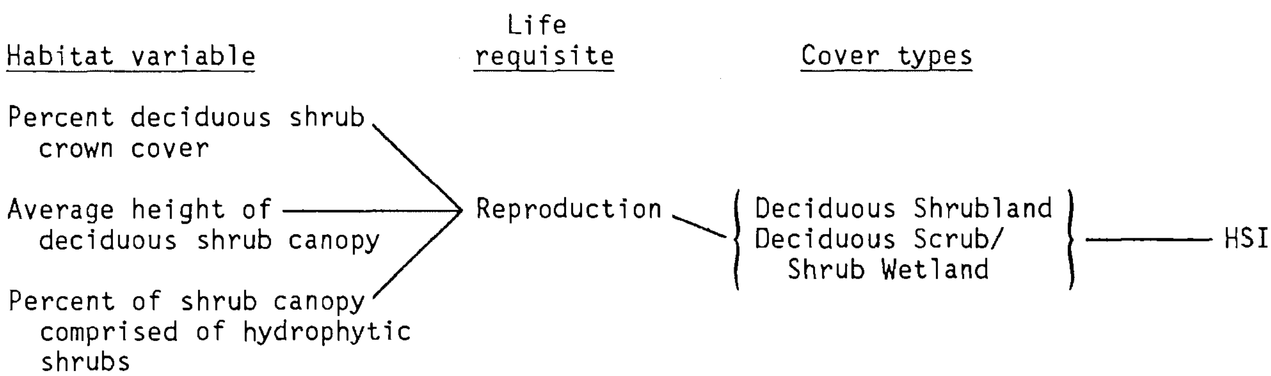


Figure 1. Relationship between habitat variables, life requisites, cover types, and the HSI for the yellow warbler.

The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the yellow warbler and to explain and justify the variables and equations that are used in the HSI model. Specifically, these sections cover the following: (1) identification of variables that will be used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationship between variables.

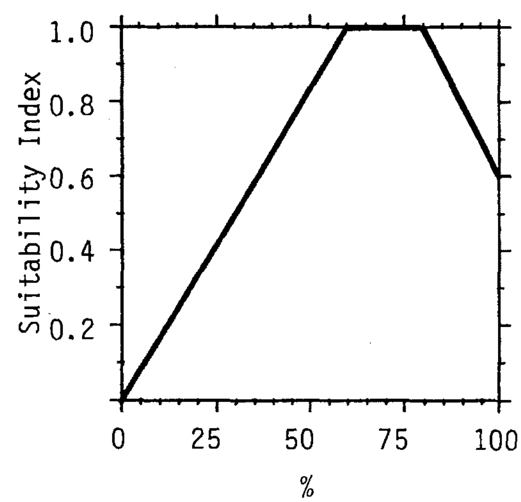
Reproduction component. Optimal nesting habitat for the yellow warbler is provided in wet areas with dense, moderately tall stands of hydrophytic deciduous shrubs. Upland shrub habitats on dry sites will provide only marginal suitability.

It is assumed that optimal habitats contain 100% hydrophytic deciduous shrubs and that habitats with no hydrophytic shrubs will provide marginal suitability. Shrub densities between 60 and 80% crown cover are assumed to be optimal. As shrub densities approach zero cover, suitability also approaches zero. Totally closed shrub canopies are assumed to be of only moderate suitability, due to the probable restrictions on movement of the warblers in those conditions. Shrub heights of 2 m (6.6 ft) or greater are assumed to be optimal, and suitability will decrease as heights decrease to zero.

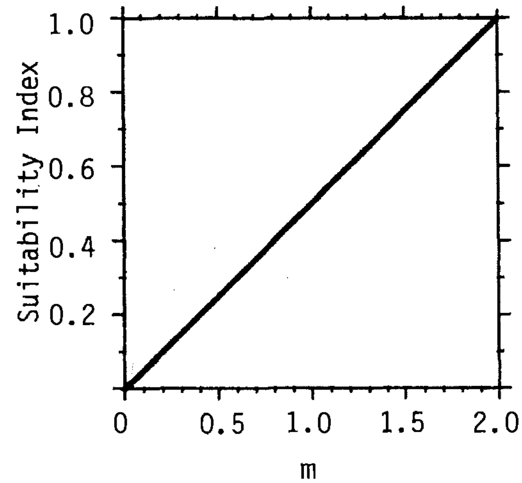
Each of these habitat variables exert a major influence in determining overall habitat quality for the yellow warbler. A habitat must contain optimal levels of all variables to have maximum suitability. Low values of any one variable may be partially offset by higher values of the remaining variables. Habitats with low values for two or more variables will provide low overall suitability levels.

Model Relationships

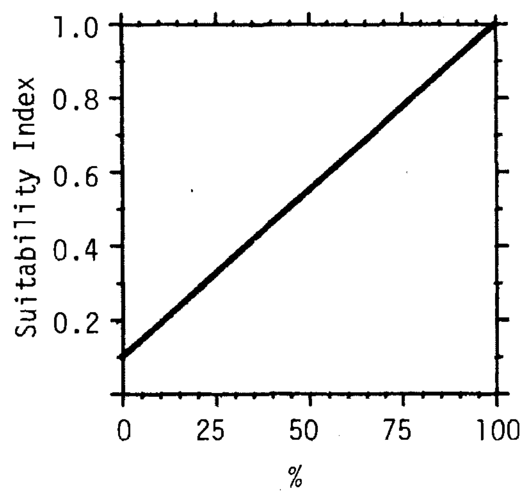
Suitability Index (SI) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described in the previous section.

Cover type	Variable		
DS,DSW	V_1	Percent deciduous shrub crown cover.	

DS,DSW V_2 Average height of deciduous shrub canopy.



DS,DSW V_3 Percent of deciduous shrub canopy comprised of hydrophytic shrubs.



Equations. In order to obtain life requisite values for the yellow warbler, the SI values for appropriate variables must be combined with the use of equations. A discussion and explanation of the assumed relationship between variables was included under Model Description, and the specific equation in this model was chosen to mimic these perceived biological relationships as closely as possible. The suggested equation for obtaining a reproduction value is presented below.

Life requisite	Cover type	Equation
Reproduction	DS,DSW	$(V_1 \times V_2 \times V_3)^{1/2}$

HSI determination. The HSI value for the yellow warbler is equal to the reproduction value.

Application of the Model

Definitions of variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 2.

Variable (definition)		Cover types	Suggested technique
V_1	Percent deciduous shrub crown cover (the percent of the ground that is shaded by a vertical projection of the canopies of woody deciduous vegetation which are less than 5 m (16.5 ft) in height).	DS,DSW	Line intercept
V_2	Average height of deciduous shrub canopy (the average height from the ground surface to the top of those shrubs which comprise the uppermost shrub canopy).	DW,DSW	Graduated rod
V_3	Percent of deciduous shrub canopy comprised of hydrophytic shrubs (the relative percent of the amount of hydrophytic shrubs compared to all shrubs, based on canopy cover).	DS,DSW	Line intercept

Figure 2. Definitions of variables and suggested measurement techniques.

SOURCES OF OTHER MODELS

No other habitat models for the yellow warbler were located.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

Habitat preferences of the yellow warbler (Dendroica petechia) are described in this publication. It is one of a series of Habitat Suitability Index (HSI) models and was developed through an analysis of available information on the species-habitat requirements of the species. Habitat use information is presented in a review of the literature, followed by the development of an HSI model, designed for use in impact assessment and habitat management activities.

17. Document Analysis a. Descriptors

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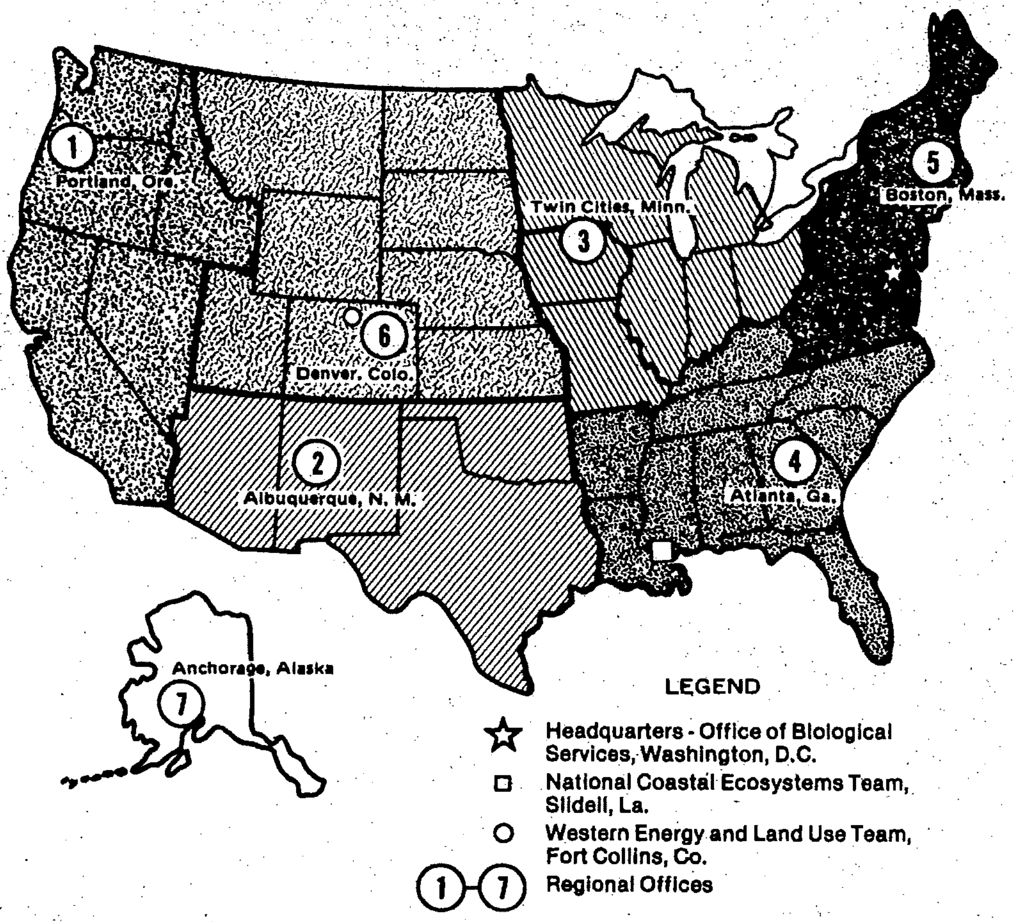

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Draft Habitat Suitability Information: Modified Rainbow Trout Model

U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
Habitat Conservation Division
Sacramento, California

July 10, 2000

Authored by:
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INTRODUCTION

This model was developed for use in evaluating the habitat impacts and mitigation for the Corte Madera Creek Flood Control Project. Corte Madera Creek is located in Marin County, California, about 9 miles north of the Golden Gate Bridge where it discharges into San Francisco Bay. In this particular project, the majority of elements impinge on urban landscaping -- involving the use of flood protection improvements to accommodate flood water surface elevations. Native habitat impacts are localized with in short sections of the invert and associated riparian corridor in the lower, non-tidal portions of the river. The habitat along the river is characterized as a dense, but narrow riparian corridor. One of the most important species of interest in this watershed area is the steelhead, which is the anadromous form of the rainbow trout, a species which spawns much higher in the watershed and uses the lower reaches for adult holding and juvenile rearing.

An approved Habitat Evaluation Procedure (HEP) model has been developed by Raleigh (1984) for rainbow trout and steelhead, however, that model combines 18 variables into component scores for all life stages. In addition, the Raleigh (1984) model includes a number of physico-chemical variables which would not be modified by the limited construction activities such as proposed for Corte Madera Creek. Although including such variables does not invalidate its use here, they do render the model relatively insensitive to changes in any one or two variables, as would be the case in this project. According to a recent study (Marshall 1994), the Corte Madera Watershed water quality was characterized as good. Marshall found that dissolved oxygen, pH, and temperature were all within acceptable limits. Since water quality in Corte Madera Creek is adequate for rainbow trout, water quality variables from the original trout model were employed to be evaluated in the revised model described in this report. To increase the sensitivity of the analysis, we have formulated a simplified model with six key habitat variables that best represent the values of the potential construction sites for adult holding and juvenile rearing habitat, that would be impacted by bank hardening and/or channel modification

Model applicability

<u>Geographic area</u>: This model was developed specifically for lower Corte Madera Creek, located in Marin County, California, but may be applicable to other lower non- tidal reaches of small streams in the north or south San Francisco Bay area where there is no significant water quality issues.

<u>Season</u>: This model rates the summer season, but could be used for year-round freshwater habitat of the rainbow trout.

<u>Cover types</u>: This model is applicable to the stream area, including habitat features within the bankful stage contributed by vegetation roots woody debris, and substrates, commonly referred to as Shaded Riverine Aquatic cover (SRA cover).

Length of habitat: Intended for short impacts generally <700 lineal feet, where such impacts would not cause changes in temperature within the site or downstream.

MODEL DESCRIPTION

This model consists of three components: Vegetation (C_v); Geomorphic (C_g); and Instream (C_i). Since there is no spawning habitat in the lower creek no variables were selected to evaluate spawning suitability. The following is a description of the components and variables that make up each component.

Vegetation Component (C_v): This component is included to evaluate the quality of food supply, cover, and temperature control. Variable 1 (V1)-Percent of streamside vegetation- This variable deals directly with invertebrate and detritus input into the stream. Variable 2 (V2)- % of midday shade- Shoreline vegetation provides shading which keeps shallow water streams cooler than being exposed directly to sunlight, and provides overstream cover to adult and juvenile fish. In addition, streamside vegetation also provides bank stability by establishing an erosion resistant matrix of roots and soil.

Geomorphic Component (C_g): This group of variables is included to represent habitat quality based on morphometric factors independent of cover. Variable 3 (V3)-Average thalweg depth- This was included, because average water depth affects the amount and quality of pools and instream cover available to adult trout and the migratory access to spawning and rearing areas. Variable 4 (V4)- % pools- Pools can be used as holding areas for adults.

Instream Component (C_i): These variables represent the habitat quality of the instream habitat for the trout. Variable 5 (V5)-% instream cover- Adult and juvenile trout utilize instream cover for escape, winter cover, and resting areas. Variable 6 (V6)- % riffle fines- The presence of excessive fines in riffle run areas reduces the production of aquatic insects.

SUITABILITY INDEX (SI) GRAPHS FOR MODEL VARIABLES

This section contains suitability index graphs for the 6 variables selected to evaluate specific habitat impacts from the Corte Madera Creek Flood Control Project. Equations and instructions for combining groups of variables SI scores into component scores and component scores into trout HSI scores are included.

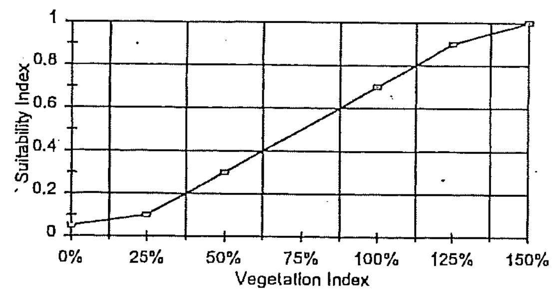
The graphs were constructed by quantifying information on the effect of each habitat variable on growth, survival, or biomass of rainbow trout. The curves were built on the assumption that increments of growth, survival, or biomass plotted on the y-axis of the graph could be directly converted into an index of suitability from 0.0 to 1.0 for the species, with 0.0 indicating unsuitable conditions and 1.0 indicating optimal conditions. The graphs for each of the six variables were obtained from the original rainbow trout habitat suitability model (Raleigh 1984), and the assumptions from Raleigh (1984) are repeated below (Table 1).

Variables

Vegetative Component (V1 and V2)

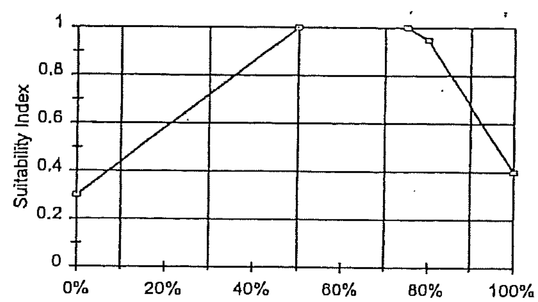
V1 - Percent of streamside vegetation

Average percent vegetational ground cover and canopy closure (trees shrubs, and grasses- forbs) along the streambank during the summer for allochthonous input. Vegetation Index= 2(%shrubs) + 1.5(% grasses) + (% trees). (For streams less than or equal to 50 m wide)



V2 - Percent of midday shade

Percent of stream area shaded by vegetation between 1000 and 1400 hours (for streams less than or equal to 50 m wide). Do not use for cold (<18 degrees C max. temp.), unproductive streams.



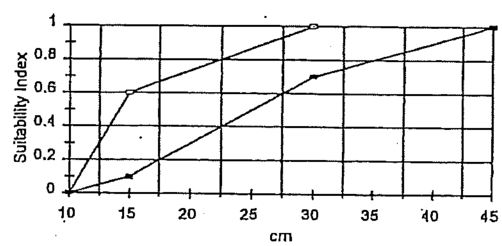
Geomorphic Component (V3 and V4)

V3 - Average thalweg depth

Average thalweg depth (cm) during the late growing season low water period (adult).

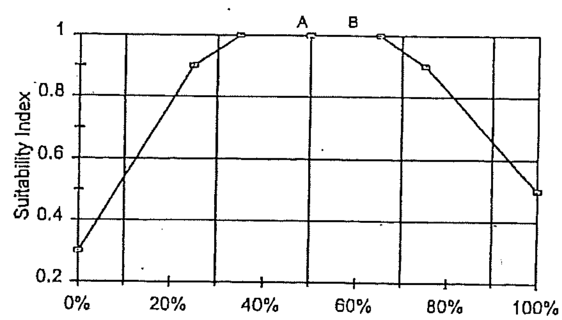
A = 5 m stream width

B => 5 m stream width



V4 - Percent of pools

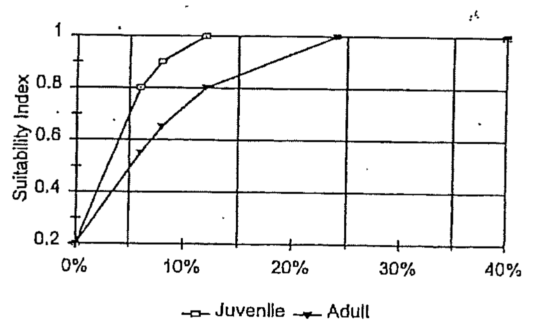
Percent pools during the late growing season low water period.



Instream Component (V5 and V6)

V5 - Percent of instream cover

Percent instream cover during the late growing season low water period at depths greater than or equal 15 cm and velocities < 15 cm/sec.



V6 - Percent of riffle fines
Percent fines (less than 3mm) in riffle run during average summer flows.

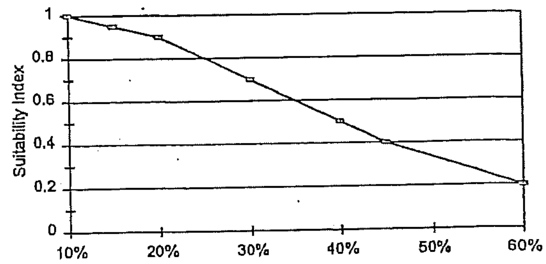


Table 1. List of Variables, sources and assumptions associated with the HEP model specifically developed for the Corte Madera Creek Flood Control project.

Variable and source	Assumptions
V1-Idyll 1942 Delise and Eiliason 1961 Chapman 1966 Hunt 1971	The average percent vegetation along the streambank is related to the amount of allochthonous materials deposited annually in the stream. Shrubs are the best source of allochthonous materials, followed by grasses and forbs, and then trees. The vegetational index is a reasonable approximations of optimal and suboptimal conditions for most trout stream habitats.
V2-Sabean 1976 1977	The percent of shaded stream area during midday that is associated with optimal water temperatures and photosynthesis rates is optimal.[b]
V3-Delise and Eliason 1961	Average thalweg depth that provide the best combination of pools, instream cover, and instream movement of adult trout are optimal.
V4- Elser 1968 Forune and Thompson 1969 Hunt 1971	The percent pools during late summer low flows is associated with the greatest trout abundance is optimal.
V5-Boussu 1954 Elser 1968 Lewis 1969 Wesche 1980	Trout standing crops are correlated with the amount of usable cover. Usable cover is associated with water greater than or equal to 15 cm deep and velocities less than or equal to 15 cm/sec. These conditions are associated more with pool than with riffle conditions. The best ratio of habitat conditions is about 50% pool area to 50% riffle area. Not all of the area of a pool provides usable cover. Thus, it is assumed that optimal conditions exist when usable cover comprises <.50% of total stream area.
V6-Cordone and Kelly 1961 Bjournn 1969 Phillips et al. 1975 Crouse et al. 1981	The percent fines associated with the highest standing crops of food organisms, embryos, and fry in each designated area are optimal.

[b] Shading is highly variable from site to site. Low elevations with warmer climates require abundant shading to maintain cool waters. At higher elevations with cooler climates, the absence of shading is beneficial because it results in higher photosynthetic rates and warming of water to a more optimal temperature.

HABITAT SUITABILITY INDEX (HSI) CALCULATION

a) Vegetation Component Score:
$(C_v) = (V1+V2)/2$

b) Geomorphic Component Score:
$(C_g) = (V3+V4)/2$

c) Instream Component Score:
Equation: $(C_i) = (V5+V6)/2$

$$HSI = (C_v \times C_g \times C_i)^{1/3}$$

MITIGATION SITE SCREENING CRITERIA:

The screening criteria were developed in to assist the Corps in selecting appropriate mitigation site for the project impacts. The mitigation site should have potential for significant enhancement. In order of descending preference, site selection should be: a) on the mainstem Corte Madera Creek within its watershed, b) on tributaries of Corte Madera Creek, c) on other streams or creeks within the north bay San Francisco, or d) at any other priority site as determined through consultation with the USFWS, National Marine Fishery Service and California Department of Fish and Game. The mitigation site should achieve, or have the potential to achieve, maximum habitat value as determined by the modified model discussed above. In addition, the mitigation area should meet the following criteria:

1) Temperature- Maximum water temperatures should achieve or have the potential to achieve acceptable thermal conditions to support adult and juvenile rainbow trout and steelhead.

2) Passability- The site should be bot accessible to steelhead and also allows for upstream and downstream migration through this site.

3) Revegetation Potential- Since the project calls for the removal of streamside vegetation, the mitigation area should have bare to sparsely vegetated stream bank habitat, and have sufficient channel capacity to allow revegetation with native plant species.

4) Flow- Since juvenile steelhead remain in the creek for 1-2 years before they outmigrate, the area should have perennial supply of water and have adequate flows for trout and steelhead survival.

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APPENDIX C

HEP DATA OUTPUTS

CORTE MADERA CREEK FLOOD RISK REDUCTION GENERAL REEVALUATION REPORT

AUGUST 2018

DATA ANALYSIS/ASSUMPTIONS
CORTE MADERA CREEK FLOOD RISK REDUCTION GENERAL REEVALUATION REPORT PROJECT, MARIN COUNTY, CALIFORNIA

UNDERGROUND BYPASS – INTAKE AREA
URBAN/RIPARIAN COVER – SHRUB STRATA

TSP – Future With the TSP Implemented

ASSUME:

1. The underground bypass intake area will involve an area of 0.05 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will not be planted with woody vegetation, although some shrubs may encroach into the edges of the area of the life of the project.
4. There are no foreseeable changes in the existing management practices in the future.

Yellow Warbler

TY0- Baseline (measured)

V_1- % deciduous scrub-shrub crown cover	V_1 = 5.00%
V_2- Average height of deciduous scrub-shrub canopy	V_2 = 11.87 feet
V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	V_3 = 67.57%

HSI = $(SI_1*SI_2*SI_3)$^1/2 = 0.24

TY1-
V_1 = 5%
V_2 = 3.0 feet
V_3 = 96%

HSI = 0.19

TY10-
V_1 = 25%
V_2 = 8.0 feet
V_3 = 96%

HSI = 0.63

TY25-
V_1 = 33%
V_2 = 12.0 feet
V_3 = 96%

HSI = 0.72

TY50-
V_1 = 45%
V_2 = 12.0 feet
V_3 = 96%

HSI = 0.85

UNDERGROUND BYPASS – INTAKE AREA
URBAN/RIPARIAN COVER – SHRUB STRATA

No Action – Future Without TSP Implementation

ASSUME:

1. The underground bypass intake area will involve an area of 0.05 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will not be planted with woody vegetation, although some shrubs may encroach into the edges of the area of the life of the project.
4. There are no foreseeable changes in the existing management practices in the future.

Yellow Warbler

TY0- Baseline (measured)

V_1- % deciduous scrub-shrub crown cover	$V_1 = 5.00\%$
V_2- Average height of deciduous scrub-shrub canopy	$V_2 = 11.87$ feet
V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	$V_3 = 67.57\%$

HSI = $(SI_1*SI_2*SI_3)$^1/2 = 0.24

Without TSP implementation, the habitat conditions are not expected to change over the life of the project.

UNDERGROUND BYPASS – INTAKE AREA
URBAN/RIPARIAN COVER – MAIN CANOPY STRATA

TSP – Future With the TSP Implemented

ASSUME:

1. The underground bypass intake area will involve an area of 0.05 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will not be planted with woody vegetation; main canopy trees rooted outside the impact area are expected to expand into the growing space.
4. Some mature trees occupying the growing space may be removed after 25 years.
5. There are no foreseeable changes in the existing management practices directly on the Intake Area lands.
6. Pine canopy cover is not an important component of natural riparian cover along Corte Madera Creek; therefore values are set to produce an HSI of 1.0 to remove it from consideration.

Hairy Woodpecker

TY0- Baseline (measured)
V1- Number of snags (> 10 in dbh) per acre — $V_1 = 0$
V2 and V3- Mean dbh (reproduction component) — V_2 and V_3= 15.1 inches
V4- % Main canopy cover — $V_4 = 12\%$
V5- % Pine canopy cover — V_5 = set to 100%

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.0$

TY1-
$V_1 = 0$
V_2 and V_3 = 15.1 inches
$V_4 = 12\%$
$V_5 = 100\%$

$HSI = 0.0$

TY10-
$V_1 = 0$
V_2 and V_3 = 15.1 inches
$V_4 = 20\%$
$V_5 = 100\%$

$HSI = 0.0$

TY25-
$V_1 = 1$
V_2 and V_3 = 11.0 inches
$V_4 = 30\%$
$V_5 = 100\%$

$HSI = 0.18$

TY50-
$V_1 = 1$
V_2 and V_3 = 15.0 inches
$V_4 = 30\%$
$V_5 = 100\%$

$HSI = 0.22$

UNDERGROUND BYPASS – INTAKE AREA
URBAN/RIPARIAN COVER – MAIN CANOPY STRATA

TSP – Future Without TSP Implementation

ASSUME:

1. The underground bypass intake area will involve an area of 0.05 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will not be planted with woody vegetation; main canopy trees rooted outside the impact area are expected to expand into the growing space.
4. Some mature trees occupying the growing space may be removed after 25 years.
5. There are no foreseeable changes in the existing management practices directly on the Intake Area lands.
6. Pine canopy cover is not an important component of natural riparian cover along Corte Madera Creek; therefore values are set to produce an HSI of 1.0 to remove it from consideration.

Hairy Woodpecker

TY0- Baseline (measured)

V1- Number of snags (> 10 in dbh) per acre	$V_1 = 0$
V2 and V3- Mean dbh (reproduction component)	V_2 and V_3= 15.1 inches
V4- % Main canopy cover	V_4 = 12%
V5- % Pine canopy cover	V_5 = set to 100%

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.0$

Without TSP implementation, the habitat conditions are not expected to change over the life of the project.

UNDERGROUND BYPASS – OUTFLOW AREA
URBAN/RIPARIAN COVER – SHRUB STRATA

TSP – Future With the TSP Implemented

ASSUME:

1. The underground bypass intake area will involve an area of 0.06 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will not be planted with woody vegetation, although some shrubs may encroach into the edges of the area of the life of the project.
4. There are no foreseeable changes in the existing management practices in the future.

Yellow Warbler

TY0- Baseline (measured)

V_1- % deciduous scrub-shrub crown cover	$V_1 = 5.00\%$
V_2- Average height of deciduous scrub-shrub canopy	$V_2 = 11.87$ feet
V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	$V_3 = 67.57\%$

HSI = $(SI_1*SI_2*SI_3)$^1/2 = 0.24

TY1-
$V_1 = 5\%$
$V_2 = 0.0$ feet
$V_3 = 90\%$

HSI = 0.0

TY10-
$V_1 = 0\%$
$V_2 = 8.0$ feet
$V_3 = 96\%$

HSI = 0.0

TY25-
$V_1 = 0\%$
$V_2 = 12.0$ feet
$V_3 = 96\%$

HSI = 0.0

TY50-
$V_1 = 0\%$
$V_2 = 12.0$ feet
$V_3 = 96\%$

HSI = 0.0

UNDERGROUND BYPASS – OUTFLOW AREA
URBAN/RIPARIAN COVER – SHRUB STRATA

No Action – Future Without TSP Implementation

ASSUME:

1. The underground bypass intake area will involve an area of 0.06 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will not be planted with woody vegetation, although some shrubs may encroach into the edges of the area of the life of the project.
4. There are no foreseeable changes in the existing management practices in the future.

Yellow Warbler

<u>TY0</u>- Baseline (measured)

V_1- % deciduous scrub-shrub crown cover	$V_1 = 5.00\%$
V_2- Average height of deciduous scrub-shrub canopy	$V_2 = 11.87$ feet
V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	$V_3 = 67.57\%$

HSI = $(SI_1*SI_2*SI_3)$^1/2 = 0.24

Without TSP implementation, the habitat conditions are not expected to change over the life of the project.

UNDERGROUND BYPASS – OUTFLOW AREA
URBAN/RIPARIAN COVER – MAIN CANOPY STRATA

TSP – Future With the TSP Implemented

ASSUME:

1. The underground bypass intake area will involve an area of 0.06 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will not be planted with woody vegetation; main canopy trees rooted outside the impact area are expected to expand into the growing space.
4. Some mature trees occupying the growing space may be removed after 25 years.
5. There are no foreseeable changes in the existing management practices directly on the Intake Area lands.
6. Pine canopy cover is not an important component of natural riparian cover along Corte Madera Creek; therefore values are set to produce an HSI of 1.0 to remove it from consideration.

Hairy Woodpecker

TY0- Baseline (measured)

V1- Number of snags (> 10 in dbh) per acre — $V_1 = 0$

V2 and V3- Mean dbh (reproduction component) — V_2 and V_3 = 15.1 inches

V4- % Main canopy cover — $V_4 = 12\%$

V5- % Pine canopy cover — V_5 = set to 100%

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.0$

TY1-

$V_1 = 0$
V_2 and V_3 = 15.1 inches
$V_4 = 12\%$
$V_5 = 100\%$

HSI = 0.0

TY10-

$V_1 = 0$
V_2 and V_3 = 15.1 inches
$V_4 = 15\%$
$V_5 = 100\%$

HSI = 0.0

TY25-

$V_1 = 1$
V_2 and V_3 = 11.0 inches
$V_4 = 15\%$
$V_5 = 100\%$

HSI = 0.0

TY50-

$V_1 = 1$
V_2 and V_3 = 15.0 inches
$V_4 = 18\%$
$V_5 = 100\%$

HSI = 0.03

UNDERGROUND BYPASS – OUTFLOW AREA
URBAN/RIPARIAN COVER – MAIN CANOPY STRATA

TSP – Future Without TSP Implementation

ASSUME:

1. The underground bypass intake area will involve an area of 0.06 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will not be planted with woody vegetation; main canopy trees rooted outside the impact area are expected to expand into the growing space.
4. Some mature trees occupying the growing space may be removed after 25 years.
5. There are no foreseeable changes in the existing management practices directly on the Intake Area lands.
6. Pine canopy cover is not an important component of natural riparian cover along Corte Madera Creek; therefore values are set to produce an HSI of 1.0 to remove it from consideration.

Hairy Woodpecker

TY0- Baseline (measured)

V1- Number of snags (> 10 in dbh) per acre	$V_1 = 0$
V2 and V3- Mean dbh (reproduction component)	V_2 and V_3= 15.1 inches
V4- % Main canopy cover	$V_4 = 12\%$
V5- % Pine canopy cover	V_5 = set to 100%

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.0$

Without TSP implementation, the habitat conditions are not expected to change over the life of the project.

ALLEN PARK RIPARIAN CORRIDOR
FLOODPLAIN
URBAN/RIPARIAN COVER – SHRUB STRATA

TSP – Future With the TSP Implemented

ASSUME:

1. The floodplain area to be planted with riparian vegetation will involve an area of 0.84 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will be planted with native woody vegetation, although no maintenance will occur over the life of the project.

Yellow Warbler

TY0- Baseline (measured)

V_1- % deciduous scrub-shrub crown cover	V_1 = 46.67%
V_2- Average height of deciduous scrub-shrub canopy	V_2 = 15.0 feet
V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	V_3 = 0%

HSI = $(SI_1 * SI_2 * SI_3)$^1/2 = 0.27

TY1-
V_1 = 40%
V_2 = 6.0 feet
V_3 = 90%

HSI = 0.74

TY10-
V_1 = 48%
V_2 = 11.0 feet
V_3 = 96%

HSI = 0.87

TY25-
V_1 = 60%
V_2 = 15.0 feet
V_3 = 97%

HSI = 0.98

TY50-
V_1 = 60%
V_2 = 15.0 feet
V_3 = 97%

HSI = 0.98

ALLEN PARK RIPARIAN CORRIDOR
FLOODPLAIN
URBAN/RIPARIAN COVER – SHRUB STRATA

TSP – Future Without TSP Implementation

ASSUME:

1. The floodplain area is 0.84 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will be maintained much like the current state over the next 51 years.

Yellow Warbler

TY0- Baseline (measured)

V_1- % deciduous scrub-shrub crown cover	$V_1 = 46.67\%$
V_2- Average height of deciduous scrub-shrub canopy	$V_2 = 15.0$ feet
V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	$V_3 = 0\%$

$HSI = (SI_1*SI_2*SI_3)^{1/2} = 0.27$

Without TSP implementation, the habitat conditions are not expected to change over the life of the project.

ALLEN PARK RIPARIAN CORRIDOR
FLOODPLAIN
URBAN/RIPARIAN COVER – MAIN CANOPY

TSP – Future With the TSP Implemented

ASSUME:

1. The floodplain area to be planted with riparian vegetation will involve an area of 0.84 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will be planted with native woody vegetation, although no maintenance will occur over the life of the project.

Hairy Woodpecker

TY0- Baseline (measured)

V1- Number of snags (> 10 in dbh) per acre	$V_1 = 0$
V2 and V3- Mean dbh (reproduction component)	V_2 and V_3= 21.41 inches
V4- % Main canopy cover	V_4 = 100%
V5- % Pine canopy cover	V_5 = set to 100%

HSI = $[SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.60$

TY1-

$V_1 = 0$
V_2 and V_3 = 16.0 inches
V_4 = 60%
V_5 = 100%

HSI = 0.48

TY10-

$V_1 = 2$
V_2 and V_3 = 17.0 inches
V_4 = 66%
V_5 = 100%

HSI = 0.73

TY25-

$V_1 = 4$
V_2 and V_3 = 19.0 inches
V_4 = 78%
V_5 = 100%

HSI = 0.90

TY50-

$V_1 = 5$
V_2 and V_3 = 21.0 inches
V_4 = 90%
V_5 = 100%

HSI = 1.0

ALLEN PARK RIPARIAN CORRIDOR
FLOODPLAIN
URBAN/RIPARIAN COVER – MAIN CANOPY

TSP – Future Without TSP Implementation

ASSUME:

1. The floodplain area is 0.84 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. The area will be maintained much like the current state over the next 51 years.

Hairy Woodpecker

TY0-	Baseline (measured)	
	V1- Number of snags (> 10 in dbh) per acre	$V_1 = 0$
	V2 and V3- Mean dbh (reproduction component)	V_2 and V_3= 21.41 inches
	V4- % Main canopy cover	V_4 = 100%
	V5- % Pine canopy cover	V_5 = set to 100%

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.60$

Without TSP implementation, the habitat conditions are not expected to change over the life of the project.

ALLEN PARK RIPARIAN CORRIDOR
FLOODWALL CREEKSIDE BUFFER
And
FLOODWALL LANDSIDE BUFFER
URBAN/RIPARIAN COVER – SHRUB STRATA

TSP – Future With the TSP Implemented

ASSUME:

1. The creekside buffer area adjacent to the Allen Park riparian corridor floodwalls will involve an area of 0.42 acre.
2. The landside buffer area adjacent to the Allen Park riparian corridor floodwalls will involve an area of 0.59 acre.
3. The life of the project would be 50 years after construction, for a total of 51 years.
4. The area will not be planted with woody vegetation, although some shrubs rooted outside of the buffer area may encroach into the growing space at the edges of the buffer, over the life of the project.

Yellow Warbler

TY0- Baseline (measured)

V_1- % deciduous scrub-shrub crown cover	V_1 = 46.67%
V_2- Average height of deciduous scrub-shrub canopy	V_2 = 15.0 feet
V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	V_3 = 0%

HSI = $(SI_1 * SI_2 * SI_3)^{1/2}$ = 0.27

TY1-
V_1 = 0%
V_2 = 0 feet
V_3 = 0%

HSI = 0.0

TY10-
V_1 = 6.0%
V_2 = 15.0 feet
V_3 = 0%

HSI = 0.10

TY25-
V_1 = 8.0%
V_2 = 15.0 feet
V_3 = 0%

HSI = 0.11

TY50-
V_1 = 10.0%
V_2 = 15.0 feet
V_3 = 0%

HSI = 0.12

ALLEN PARK RIPARIAN CORRIDOR
FLOODWALL CREEKSIDE BUFFER
And
FLOODWALL LANDSIDE BUFFER
URBAN/RIPARIAN COVER – SHRUB STRATA

TSP – Future Without TSP Implementation

ASSUME:

1. The creekside buffer area adjacent to the Allen Park riparian corridor floodwalls totals 0.42 acre.
2. The landside buffer area adjacent to the Allen Park riparian corridor floodwalls will involve an area of 0.59 acre.
3. The life of the project would be 50 years after construction, for a total of 51 years.
4. The area will be maintained much like the current state over the next 51 years.

Yellow Warbler

TY0-	Baseline (measured)	
	V_1- % deciduous scrub-shrub crown cover	V_1 = 46.67%
	V_2- Average height of deciduous scrub-shrub canopy	V_2 = 15.0 feet
	V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	V_3 = 0%

HSI = $(SI_1*SI_2*SI_3)^{1/2}$ = 0.27

Without TSP implementation, the habitat conditions are not expected to change over the life of the project.

ALLEN PARK RIPARIAN CORRIDOR FLOODWALL CREEKSIDE BUFFER And FLOODWALL LANDSIDE BUFFER URBAN/RIPARIAN COVER – MAIN CANOPY

TSP – Future With the TSP Implemented

ASSUME:

1. The creekside buffer area adjacent to the Allen Park riparian corridor floodwalls will involve an area of 0.42 acre.
2. The landside buffer area adjacent to the Allen Park riparian corridor floodwalls will involve an area of 0.59 acre.
3. The life of the project would be 50 years after construction, for a total of 51 years.
4. The area will not be planted with woody vegetation, although some shrubs rooted outside of the buffer area may encroach into the growing space at the edges of the buffer, over the life of the project.

Hairy Woodpecker

TY0- Baseline (measured)

V1- Number of snags (> 10 in dbh) per acre	$V_1 = 0$
V2 and V3- Mean dbh (reproduction component)	V_2 and V_3= 15.10 inches
V4- % Main canopy cover	$V_4 = 12\%$
V5- % Pine canopy cover	V_5 = set to 100%

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.00$

TY1-

$V_1 = 0$
V_2 and V_3 = 0.0 inches
$V_4 = 12\%$
$V_5 = 100\%$

HSI = 0.00

TY10-

$V_1 = 0$
V_2 and V_3 = 0.0 inches
$V_4 = 0\%$
$V_5 = 100\%$

HSI = 0.00

TY25-

$V_1 = 0$
V_2 and V_3 = 0.0 inches
$V_4 = 0\%$
$V_5 = 100\%$

HSI = 0.00

TY50-

$V_1 = 0$
V_2 and V_3 = 0.0 inches
$V_4 = 0\%$
$V_5 = 100\%$

HSI = 0.00

ALLEN PARK RIPARIAN CORRIDOR
FLOODWALL CREEKSIDE BUFFER
And
FLOODWALL LANDSIDE BUFFER
URBAN/RIPARIAN COVER – MAIN CANOPY

TSP – Future Without TSP Implementation

ASSUME:

1. The creekside buffer area adjacent to the Allen Park riparian corridor floodwalls totals 0.42 acre.
2. The landside buffer area adjacent to the Allen Park riparian corridor floodwalls will involve an area of 0.59 acre.
3. The life of the project would be 50 years after construction, for a total of 51 years.
4. The area will be maintained much like the current state over the next 51 years, although normal tree growth and decay will occur.

Hairy Woodpecker

TY0- Baseline (measured)

V1- Number of snags (> 10 in dbh) per acre	$V_1 = 0$
V2 and V3- Mean dbh (reproduction component)	V_2 and V_3= 15.10 inches
V4- % Main canopy cover	$V_4 = 12.0\%$
V5- % Pine canopy cover	V_5 = set to 100%

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.00$

TY1-

$V_1 = 0$
V_2 and V_3 = 15.10 inches
$V_4 = 12\%$
$V_5 = 100\%$

HSI = 0.00

TY10-

$V_1 = 0$
V_2 and V_3 = 15.10 inches
$V_4 = 20\%$
$V_5 = 100\%$

HSI = 0.05

TY25-

$V_1 = 0$
V_2 and V_3 = 15.10 inches
$V_4 = 30\%$
$V_5 = 100\%$

HSI = 0.16

TY50-

$V_1 = 1$
V_2 and V_3 = 15.10 inches
$V_4 = 30\%$
$V_5 = 100\%$

HSI = 0.22

GRANTON PARK FLOODWALL BUFFER
And
COLLEGE PARK FLOODWALL BUFFER
URBAN/RIPARIAN COVER – SHRUB STRATA

TSP – Future With the TSP Implemented

ASSUME:

1. Vegetation free buffers on the waterside of the floodwalls will not be necessary because the floodwalls will be adjacent to the existing aquatic habitat.
2. The Granton Park landside buffer will involve an area of 0.37 acre.
3. The College Avenue landside buffer will involve an area of 0.34 acre.
4. The life of the project would be 50 years after construction, for a total of 51 years.
5. The area will not be planted with woody vegetation, although some shrubs rooted outside of the buffer area may encroach into the growing space at the edges of the buffer, over the life of the project.

Yellow Warbler

TY0- Baseline (measured)

V_1- % deciduous scrub-shrub crown cover	$V_1 = 46.67\%$
V_2- Average height of deciduous scrub-shrub canopy	$V_2 = 15.0$ feet
V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	$V_3 = 0\%$

HSI = $(SI_1*SI_2*SI_3)$^1/2 = 0.27

TY1-

$V_1 = 0\%$
$V_2 = 0$ feet
$V_3 = 0\%$

HSI = 0.0

TY10-

$V_1 = 6.0\%$
$V_2 = 15.0$ feet
$V_3 = 0\%$

HSI = 0.10

TY25-

$V_1 = 8.0\%$
$V_2 = 15.0$ feet
$V_3 = 0\%$

HSI = 0.11

TY50-

$V_1 = 10.0\%$
$V_2 = 15.0$ feet
$V_3 = 0\%$

HSI = 0.12

GRANTON PARK FLOODWALL BUFFER
And
COLLEGE PARK FLOODWALL BUFFER
URBAN/RIPARIAN COVER – SHRUB STRATA

TSP – Future Without TSP Implementation

ASSUME:

1. Vegetation free buffers on the waterside of the floodwalls will not be necessary because the floodwalls will be adjacent to the existing aquatic habitat.
2. The Granton Park landside buffer will involve an area of 0.37 acre.
3. The College Avenue landside buffer will involve an area of 0.34 acre.
4. The life of the project would be 50 years after construction, for a total of 51 years.
5. The area will be maintained much like the current state over the next 51 years.

Yellow Warbler

<u>TY0</u>- Baseline (measured)

V_1- % deciduous scrub-shrub crown cover	$V_1 = 46.67\%$
V_2- Average height of deciduous scrub-shrub canopy	$V_2 = 15.0$ feet
V_3- % deciduous scrub-shrub comprised of hydrophytic shrubs (100%)	$V_3 = 0\%$

HSI = $(SI_1*SI_2*SI_3)^{1/2} = 0.27$

Without TSP implementation, the habitat conditions are not expected to change over the life of the project.

GRANTON PARK FLOODWALL BUFFER
And
COLLEGE PARK FLOODWALL BUFFER
URBAN/RIPARIAN COVER – MAIN CANOPY

TSP – Future With the TSP Implemented

ASSUME:

1. Vegetation free buffers on the waterside of the floodwalls will not be necessary because the floodwalls will be adjacent to the existing aquatic habitat.
2. The Granton Park landside buffer will involve an area of 0.37 acre.
3. The College Avenue landside buffer will involve an area of 0.34 acre.
4. The life of the project would be 50 years after construction, for a total of 51 years.
5. The area will not be planted with woody vegetation, although some shrubs rooted outside of the buffer area may encroach into the growing space at the edges of the buffer, over the life of the project.

Hairy Woodpecker

TY0- Baseline (measured)

V1- Number of snags (> 10 in dbh) per acre	$V_1 = 0$
V2 and V3- Mean dbh (reproduction component)	V_2 and V_3= 15.10 inches
V4- % Main canopy cover	$V_4 = 12\%$
V5- % Pine canopy cover	V_5 = set to 100%

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.00$

TY1-
$V_1 = 0$
V_2 and V_3 = 0.0 inches
$V_4 = 12\%$
$V_5 = 100\%$

HSI = 0.00

TY10-
$V_1 = 0$
V_2 and V_3 = 0.0 inches
$V_4 = 0\%$
$V_5 = 100\%$

HSI = 0.00

TY25-
$V_1 = 0$
V_2 and V_3 = 0.0 inches
$V_4 = 0\%$
$V_5 = 100\%$

HSI = 0.00

TY50-
$V_1 = 0$
V_2 and V_3 = 0.0 inches
$V_4 = 0\%$
$V_5 = 100\%$

HSI = 0.00

GRANTON PARK FLOODWALL BUFFER
And
COLLEGE PARK FLOODWALL BUFFER
URBAN/RIPARIAN COVER – MAIN CANOPY

TSP – Future Without TSP Implementation

ASSUME:

1. Vegetation free buffers on the waterside of the floodwalls will not be necessary because the floodwalls will be adjacent to the existing aquatic habitat.
2. The Granton Park landside buffer will involve an area of 0.37 acre.
3. The College Avenue landside buffer will involve an area of 0.34 acre.
4. The life of the project would be 50 years after construction, for a total of 51 years.
5. The area will be maintained much like the current state over the next 51 years, although normal tree growth and decay will occur.

Hairy Woodpecker

TY0- Baseline (measured)

V1- Number of snags (> 10 in dbh) per acre	$V_1 = 0$
V2 and V3- Mean dbh (reproduction component)	V_2 and V_3= 15.10 inches
V4- % Main canopy cover	$V_4 = 12.0\%$
V5- % Pine canopy cover	V_5 = set to 100%

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.00$

TY1-

$V_1 = 0$
V_2 and V_3 = 15.10 inches
$V_4 = 12\%$
$V_5 = 100\%$

HSI = 0.00

TY10-

$V_1 = 0$
V_2 and V_3 = 15.10 inches
$V_4 = 20\%$
$V_5 = 100\%$

HSI = 0.05

TY25-

$V_1 = 0$
V_2 and V_3 = 15.10 inches
$V_4 = 30\%$
$V_5 = 100\%$

HSI = 0.16

TY50-

$V_1 = 1$
V_2 and V_3 = 15.10 inches
$V_4 = 30\%$
$V_5 = 100\%$

HSI = 0.22

CORTE MADERA CREEK
AQUATIC HABITAT
UPSTREAM TRANSITION ZONE

TSP – Future With the TSP Implemented

ASSUME:

1. The transition zone will involve grading within the streambed to accommodate fish ladder removal in an area of about 0.64 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. No maintenance will occur throughout the life of the project, although natural processes will occur.
4. Streamside vegetation will remain in place during bed grading.

Rainbow Trout

TY0- Baseline (measured)

V1- % Streamside vegetation, all strata combined	$V_1 = 137.6$
V2- % Midday shade	$V_2 = 76.36$
V3- Mean thalweg depth	$V_3 = 33.91$
V4- % Pools	$V_4 = 40.0$
V5- % Instream cover	$V_5 = 35.2$

HSI = $[SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.99$

TY1-

$V_1 = 113.0\%$
$V_2 = 57.7\%$
$V_3 = 33.9$
$V_4 = 40\%$
$V_5 = 12\%$

HSI = 0.94

TY10-

$V_1 = 125.0\%$
$V_2 = 64.0\%$
$V_3 = 33.9$
$V_4 = 40\%$
$V_5 = 22.0\%$

HSI = 0.94

TY25-

$V_1 = 137.6\%$
$V_2 = 76.3\%$
$V_3 = 33.9$
$V_4 = 40\%$
$V_5 = 35.2\%$

HSI = 0.99

TY50-

$V_1 = 137.6\%$
$V_2 = 76.3\%$
$V_3 = 33.9$
$V_4 = 40\%$
$V_5 = 35.2\%$

HSI = 0.99

CORTE MADERA CREEK
AQUATIC HABITAT
UPSTREAM TRANSITION ZONE

TSP – Future Without TSP Implementation

ASSUME:

1. The transition zone will involve grading within the streambed to accommodate fish ladder removal in an area of about 0.64 acre.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. Conditions will continue throughout the life of the project much the same as they currently are.

Rainbow Trout

TY0- Baseline (measured)

V1- % Streamside vegetation, all strata combined	$V_1 = 137.6$
V2- % Midday shade	$V_2 = 76.36$
V3- Mean thalweg depth	$V_3 = 33.91$
V4- % Pools	$V_4 = 40.0$
V5- % Instream cover	$V_5 = 35.2$

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.99$

Without TSP implementation, the aquatic habitat conditions are not expected to change over the life of the project in the transition zone upstream of the fish ladder.

CORTE MADERA CREEK
AQUATIC HABITAT
DOWNSTREAM BED RESTORATION ZONE

TSP – Future With the TSP Implemented

ASSUME:

1. The restoration zone will involve removal of the concrete channel for a length of about 900 feet downstream of the fish ladder, or an acreage of about 0.72 acre.
2. Transition to the Allen Park floodplain will be graded into the area.
3. The life of the project would be 50 years after construction, for a total of 51 years.
4. No maintenance will occur throughout the life of the project, although natural processes will occur.

Rainbow Trout

TY0- Baseline (measured)

V1- % Streamside vegetation, all strata combined	$V_1 = 113.75$
V2- % Midday shade	$V_2 = 57.77$
V3- Mean thalweg depth	$V_3 = 5.27$
V4- % Pools	$V_4 = 0.0$
V5- % Instream cover	$V_5 = 3.3$
V6- % Riffle fines	$V_6 = 6.67$

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.0$

TY1-

$V_1 = 80.0\%$
$V_2 = 40.0\%$
$V_3 = 33.9$
$V_4 = 35\%$
$V_5 = 10\%$
$V_6 = 10.6\%$

HSI = 0.84

TY10-

$V_1 = 100.0\%$
$V_2 = 50.0\%$
$V_3 = 33.9$
$V_4 = 40\%$
$V_5 = 35.2\%$
$V_6 = 10.6\%$

HSI = 0.95

TY25-

$V_1 = 125.0\%$
$V_2 = 70.0\%$
$V_3 = 33.9$
$V_4 = 40\%$
$V_5 = 35.2\%$
$V_6 = 10.6$

HSI = 0.98

DOWNSTREAM BED RESTORATION ZONE
TSP – Future With the TSP Implemented (Continued)

TY50-

$V_1 = 137.6\%$
$V_2 = 76.3\%$
$V_3 = 33.9$
$V_4 = 40\%$
$V_5 = 35.2\%$
$V_6 = 10.6\%$

HSI = 0.99

CORTE MADERA CREEK
AQUATIC HABITAT
DOWNSTREAM BED RESTORATION ZONE

TSP – Future Without TSP Implementation

ASSUME:

1. The concrete channel for a length of about 900 feet downstream of the fish ladder, or an acreage of about 0.72 acre, will remain in place as is.
2. The life of the project would be 50 years after construction, for a total of 51 years.
3. No maintenance will occur throughout the life of the project, although natural processes will occur.

Rainbow Trout

TY0- Baseline (measured)

V1- % Streamside vegetation, all strata combined	$V_1 = 113.75$
V2- % Midday shade	$V_2 = 57.77$
V3- Mean thalweg depth	$V_3 = 5.27$
V4- % Pools	$V_4 = 0.0$
V5- % Instream cover	$V_5 = 3.3$
V6- % Riffle fines	$V_6 = 6.67$

$HSI = [SI_1 + (0.75*SI_2)]*(SI_3*SI_4*SI_5) = 0.0$

Without TSP implementation, the aquatic habitat conditions are not expected to change over the life of the project in the concrete channel as it currently exists downstream of the fish ladder.