COUNTY OF SANTA CRUZ

FISH AND WILDLIFE ADVISORY COMMISSION

701 OCEAN STREET, ROOM 312, SANTA CRUZ, CA 95060
(831) 454-3154 FAX: (831) 454-3128

AGENDA
February 7, 2019
7:00 PM
Fifth Floor Conference Room, Room 520, 701 Ocean Street
PLEASE NOTE: Outside doors will be open 6:45-7:30 and then locked for security.
Please arrive during this time.
Staff can be contacted at 831-227-7404, but may not be available to answer the call during the meeting.

1. CALL TO ORDER
2. ROLL CALL
3. APPROVAL OF MINUTES
4. PUBLIC COMMENTS
5. BUSINESS MATTERS
   A. Report on budget and Fish and Game Propagation Fund (15 minutes)
      i) Staff: current budget and Stream Enhancement Fund balance
      ii) Edward Browne, District Attorney: current and upcoming cases
   B. Monterey Bay Salmon and Trout Project Request for Funding, Ben Harris (10 minutes)
   C. Wildlife Conservation and Current Issues –Terris Kasteen, CDFW (20 minutes)
   D. Discuss Significant Tree Ordinance and idea of expanding coverage outside coastal zone (20 minutes)
   E. Update and discussion of PG & E's Community Wildfire Safety Program (15 minutes)
   F. Discuss and approve Biennial Report (10 minutes)
6. PRESENTATIONS AND ANNOUNCEMENTS BY COMMMISSIONERS (15 minutes) – *start 8:45 pm*
   A. Commissioner Baron – update on CAL IPC (Invasive Plant Council)
7. STAFF REPORTS/ANNOUNCEMENTS (5 minutes)
8. CORRESPONDENCE
   A. Feb 5, 2019 email from Nancy Macy re: PG & E Community Wildlife Safety Program
   B. November 29, 2018 Letter from the Valley Women's Club of San Lorenzo Valley supporting extension of the Significant Tree Ordinance outside the coastal zone.
   C. December 5, 2018 Letter from the Sierra Club, Santa Cruz Group, in support of a Heritage Tree Ordinance for areas outside the Coastal Zone
   D. Jean Brocklebank email in support of extending the Significant Tree Ordinance outside the Coastal Zone
   E. December 6 email from David Kossack commenting on City of Santa Cruz Habitat Conservation Plan
   F. Materials Submitted by David Kossack regarding the Scotts Creek Bridge Replacement/Lagoon Project
   G. Notice of change of date for adoption hearing for filleting of California sheephead on vessels and recreational take of purple sea urchin
   H. Notice of proposed regulatory action relative to archery equipment and crossbow regulations
   I. Notice of proposed regulatory action relative to mammal hunting regulations
   J. Notice of proposed regulatory action relative to Klamath River Basin sport fishing regulations
   K. Notice of proposed regulatory action relative to Central Valley salmon sport fishing
   L. Notice of proposed regulatory action relation to waterfowl hunting regulations
   M. Notice of Findings regarding Humboldt marten as endangered
9. ADJOURNMENT

The County of Santa Cruz does not discriminate on the basis of disability, and no person shall, by reason of a disability, be denied the benefits of its services, programs, or activities. The Planning Department Conference Room is located in an accessible facility. If you are a person with a disability and require special assistance in order to participate in the meeting, please contact Kristen Kittleson at (831)454-3154 or TDD number (454-2123) at least 72 hours in advance of the meeting in order to make arrangements. Persons with disabilities may request a copy of the agenda in an alternative format. As a courtesy to those affected, please attend the meeting smoke and scent free.

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Fish and Wildlife Advisory Commission

MINUTES

Santa Cruz County Governmental Center
Board of Supervisors Chambers, Fifth Floor
Santa Cruz, California

December 6, 2018

1. CALL TO ORDER. The meeting was called to order at 7:02 PM
2. ROLL CALL.

Present: Commissioners Berry, Robin, Johnson, Baron, Frediani, Lee, Freeman
Excused: Wise, Cooley, Parmenter
Absent: none

Guests included John Ricker, Water Resources Division Director, Becky Steinbruner, Water for Santa Cruz County, Larry Freeman, consulting hydrologist, Steve Schindler and Todd Todgazzini, CDFW, David Kossack, San Andreas Land Conservancy.

3. APPROVAL OF MINUTES. Commissioner Freeman made a motion to approve the October minutes; Commissioner Baron seconded the motion. All aye; the motion passed.
4. PUBLIC COMMENT. There were no general public comments.
5. PRESENTATIONS
   A. **Edward Browne, District Attorney – Report on code enforcement.** Mr. Browne was unable to attend the meeting. Captain Todd Tognazzini provided information about the fines and settlements to the Fish and Game Propagation Fund. Other counties have seen similar funding declines, some of which can be related to legislation changes affecting how crimes are handled. Also, court assessments have increased, so while fines can be quite high, the percentage going to the Fish and Game Propagation Fund can be quite small. For example, an $800 fine for trespassing at Bonny Doon Ecological Preserve may result in less than $20 going to the Propagation Fund. CDFW continues to enforce 1600 violations, but the District Attorney's office decides how the violation will be handled. Captain Tognazzini told the commission that there is a one-year statute of limitations on enforcement.
   B. **20 Years of Habitat Conservation Planning for the City of Santa Cruz Water Department, Chris Berry, City of Santa Cruz Water Department.** Mr. Berry's presentation explained how the HCP is a component of a 30- year permit that covers the take of species impacted by otherwise lawful operations. The HCP covers species that are

impacted by the Water Department and Public Works' operations. The HCP will cover 30 years of activities.

6. BUSINESS MATTERS
   A. **Discuss and approve meeting schedule for 2019**. The Commission approved a schedule to meet in February, March, May, June, September, October, November and December. The meeting schedule will be distributed to the commission and posted on-line.
   B. **Discuss future meeting topics and discussion of commissioners following and reporting on specific topics.** Commission reviewed list developed at the last meeting and added: Pajaro, mountain lions, open space and conservation and landscape connectivity.
   C. **Discuss and approve Annual Report.** Staff was unable to prepare to the Annual Report for this meeting; it will be reviewed at the next meeting.
   D. **Update and discussion PG & E's Community Wildfire Safety Program**. Chair Berry participates in the Fire Safe Santa Cruz County Council https://www.firesafesantacruz.org/about-fire-safe-santa-cruz-county. PG & E's upper management is reconsidering the whole Community Wildfire Safety Program. This is a rapidly evolving and complex issue. The County's Planning Department is still working on the encroachment permits for vegetation management along County roads.
   E. **Update on low-flow fishing letter**. Staff with the Board of Supervisors asked for some further clarification and expected support or resistance by the community.
7. PRESENTATIONS AND ANNOUNCEMENTS BY COMMMISSIONERS. Commissioner Robin and Frediani attended the Biodiversity for a Livable Climate Conference
8. STAFF REPORTS/ANNOUNCEMENTS
   A. New policy on public comment and written correspondence
9. ADJOURNMENT – 9:02 PM.

NOTE: The next meeting is scheduled for February 7, 2019.

Submitted by K. Kittleson; Water Resources/Fish and Wildlife/2018 FWAC Meetings

Fish and Wildlife Advisory Commission

Budget and Public Grants Program Update

January 31, 2019

The following table shows the most recent (2017-18) and current year (2018-19) budgets:

Fiscal Year	Anticipated Revenue	Actual Revenue	Reserve at Beginning of Fiscal Year	Budgeted for Grant Program	Allocated from Grant Program
2017-18	$10,100	$14,065	$13,329	$15,000	$12,445
2018-19 - OCT	$7,100	$1,009	$15,329	$15,000	
2018-19 JAN	$7,100	$ 2,208	$15,329	$15,000	

Definition of terms:

Fiscal year runs July 1 to June 30 of the following year

Anticipated Revenue is the amount of revenue (fines and judgements) expected

Actual Revenue is the actual amount received by the Fish and Game Propagation Fund

Reserve is the amount of funding in reserve at the beginning of each fiscal year. Spending in excess of revenue reduces the reserve.

Budgeted for the Grant Program – expected spending for the Public Grants Program

Allocated from the Grant Program – actual amount allocated

2018-2019

The Fish and Wildlife Advisory Commission agreed to postpone the Public Grants Program for one year until Fall 2019. This one -year break will provide time for Environmental Health to:

- Replace the Water Resources staff person that provided additional support for the public grants program
- Allow the Fish and Game Propagation Fund to accumulate funds PRIOR to allocating them to the Public Grants Program for spending
- Eliminate the need to spend reserves in 2018-19
- Evaluate ways to streamline the administration and fiscal process of the Public Grants Program
- Allow FWAC to evaluate the program and make any desired changes

County of Santa Cruz Fish and Wildlife Advisory Commission

GRANT APPLICATION

GRANT CONTACT INFORMATION

This information will not be posted on-line as part of the public notification process.

A. Application Date ____1/15/19____

B. Name of organization or individual submitting the proposal

Monterey Bay Salmon & Trout Project

C. Contact Person – Name, address, phone and email

Ben Harris, MBSTP Executive Director
101 Cooper St., Santa Cruz, CA, 95060
(831)-531-2051 (O); (304)-777-7231 (C)
E-mail: ed.mbstp@gmail.com

D. Fund Recipient: Name on the check and mailing address:

Monterey Bay Salmon and Trout Project
101 Cooper St., Santa Cruz, CA, 95060

E. Have you received a grant from the Fish and Game Advisory Commission previously?

Yes

If you receive grant funding as a first-time applicant, the fund recipient will be required to register with the County of Santa Cruz and to submit a W-9.

If you have received grant funding previously, you will need to either confirm that the name and address of the fund recipient is the same or you will need to resubmit a new W-9.

NOTE: If your request is approved for funding, you will be required to report back to the Commission with a ½ - 1 page summary of the project, including how the funds were expended and the success of the project. If the grantee submits a new request for funding, a progress or completion report must be submitted by August 15th of that year. If the grantee does not plan to request other funding, a progress or completion report must be completed within a year of receiving the funds.

County of Santa Cruz Fish and Wildlife Advisory Commission
GRANT APPLICATION

1. Project name

   MBSTP Steelhead Stranding Rescue Program

2. Name of organization or individual submitting the proposal

   Monterey Bay Salmon & Trout Project
   Ben Harris, Executive Director

3. Amount of funding requested

   $300

For each of the following sections, give a brief description:

4. Project Description

   The MBSTP Steelhead Stranding Rescue Program is a volunteer-supported effort to rescue local juvenile steelhead from poor habitat conditions encountered in area watersheds in the later summer months. MBSTP desires to continue and expand this effort to support local wild steelhead recovery. In order to do so, our organization requires small equipment and materials (dip nets, buckets, portable aerators) to effectively accomplish these recue efforts.

5. Project objectives and goals

   The primary objective of the MBSTP Juvenile Steelhead Rescue Program is to assist in the recovery of local wild steelhead populations. This is accomplished by transporting fish from stream sections which will dry up to habitats which will retain adequate water flow throughout the year. It is MBSTP's goal to see this program applied in the San Lorenzo and Pajaro watersheds for the foreseeable future, expanding to new streams as needs are recognized and state permission is secured. In quantifiable terms, MBSTP seeks to rescue at least 1,500 juvenile steelhead from drying streams in Santa Cruz County in the summer of 2019.

6. Background and history of the problem

   As the dry season progresses and creek levels drop, wild juvenile steelhead can become stranded in drying stream sections and die. This problem is encountered on many tributaries to the San Lorenzo and Pajaro River systems, where these rescue efforts are primarily focused. Over the past few years, stranding rescues have worked in cooperation with County of Santa Cruz and CDFW officials in the Bean Creek and Corralitos Creek watersheds to rescue over 1,000 juvenile steelhead from sub-optimal habitat conditions.

7. How will the project be accomplished (design specifications or plans, if applicable)

Juvenile steelhead will be rescued from drying stream habitats with assistance from CDFW personnel operating backpack electrofishing equipment. Candidate stream sections will be identified no later than June 30, 2019. Local volunteer observers will report on stream conditions. Due to the nature of local stream hydrology and habitat conditions, volunteer crews must be ready to operate under short notice and demanding timeframes. When creek sections are identified as going dry, stranding rescue teams must be prepared to engage in work within 48 hours.

Once candidate streams have been identified, the timeframe has been established and rescue crews are in place, the operation may commence. CDFW personnel shock creek sections with a backpack electrofishing unit. MBSTP volunteers and County personnel are on hand to assist with netting fish, loading them into aerated buckets, and transporting them to coolers on a waiting MBSTP fish transport truck. All fish will be kept under the care of the MBSTP Fish Culturist, ensuring survival through the rescue and transport process. Once loading densities in the coolers have reached capacity or work hours are coming to a close, all fish are transported to river sections which will retain water throughout the dry season. Fish are moved via aerated bucket to suitable release sites, identified in coordination with CDFW.

Releasing these steelhead to more suitable (survivable) rearing habitats works to address human-sourced impacts on salmonid populations in Santa Cruz County watersheds, and also helps to support and recover locally-adapted genetics in wild fish.

7. Budget (include sufficient detail to explain use of grant monies). Specify if there are any sources of other funds committed to the proposed project.

Item	Funds Requested	Match Contribution	Total Amount
6x D-frame, plastic mesh dipnets	$150	$150	$300
12x Five Gallon buckets	$0	$50	$50
24x Portable aquarium aerators	$50	$150	$200
3x 100qt. Igloo Coolers	$200	$100	$300
TOTAL AMOUNTS	**$400**	**$450**	**$850**

8. Timeline for completion

All work under this project will be completed by September 1, 2019. Supplies purchased under this grant will be used continuously, and are anticipated to contribute to local stranding rescues for years to come. All supplies purchased under this grant will be acquired no later than July 31, 2019.

9. Background or history of your organization

MBSTP has been working to recover and support salmon and steelhead populations of the Monterey Bay region for over 40 years. These steelhead stranding rescues have occurred intermittently over the past three years, and our organization wishes to continue and expand this program. MBSTP coordinates with CDFW and NOAA for coho salmon recovery efforts on the Central Coast through our genetic conservation hatchery located on a tributary to Scott Creek, north of Santa Cruz. Our organization also engages in chinook salmon net pen releases in Monterey Bay to support local sport and commercial fisheries. We participate in community outreach and education through our Salmon and Trout Education Program (STEP), which has spread the message of watershed stewardship to thousands of local K-12 students.

Chapter 16.34
SIGNIFICANT TREES PROTECTION

Sections:

16.34.010 Purpose.

(A) The Board of Supervisors of Santa Cruz County finds that the trees and forest communities located within the County’s Coastal Zone are a valuable resource. Removal of significant trees could reduce scenic beauty and the attractiveness of the area to residents and visitors.

(B) The Board of Supervisors further finds that the preservation of significant trees and forest communities on private and public property is necessary to protect and enhance the County's natural beauty, property values, and tourist industry. The enactment of this chapter is necessary to promote the public health, safety, and general welfare of the County, while recognizing individual rights to develop, maintain, and enjoy the use of private property to the fullest possible extent. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.015 Scope.

This chapter regulates the removal of trees in the Coastal Zone when not included in the provisions of a discretionary permit. This chapter establishes the type of trees to be protected, the circumstances under which they may be removed, and the procedures for obtaining a permit for their removal. The provisions of this chapter apply to all persons as defined herein; they also establish standards applicable to tree cutting activities of public agencies required to obtain a Coastal Zone permit pursuant to Chapter 13.20 SCCC. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.020 Amendment.

Any revision to this chapter which applies to the Coastal Zone shall be reviewed by the Executive Director of the California Coastal Commission to determine whether it constitutes an amendment to the Local Coastal Program. When an ordinance revision constitutes an amendment to the Local Coastal Program, such revision shall be processed pursuant to the hearing and notification provisions of Chapter 13.03 SCCC and shall be subject to approval by the California Coastal Commission. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.030 Definitions.

All terms used in this chapter shall be as defined in the General Plan and Local Coastal Program Land Use Plan glossaries and as follows:

"Coastal Zone" means that unincorporated area of the County of Santa Cruz as defined by the California Coastal Act of 1976, Division 20 of the California Public Resources Code. This area is identified on the General Plan and Local Coastal Program Land Use Plan maps.

"Diameter at breast height (d.b.h.)" means the average diameter of a tree outside the bark at a point four and one-half feet above the highest level ground.

"Person" means any individual, group, firm, organization, association, limited liability company, or other business association, corporation, including any utility, partnership, business, trust company, special district or public agency thereof, or other party, or as specified in Section 53090 of the California Government Code; or the State or a State agency or city when not engaged in a sovereign activity.

Where a coastal development permit is required pursuant to Chapter 13.20 SCCC, State and Federal agencies may be required to comply with various provisions of this chapter as a condition of the coastal development permit.

“Planning Director” means the Director of the Planning Department or his or her authorized designee charged with the administration and enforcement of this chapter.

“Significant tree,” for the purposes of this chapter, shall include any tree, sprout clump, or group of trees, as follows:

(A) Within the urban services line or rural services line, any tree which is equal to or greater than 20 inches d.b.h. (approximately five feet in circumference); any sprout clump of five or more stems each of which is greater than 12 inches d.b.h. (approximately three feet in circumference); or any group consisting of five or more trees on one parcel, each of which is greater than 12 inches d.b.h. (approximately three feet in circumference).

(B) Outside the urban services line or rural services line, where visible from a scenic road, any beach, or within a designated scenic resource area, any tree which is equal to or greater than 40 inches d.b.h. (approximately 10 feet in circumference); any sprout clump of five or more stems, each of which is greater than 20 inches d.b.h. (approximately five feet in circumference); or, any group consisting of 10 or more trees on one parcel, each greater than 20 inches d.b.h. (approximately five feet in circumference).

(C) Any tree located in a sensitive habitat as defined in Chapter 16.32 SCCC. Also see SCCC 16.34.090(C), exemption of projects with other permits.

“Significant tree removal permit” means a permit issued pursuant to the provisions of this chapter.

“Sprout clump” means individual stems arising from one root collar and sharing a common root system. [Ord. 5182 § 14, 2014; Ord. 4346 §§ 73, 74, 1994; Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.040 Permit required.

Except for those exempt activities as enumerated in SCCC 16.34.090, no person shall do, cause, permit, aid, abet, suffer, or furnish equipment or labor to remove, cut down, or trim more than one-third of the green foliage of, poison, or otherwise kill or destroy any significant tree as defined in this chapter within the Coastal Zone until a significant tree removal approval for the project has been obtained pursuant to Chapter 18.10 SCCC, Level II. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.050 Application and fee.

Applications for significant tree removal approvals granted pursuant to this chapter shall be made in accordance with the requirements of Chapter 18.10 SCCC, Level II, and shall include the following:

(A) Applicant's or authorized representative's name, address, and telephone number.

(B) Property Description. The description of the site(s) involved, including the street address, if any, and the assessor's parcel number.

(C) Required Information. The following information shall be provided in writing:

(1) A site plan sufficient to identify and locate the trees to be removed, other trees, buildings, proposed buildings, and other improvements.

(2) A description of the species, circumference or diameter at breast height, estimated height, and general health of the tree(s) to be removed.

(3) A description of the method to be used in removing the tree(s).

(4) Reason(s) for removal of the tree(s).

(5) Proposed visual impact mitigation measures as appropriate. Size, location, and species of replacement trees, if any, shall be indicated on the site plan.

(D) Applicant's Property Interest. Evidence that the applicant is the owner or purchaser under contract of the premises involved, is the owner of a leasehold interest, or has written permission of the owner to make the application.

(E) Further Information. Such further information as may be required by the Planning Director, including but not limited to the opinion of a registered professional forester, tree surgeon, or other qualified expert.

(F) Filing Fee. A filing fee, set by resolution of the Board of Supervisors, shall accompany the application. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.060 Required findings.

One or more of the following findings shall be made prior to granting approvals pursuant to this chapter in addition to the findings required for the issuance of a development permit in accordance with Chapter 18.10 SCCC:

(A) That the significant tree is dead or is likely to promote the spread of insects or disease.

(B) That removal is necessary to protect health, safety, and welfare.

(C) That removal of a nonnative tree is part of a plan approved by the County to restore native vegetation and landscaping to an area.

(D) That removal will not involve a risk of adverse environmental impacts such as degrading scenic resources.

(E) That removal is necessary for operation of active or passive solar facilities, and that mitigation of visual impacts will be provided.

(F) That removal is necessary in conjunction with another permit to allow the property owner an economic use of the property consistent with the land use designation of the Local Coastal Program Land Use Plan.

(G) That removal is part of a project involving selective harvesting for the purpose of enhancing the visual qualities of the landscape or for opening up the display of important views from public places.

(H) That removal is necessary for new or existing agricultural purposes consistent with other County policies and that mitigation of visual impacts will be provided. Also see SCCC 16.34.090(D), exemption of tree crops. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.065 Approvals.

Significant tree removal applications shall be processed according to Chapter 18.10 SCCC, Level II. Approvals shall be granted by the Planning Director or his designee. Notices of actions taken pursuant to this chapter shall be in accordance with Chapter 18.10 SCCC. [Ord. 3443 § 1, 1983].

16.34.070 Conditions of approval.

In granting any permit as provided herein, the Planning Director may attach reasonable conditions to mitigate visual impacts and ensure compliance with the provisions of this chapter, including but not limited to replacement of trees removed with trees acceptable to the Planning Director. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.080 Emergencies.

In the case of emergency caused by the hazardous or dangerous condition of a tree and requiring immediate action for the safety of life or property, such necessary action may be taken to remove the tree or otherwise reduce or eliminate the hazard without complying with the other provisions of this article, except that the person responsible for cutting or removal of the tree shall report such action to the Planning Director within 10 working days thereafter. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.090 Exemptions.

The following work is exempted from all provisions of this chapter:

(A) Timber operations which are in accordance with a timber harvesting plan submitted pursuant to the provisions of the Z'berg-Nejedly Forest Practices Act of 1973 (commencing with Section 4511).

(B) Any activity done pursuant to a valid timber harvest permit, or a notice of timber harvesting, approved pursuant to Chapter 16.52 SCCC.

(C) Any tree removal authorized pursuant to a valid discretionary permit approved pursuant to Chapter 13.10 (Zoning Regulations), Chapter 13.20 (Coastal Zone Regulations), Chapter 14.01 (Subdivision Regulations), Chapter 16.20 (Grading Regulations), Chapter 16.22 (Erosion Control), Chapter 16.30 (Riparian Corridor and Wetlands Protection), Chapter 16.32 (Sensitive Habitat Protection), or Chapter 16.54 SCCC (Mining Regulations).

(D) Removal of tree crops pursuant to agricultural operations. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.100 Inspection.

Repealed by Ord. 4392A. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.105 Violations.

(A) It shall be unlawful for any person to do, cause, permit, aid, abet or furnish equipment or labor to remove, cut down, trim more than one-third of the foliage of, poison, or otherwise kill or destroy any significant tree as defined in SCCC 16.34.030 within the Coastal Zone unless: (1) a development permit has been obtained and is in effect which authorizes such activity; or (2) the activity is exempt from the requirement for such a permit by reason of the provisions of SCCC 16.34.090; or (3) there was an emergency caused by the hazardous or dangerous condition of the tree which required the action to be taken immediately for the safety of life or property.

(B) It shall be unlawful for any person to exercise any development permit which authorizes actions affecting significant trees without complying with all of the conditions of such permit. [Ord. 3451-A § 24, 1983].

16.34.110 Enforcement penalties, remedies and procedures for violations.

Any violation of any provision of this chapter shall be subject to the enforcement penalties, remedies, and procedures set forth in SCCC Title 19, Enforcement of Land Use Regulations. [Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.120 Appeals.

All appeals of actions taken pursuant to the provisions of this chapter shall be made in conformance with the procedures set forth in Chapter 18.10 SCCC; provided, however, that code enforcement actions and decisions are not subject to administrative appeal except for appeals of revocation of permits pursuant to SCCC 18.10.136(C). [Ord. 4392A § 13, 1996; Ord. 3443 § 1, 1983; Ord. 3341 § 1, 1982].

16.34.130 Expiration.

Unless otherwise specified, approvals issued pursuant to this chapter shall expire one year from the date of issuance if not exercised. Where approvals are issued in conjunction with a development permit granted pursuant to Chapter 18.10 SCCC, the approval shall expire in accordance with the provisions of Chapter 18.10 SCCC. [Ord. 3443 § 1, 1983].

16.34.140 Amendment.

Amendments to approvals granted pursuant to this chapter, whether for change of project, conditions, or expiration date or other time limits, shall be processed in accordance with the provisions of Chapter 18.10 SCCC. [Ord. 3443 § 1, 1983].

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FISH AND WILDLIFE ADVISORY COMMISSION
Report for Calendar Years 2017 and 2018

DRAFT

Roles of the Commission

The Fish and Wildlife Advisory Commission (Commission) advises the Santa Cruz County Board of Supervisors (Board) on issues relating to fish and wildlife, and also recommends projects for funding with the County's portion of Fish and Game Code fine monies and judgments.

Meeting Dates, Time and Location

The Commission meets generally six times a year in March, May, June, September, November and December at 7:00 pm in the Fifth Floor Redwood Conference Room, Room 520, at 701 Ocean Street, Santa Cruz.

Commission Structure

As of December 31, 2018, the Commission consists of Chairperson Chris Berry, representing the 1st District, and Vice Chair Jodi Frediani, representing the 3rd District. Other commissioners include Lois Robin, 1st District; Rogers Johnson and Sandra Baron, 2nd District; Kristen Lee, 3rd District; Mathew Wise and Samuel Cooley, 4th District; Matt Freeman and Ross Parmenter, 5th District.

Commission Staff

Kristen Kittleson, Resource Planner with Environmental Health, is the administrative staff to the Commission.

Annual Goals and Accomplishments – 2017 and 2018

Over 2017 and 2018, the Commission considered and made recommendations regarding a range of topics including cannabis cCultivation, coho and steelhead conservation, riparian habitats, climate change and federal regulations affecting the environment. The Commission followed closely the County's development of a Cannabis Cultivation Ordinance and discussed this issue at several meetings and submitted two comment letters to the Board. The Commission also commented on the County's Strategic Plan and the importance of water resources to our community and aquatic ecosystems.

The Commission continues to follow steelhead and coho salmon recovery efforts. Over the past two years, the Commission has heard a presentation by Dr. Kiernan, National Marine Fisheries Service about coho conservation, by Monterey Bay Salmon and Trout Project about conservation efforts and by the County's fishery resource planner on the Juvenile Steelhead and Stream Habitat Monitoring Program.

In September 2017, the FWAC participated in a joint meeting with the Water Advisory Commission and Commission on the Environment on the County's Climate Action Strategy and other approaches to address Climate Change Adaption.

In 2017, the Commission recommended $15,000 in funding for 9 projects that included transportation for O'Neill Sea Odyssey stewards, California Turn In Poachers program, wildlife rescue, Invasive Weed Management and several outreach projects for snowy plovers, marine conservation, winter preparedness and watershed conservation.

In 2018, the Commission recommended $12,445 in funding for six projects that included teacher training and equipment for the Classroom Aquarium Education Program, student education and trash removal on Scotts Creek beach, transportation for students attending O'Neill Sea Odyssey program, wildlife rehabilitation, Scotts Creek hydrology study and ivy removal at a Santa Cruz Long-Toed Salamander Ecological Reserve.

Over 2017 and 2018, fines and settlements deposited into the Fish and Game Propagation Fund dropped off significantly and the Commission suspended the Public Grants Program for the 2018-19 fiscal year. The Commission is collecting information about the financial situation but hopes to solicit proposals for the Public Grants Program for fiscal year 2019-20. This is an important funding source that supports local conservation organizations with small projects and outreach programs.

Additional Activities

The Commission provides a forum for members of the public to voice concerns or issues on fish and wildlife related issues. In the past two years, the Commission heard public comments about cannabis cultivation, low-flow fishing regulations, the Highway 1 bridge at Scotts Creek, riparian conservation, the Significant Tree Ordinance and wildlife preparedness. In 2018, the Commission updated their public comment policy to encourage more public participation on agenda topics and to clarify how to submit those comments.

Future Goals

The Commission scheduled 8 meetings for 2018 to allow more time to address a wide range of topics including funding for the Public Grants Program, PG & E's Community Wildlife Safety Program, CDFW's low flow fishing regulations, 40 years of San Lorenzo watershed management, land and open space conservation and management, invasive plants, climate change, Pajaro River, impact of crab traps on whales and wildlife. The Commission will continue to follow the implementation of the cannabis cultivation ordinance, coho salmon and steelhead recovery planning, and riparian corridor enhancement. The Commission will continue to provide a forum for public input regarding fish and wildlife issues.

Fish and Wildlife Advisory Commission Attendance 2017 and 2018

Commissioner	**District**	**Mar '17**	**May '17**	**June '17**	**Sept '17**	**Nov '17**	**Dec '17**	**Mar '18**	**May '18**	**June '18**	**Oct '18**	**Dec '18**
Berry	I	P	P	P	P	P	P	P	P	P	P	P
Robin	I	P	P	P	P	P	P	Ex	P	P	P	P
Johnson	II	P	P	P	Ex	P	Ex	P	P	P	Ab	P
Baron	II	P	P	P	P	P	P	P	P	P	P	P
Frediani	III	Ex	P	P	P	P	P	Ex	Ex	Ex	Ex	P
Noyes	III	P	---	---	---	---	---	---	---	---	---	---
Lee	III	---	---	---	---	P	P	P	P	P	Ab	P
Shikuma	IV	P	P	P	Ex	---	---	---	---	---	---	---
Maridon	IV	P	Ex	Ex	---	---	---	---	---	---	---	---
Wise	IV	---	---	---	P	P	P	Ex	Ex	P	P	Ex
Cooley	IV	---	---	---	---	---	---	P	P	Ex	Ex	Ex
Freeman	V	P	Ex	Ex	P	P	P	P	Ex	Ex	P	P
Grant	V	Ab	---	---	---	---	---	---	---	---	---	---
Parmenter	V	---	---	---	P	P	P	P	P	Ex	P	Ex

KEY: P = Present   Ex= Excused   Ab = Absent   --- = not on the commission

PG&E's Wildfire Safety Program is a Destructive Diversion from Wildfire Prevention

Comments from the Valley Women's Club's Environmental Committee to the County Fish and Wildlife Commission's discussion of PG&E during the Commission's meeting on February 7, 2019

Under the guise of PG&E's "*Community Wildfire Safety Program",* the San Lorenzo Valley and Bonny Doon are now embroiled in a massive, ill-conceived "enhanced vegetation management" plan, with no data to prove it will work, no recognition of severe negative environmental impacts and misplaced liability. This mistaken "Program" will eventually span the entire rural County. The CPUC claims that this project is not a "Project" as defined in CEQA law, even though it involves thousands of miles of utility wire corridors and hundreds of thousands of demolished trees across CA.

Of course, we need to assure protection against utility-associated wildfire, but PG&E is spending so much money on its unprecedented effort to cut down healthy, mature trees, that this diverts funds away from the investments necessary to make their system safer with long overdue infrastructure improvements.

There are two most important actions to dramatically increase safety. One is to install high impedance arc fault interruption devices. This "off the shelf" gear instantly cuts power to broken wires before they fall to the ground – preventing both fire and electrocution. The second is to eliminate weak, antiquated "bare line conductors," the dominant wire used throughout rural areas, by replacing it with high strength, insulated wire. This solves the problem long-term, without massive tree removals that create wind-corridors and actually speed the spread of fire brands along the ground, speaking the spread of wildfires.

The Fish and Wildlife Commission is urged to quickly advise the Board of Supervisors, along with the the State Legislature and the CPUC, to quickly require stronger safety measures than what PG&E is doing in its *"Program"*. This would save hundreds of thousands of trees across the state. The public safety improvement and the economics of doing so are far superior to continuing a massive, unproven tree removal process.

Understanding the severe negative impacts of the *Vegetation Management Program* and the thorough neglect of infrastructure that it entails, Kevin Collins personally filed a Formal Safety Complaint against PG&E's "*Community Wildfire Safety Program"* with the California Public Utilities Commission. (Docket # C1809011). The goal is to persuade the

Commission to write new regulations that will prioritize equipment upgrades over vegetation removal. You can add your voice to this effort.

The private property damage and the environmental impacts of PG&E's "Program" are enormous. The cutting PG&E has been doing goes far beyond CA Public Utilities Commission regulations of a minimum 4-feet *radial* clearance (to last a year) around each wire. PG&E was instead demanding of homeowners a 30-foot wide clearance of trees and shrubs from ground to sky under every run of utility wire. This 30-foot total width of clearance is based upon a recently adopted CPUC Recommendation of 12 feet radial clearance. Guidelines and Recommendations don't have the same legal standing as Rules and Regulations. The CPUC Rule for distribution voltage wire vegetation clearance remains at 4 feet radial clearance. And this rule continues to include an exception to 6 inches of clearance from a bare wire for trees of any species and for large branches that do not move in wind.

It is untenable that confused and frightened residents have not been fully informed of their rights and are thus not empowered to define the legal limits that PG&E may go in cutting trees on their own property, after the CPUC minimum clearance rules have been complied with. Instead they deal with repeated attempts by PG&E and Davey Tree to dissuade them, including threats of liability if they refuse to allow beautiful trees to be destroyed.

Many people are hoping to save their trees while conforming to the Regulation of 4-foot radial clearance in the Code, but not the Guidelines of PG&E's "Program". (*Regulations are law. Guidelines are not.*) They are angry and distressed at having received such "threats" in person or by phone. This is particularly offensive in cases where the code standards have already been complied with.

The citizens of this county deserve better. As our Fish and Game Commission, you can advise the Board of Supervisor to take strong action to require that PG&E act immediately to upgrade our aging, weak system that threatens to continue to create wildfires.

Respectfully submitted,

Nancy B. Macy, Chair
Environmental Committee for the SLV
Valley Women's Club   www.valleywomensclub.org
nbbm@cruzio.com   831/338-6578

Valley Women's Club of San Lorenzo Valley
PO Box 574, Ben Lomond, CA 95005
www.valleywomensclub.org

November 29, 2018

Fish and Wildlife Advisory Commission
701 Ocean Street, Room 312
Santa Cruz, CA 95060

Dear Commissioners:

Santa Cruz County is home to majestic forests and valuable trees which must be protected and preserved for the health and welfare of the citizens of this county and for that of future generations. Our forests provide more than scenic beauty; they provide valuable services such as preventing the erosion of topsoil, protecting against flood hazards and the risk of landslides, counteracting pollutants in the water and air and relieving the public costs of installing and maintaining storm water drainage systems.

You are also well aware of the valuable habitat that our forests provide to a variety of rare, threatened and endangered species, as well as the importance of our forests to our local drinking water supplies.

Increasingly, forests such as ours are also being recognized as a necessary component for combating global climate change. A new peer-reviewed study from The Nature Conservancy found that 21 percent of the United States' greenhouse gas pollution could be removed through enhanced management of forest, grassland, agricultural, and coastal areas. An offset at this level would be the equivalent to pollution from every single US car and truck on the road. According to Jad Daley, the CEO of American Forests, "Planting trees and improving the health of existing forests will be a deciding factor in whether we are able to get ahead of the climate curve."

“Heritage” or “Significant” trees are the keystones of our forests. Such trees are defined as being large, older trees with unique value because they are irreplaceable. Protecting these trees with a *Heritage* or *Significant Tree Ordinance* is an important step toward a stewardship-minded approach to forest management.

Additionally, Santa Cruz residents have recently found themselves in a terrible position where they are *unable to protect their large and old growth trees* due to PG&E's "Enhanced Vegetation Management" projects. Such an ordinance could also provide relief to these residents and property owners who have fallen victim to the removal and vandalism of their trees.

For these reasons, the Valley Women's Club respectfully requests that the Fish and Wildlife Advisory Commission advise the Board of Supervisors to adopt a *Heritage* or *Significant Tree Ordinance* for areas outside of the Coastal Zone.

Thank you for your time and consideration.

Sincerely,

Sheila De Lany,
President of the Valley Women's Club

Jane Mio
Vice-President of the Valley Women's Club

SANTA CRUZ COUNTY GROUP
Of The Ventana Chapter
P.O. Box 604, Santa Cruz, CA 95061
https://ventana2.sierraclub.org/santacruz/
e-mail: sierraclubsantacruz@gmail.com

December 5th, 2018
To: Fish and Wildlife Advisory Commission
Re: County Heritage Tree Ordinance

Dear Fish & Wildlife Advisory Commissioners,

The Sierra Club would like to support the Valley Women's Club letter with the goal of creating a Santa Cruz County Heritage Tree Ordinance.

We welcome questions and input from staff or the Board of Supervisors regarding adopting a Heritage or Significant Tree Ordinance for areas outside of the Coastal Zone.

Please protect our heritage trees, our amazing allies in cleaning the air and sequestering carbon!

Sincerely,
Erica Stanojevic
Conservation Committee Chair
Santa Cruz Group of the Sierra Club

Public Comments
for the December 6, 2018 meeting of the Fish and Wildlife Advisory Commission

From Jean Brocklebank: Needless to say, I also very much support the idea of recommending to the Board of Supervisors that they pursue promulgation of a Significant Tree Ordinance for trees outside of the Coastal Zone of Influence.

Public Comments
for the December 6, 2018 meeting of the Fish and Wildlife Advisory Commission

From: **David S. Kossack, Ph. D.** <dkossack@san-andreas-land-conservancy.org>
Date: Wed, Dec 5, 2018 at 6:24 PM
Subject: Fish and Wildlife Advisory Commission Dec. 6 meeting

Public Comment on Agenda Item 5. B. December 6 meeting, SCz Co. FWAC.
20 Years of Habitat Conservation Planning for the City of Santa Cruz Water Department,
Chris Berry Watershed Compliance Manager (40 minutes)

The City of Santa Cruz has a number of water projects in motion. These include City of Santa Cruz's Newell Creek Dam Inlet/Outlet Replacement Project, CITY OF SANTA CRUZ'S WATER RIGHT RELIABILITY PROJECT, development a HCP with USFWS and development of a separate HCP with NMFS. Depending on who you talk to these projects range from out for CEQA public comment (Newell Dam Project), to fast-track to back-burner: this is a dangerous situation if you are concerned about the environment, conservation and/or habitat protection.

The City has been having discussions with NMFS and FWS since at least 2006, 12 years, but apparently neither of these HCPs have gotten beyond the planning stage. It is important that we have an opportunity to hear about the intent of the HCPs (e.g., what projects, what impacts, how does it fit in with the UCSC expansion), and get an update on their status. It would also be useful to have some input into the protection and restoration of the City's watersheds for public trust resources (fish and wildlife and the ecosystems they depend upon…). It would be a shame to let this opportunity slip away.

The title of Item 5.B. skirts the issue a bit since the City has been spending that time "developing" HCP(s) rather than implementing a plan that provides permanent habitat protection but the subject is timely. We are glad that the City is engaging the agencies that are responsible for providing stewardship in these areas. As an perspective we offer that while none of the previous political administrations that "guide" our Federal agencies have been particularly benign when it comes to fish and wildlife we should keep in mind that Donald is driving these days. Everyone complains about Donald but we also see lot of user groups (e.g., the City) heading to our Federal agencies hoping to get their best deal… Needless to say It is very important to pay attention to these processes, and we need to look at enforceable protections in perpetuity.

Here's the setup:

Before the first cut marbled murrelets (MaMu), spotted owls and martens were on every lamp post. Martens are gone, so are spotted owls but there are a few MaMu still around. MaMu feed on fish off the coast and nest in the trees of the coastal forests (e.g., coast redwood, Doug. fir). MaMu prefer the broader branches and other morphologic features of the "late seral" trees that made up the mature forest ecology of Santa Cruz County. There aren't many "late seral" trees around these days… to the point that the number of “late seral” trees determines the number of MaMu nesting sites, which defines the number MaMu offspring that can be produced in any given year. MaMu are listed under the ESA and the CESA.

The Coastal Zone provides some protection for what has been referred to as Heritage, or Significant, Trees, trees that are larger and older than the trees that have grown back since the first cut, these trees likely represent “late seral” trees. The ESA/CESA also affords some protection for trees capable of providing nesting sites for MaMu, again existing “late seral” trees. Protecting existing/remaining “late seral” trees is important as is any effort to expand these protections to “late seral” trees outside the Coastal Zone. It’s important to recognize that the number of “late seral” trees still vertical is really only a handful, either inside or outside of the Coastal Zone, and given the experience in Redwood Nat’l Park, their long term survival is probably tenuous. If MaMu populations are to recover they will need additional nesting sites. Unfortunately there is no mechanism (e.g., CEQA) capable of promoting the growth “young” trees into “late seral” trees, that is increasing the number of “late seral” trees, let alone moving “young” forests into “late seral” forests, increasing the extent of a mature forest ecology. Without a mechanism to protect “young” forests so that they can grow into “late seral” forests the 8-20 year harvest cycles of the logging industry assures that no tree escapes.

I hold up the recovery of MaMu populations in Santa Cruz County (aka SCz Mts.) by the scruff of the neck and offer it as a poster-child for the level of habitat protection and restoration that needs to be put in place by any Habitat Conservation Planning whether it is defined by a Federal agency (i.e., USFWS and/or NMFS) or otherwise.

The City of Santa Cruz’s “Watershed Planning Process” (circa 2000-2003) was to address the impacts of commercial logging in the City Water Department’s watershed properties. The Watershed Planning Process was particularly concerned with impacts to fish and wildlife but it was also concerned with the impacts of erosion and sediment on water quality. One of the motivations among many that supported the Process was to eliminate commercial logging in City watersheds all together, one of the tools capable effecting this goal is a Conservation Easement (CE). The Process Committee was aware of CEs, because I told members of the Committee about CEs. A CE dedicated to a qualified entity that takes the timber rights off the table could protect existing “late seral” trees and allow existing logged forest to grow through to “late seral” age class. It could protect the City’s watersheds in perpetuity. It is unfortunate that the management goals of other land owners that should be considered capable of providing “habitat protection and restoration” of our poster-child don’t seem to have the grip (e.g., State Parks, CDL, Rancho San Vicente).

A conservation easement on City watersheds that promotes a mature forest ecology would be good for fish, too, a denser canopy means more shade; more fog drip; cooler water temperatures; and more stream complexity. A mature forest ecology provides more carbon storage particularly beyond 100 - 1000 years with the accumulation of root mass and large/course woody debris. With respect to the proposed NMFS HCP, in addition to the San Lorenzo River the City takes water from Laguna and Liddell Creek watersheds, the Big Basin Hydrologic Unit. A City/NMFS HCP could contribute to of managing the Hydrologic Unit as a single watershed including listed CCC coho and steelhead.

Requested Motion:

- We ask that the SCz Co. FWAC pass a motion advising the Sups. to support a Conservation Easement on City of Santa Cruz watersheds capable of protecting and restoring MaMu populations and the mature forest ecologies that they depend upon.

Thank You

David Kossack
On behalf of
San Andreas Land Conservancy

Public Comments
for the February 7, 2019 meeting of the Fish and Wildlife Advisory Commission

January 31, 2019

I wanted to address an item in the October minutes that I don't believe was actually discussed at the October meeting of the FWAC: that is the comment that you provide saying CalTrans rejects the bridge(s) as fish passage issues on Scott Creek at Highway 1. I accessed the Passage Assessment Database (PAD) ID referenced (PAD ID 732371, DB record attached). Of interest was the assessment by CalTrans' contractors HDR in 2007. The survey and HDR's subsequent report were done under a couple of Task Orders (2007_TO-11 and 2008_TO-17) issued by CalTrans in response to the Waddell and Scott Creek Bridge Replacement Stakeholder meetings.

I have attached the final report for these TOs (IMPLICATIONS OF HIGHWAY BRIDGE CROSSING EFFECTS ON COASTAL LAGOONS, Assessment of the Effects of Highway 1 Bridges on Scott and Waddell Creek Lagoons, Santa Cruz County). I think that the report and it conclusions raise the very issues that the Sen. NR&W Cumulative Barriers to Fish Passage letter sent CalTrans Director Kempton is asking about…

I would appreciate it if these 3 items could be presented to the FWAC at February 7 meeting to balance out meeting and minutes.

Thank you

David Kossack
On behalf of
San Andreas Land Conservancy

California Fish Passage Assessment Database

PAD_ID	732371	
PassageID	11968	
StreamName	Scott Creek	
TributaryT	Pacific Ocean	
SiteName	Hwy 1 Bridge w/o potential passage constraints	
SiteType	Road crossing	
BarStatus	Not a barrier	
SpeciesBlocked	Null	
NumStructures	Null	
Protocol	***Caltrans Reconnaissance Protocol***	
AssessedBy	***HDR Engineering, Inc.***	
SurveyDate	***2/5/2007***	
TrtStatus	Planned	
YrTreated	Null	
TreatedBy	Null	
StructOwner	California Department of Transportation	
LandOwner	Null	
Notes	straightened esturay d/s associated with the bridge construction, Caltrans Active Fish Passage Project, date of completion unknown	
TrtRecom	Replace the existing short-span bridge with a full-span bridge to improve estuary function and lagoon rearing habitat.	
Watershed	San Francisco Coastal South	
County	Santa Cruz	
CalWatHR	Central Coast	
CalWatHU	BIG BASIN	
CalWatHA	Santa Cruz	
CalWatHSA	Davenport	
CalWatNo	330411	
NHDCOMID	142507800	
NHDComMeas	32.027747	
LLID	Null	
BegFt	Null	
Route	1	
PostMile	31.55	
DivOper	Null	
DivMobile	Null	
Updated	7/25/2012	
Source	Caltrans, CEMAR	
WebLegend	Not a Barrier	
Point_X	-122.229003	
Point_Y	37.040673	
Miles_Upst	Null	

IMPLICATIONS OF HIGHWAY BRIDGE CROSSING EFFECTS ON COASTAL LAGOONS

Assessment of the Effects of Highway 1 Bridges on Scott and Waddell Creek Lagoons, Santa Cruz County

November 2008

Prepared for
California Department of Transportation
Division of Environmental Analysis
Office of Biology and Technical Assistance
Sacramento, CA USA
43A0150

Prepared by
HDR Engineering, Inc.
Sacramento, CA

For individuals with sensory disabilities this document is available in alternate formats. Please call or write Richard Hill, Caltrans Task Order Manager, at P.O. Box, 942784, Sacramento, CA 94274−0001. 916−653−8117 Voice, or use the CA Relay Service TTY number 1−800−735−2929.

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"It is generally recognized that a lagoon is variable in extent, depth, salinity, and even position or location due to dynamic interactions between fluvial discharge, terrestrial sediment input, breaches of dune systems and beaches, and sediment delivery from the marine side of the system. Such variability is natural and contributes to the overall ecological diversity of lagoons in time and space. However, such complexity is difficult to manage, particularly when management is focused on maximizing anything but diversity. Efforts to provide steady levels of recreation or to maximize certain wildlife populations or to provide flood control usually involve physical control of driving functions, such as sedimentation, fluvial hydrology, or tidal excursion. The conflicts between management objectives and natural hydro-geomorphic functions put a premium on understanding the nature of the site and making sure objectives are achievable."

Joshua Collins, San Francisco Estuary Institute

1 Introduction

The California Department of Transportation (Caltrans) is evaluating effects of existing state highway facilities on the Coastal lagoon habitats of Scott and Waddell Creeks, Santa Cruz County. Highway 1 crosses both creeks immediately upstream of the Pacific Ocean. The facilities have altered the tidal interface at the road crossings, and, in Scott Creek, the stream reach extending through most of the historic lagoon area has been channelized. The bridges are being considered for rehabilitation and their current and potential effects on the lagoon habitats must be addressed to identify and direct permitting actions.

The subject bridges have been generally linked with degradation of lagoons and associated habitats on Scott and Waddell Creeks (NMFS 2006, Santa Cruz County 2007, Kossack 2007). The implied effects of the bridges have been specified, the mechanisms relating the bridge facilities to lagoon degradation have not. So, in its deliberation of these issues, Caltrans has identified the need to methodically address bridge effects on Scott and Waddell Creek lagoons

This assessment is to identify potential linkages between the Highway 1 bridge facilities and the Scott and Waddell Creek lagoon's dynamics, particularly as they relate to timing and duration of barrier breaching, lagoon morphology and lagoon water quality. Agency and other stakeholders are concerned that current bridge conditions interfere with migration of anadromous salmonids and create unsuitable habitat conditions for various protected species occurring in these stream systems. The assessment is intended to be a starting point for the permitting process, to identify potential effects of the bridges, rather than an evaluation of the current influences on lagoon dynamics that go well beyond the bridges' influences. Implications as to the potential effects of the bridges are to be described based on readily available information and data gaps are to be identified The breadth of investigations needed to ultimately identify effects of the current bridge configurations or potential changes in bridge design will be identified. This memorandum reports the assessment results for those issues that could be evaluated within the context of current knowledge. As such, the assessment is conceptual rather than empirical, since site-specific assessments of lagoon dynamics and thus effects of bridges on such dynamics are largely absent for the two sites of interest.

The approach has been to collect and evaluate information specific to the two systems, including historical and current information on the lagoons, their dynamics, and physical and biological attributes. Based on the knowledge that little empirical information has been acquired on the dynamics and associated physical features of these lagoons, readily available data on similar lagoon systems (based primarily on geographic proximity) were collected and used to identify applicable processes and concepts.

Ultimately, it is Caltrans goal to:

- Reduce uncertainty about lagoon conditions and processes and the effect of applicable bridge facility attributes on lagoon dynamics and habitat conditions within Scott and Waddell Creeks.
- Inform permitting agencies and other parties on the existing and potential effects associated with Highway 1 bridge facilities on Scott and Waddell Creeks.

In pursuit of that goal, this assessment provides the framework to:

- Specify the relationships between bridge facilities and lagoon dynamics and habitat conditions as they apply to Scott and Waddell Creek lagoons.
- Focus future investigations as needed to reduce uncertainties regarding these relationships.

1.1 Background

Waddell and Scott Creeks in northern Santa Cruz County support the two most persistent coho salmon populations south of San Francisco Bay (NMFS 2006). The lagoons at the mouths of these streams support a number of at-risk species, including Central California Coast Coho salmon, Central California Coast steelhead, tidewater goby, San Francisco garter snake, California red-legged frog, snowy plover and the western pond turtle (Smith 2003, Rischbieter 2000). The fishery resources supported by these watersheds have been investigated for over 70 years (Shapovalov and Taft 1954, Bond 2006). Recent, intensive investigations of the significance of the lagoons to the anadromous salmonid populations have refocused managers on the importance of these productive and apparently fragile habitats to the watershed's salmonid populations and coastal ecosystem (Bond 2006, Ammann et al. 2007, Collins et al. 2007, Hayes et al. 2007).

1.1.1 Scott Creek

The U.S. Coast Survey produced the earliest available maps of Scott Creek in 1853, as shown in **Figure 1**. Only general topographic features are indicated; the shape of the creek, location of the northern headland and beach dune features are easily identified. The existence of a lagoon is not obvious from the survey as the creek is shown connected to the Pacific Ocean. However, the mean lower low water line is indicated on the map and appears to traverse the beach and connect with the creek interior of the beach. A tidal marsh is also faintly indicated on the south side of the creek with closely spaced dashed lines (Grossinger et al (2005)). A road, agricultural development, and a low water crossing of Scott Creek are also shown. **Figure 2** provides a 1902 topographic map of the Scott Creek watershed. The map provides low resolution topography and presence of a lagoon is again not apparent. The sinuosity of Scott Creek remains identifiable as does the road crossing the creek north of the existing bridge.

Historic aerial photographs of the mouth of Scott Creek are available from 1928, showing pre-bridge conditions (**Figure 3**) similar to the original surveys described above. The 1928 photo indicates the existence of a small lagoon adjacent to the northern headland and a sandy unvegetated complex extending along the southern lagoon shoreline. The elevation of this unvegetated sand feature is unknown, but its orientation indicates tidal influence. From the photograph, the wetted area of the lagoon is wider than wetted area of the upstream channel widths, indicating impoundment of water immediately landward of the active beach. The lagoon appears shallow, with some deeper areas. The wetted surface of the lagoon is not large enough to maintain persistent tidal communication with the ocean and likely opened periodically due to freshwater inflow and less frequently by seawater overtopping during high tide and wave events. South of the lagoon, a large wetland with a small channel was present. The presence of a side channel in the wetland adjacent to the lagoon again suggests tidal influence.

The Highway 1 Bridge crossing Scott Creek was constructed in 1939. The bridge spans about 160 feet and was originally built with a channel bottom width of about 90 feet at an elevation of 0 ft (datum unknown). Per the as-built plans (**Figure 4**), the pre-bridge width of the tidal interface along the roadway alignment appears to have been about 300 feet (linear distance between high tide lines). This dimension is consistent with the 1928 aerial photograph showing the sandy feature south of the pre-existing lagoon. Portions of the lagoon at high tide may have been as wide as 450 ft, per the as-builts. Others have indicated that the beach/marsh interface may have been about 500 wide (Scotts Creek Watershed Council 2007), however, this has not been substantiated. A large dune field existed seaward of the bridge span prior to construction, with dune elevations exceeding 15 feet (datum unknown).

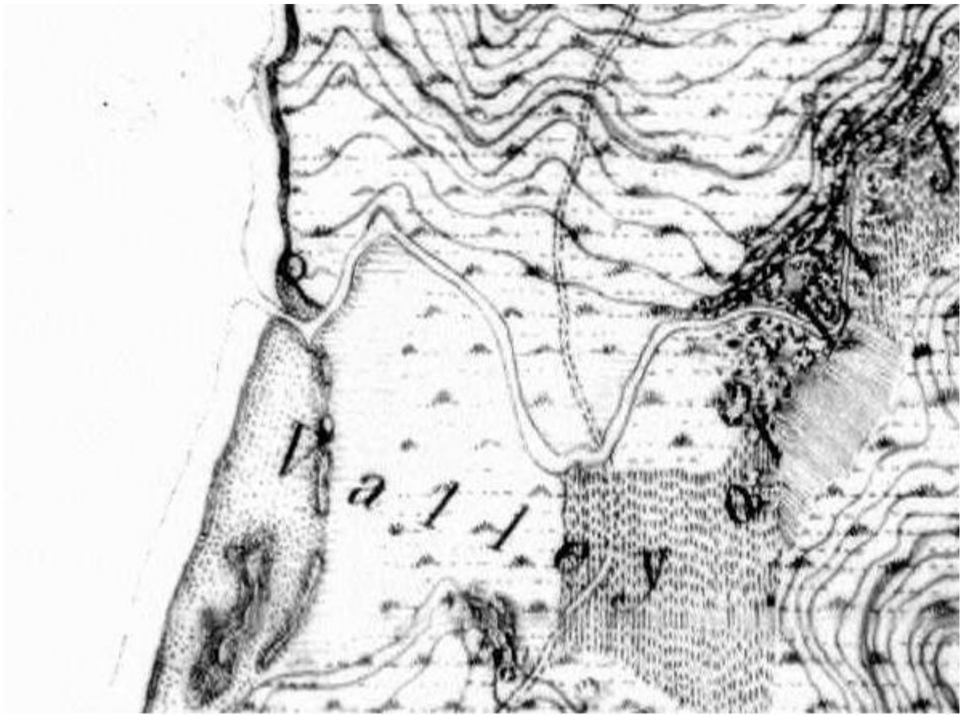

Figure 1. U.S. Coast Survey T-445 of Scott Creek by A.M. Harrison.

As part of the construction process, the northern bridge approach filled the historical lagoon tidal interface and Scott Creek was straightened and realigned. This placed the creek outlet approximately 650 ft south of its historical location and reduced the available tidal interface at high tide along the roadway alignment from 300 feet to 115 feet. The levees built to realign the creek were left in place after bridge construction and have persistently precluded the stream from its former course, north of the current alignment. In combination with other levees built in the area, wetlands areas adjoining the Scott Creek within the lagoon reach were largely isolated from tidal inundation.

Figure 5 shows an aerial photograph of Scott Creek from 1941, following completion of the bridge. Impounded water in the former lagoon areas is visible even as the creek discharges into the ocean. **Figure 6-8** provide more recent aerial photographs of Scott Creek.

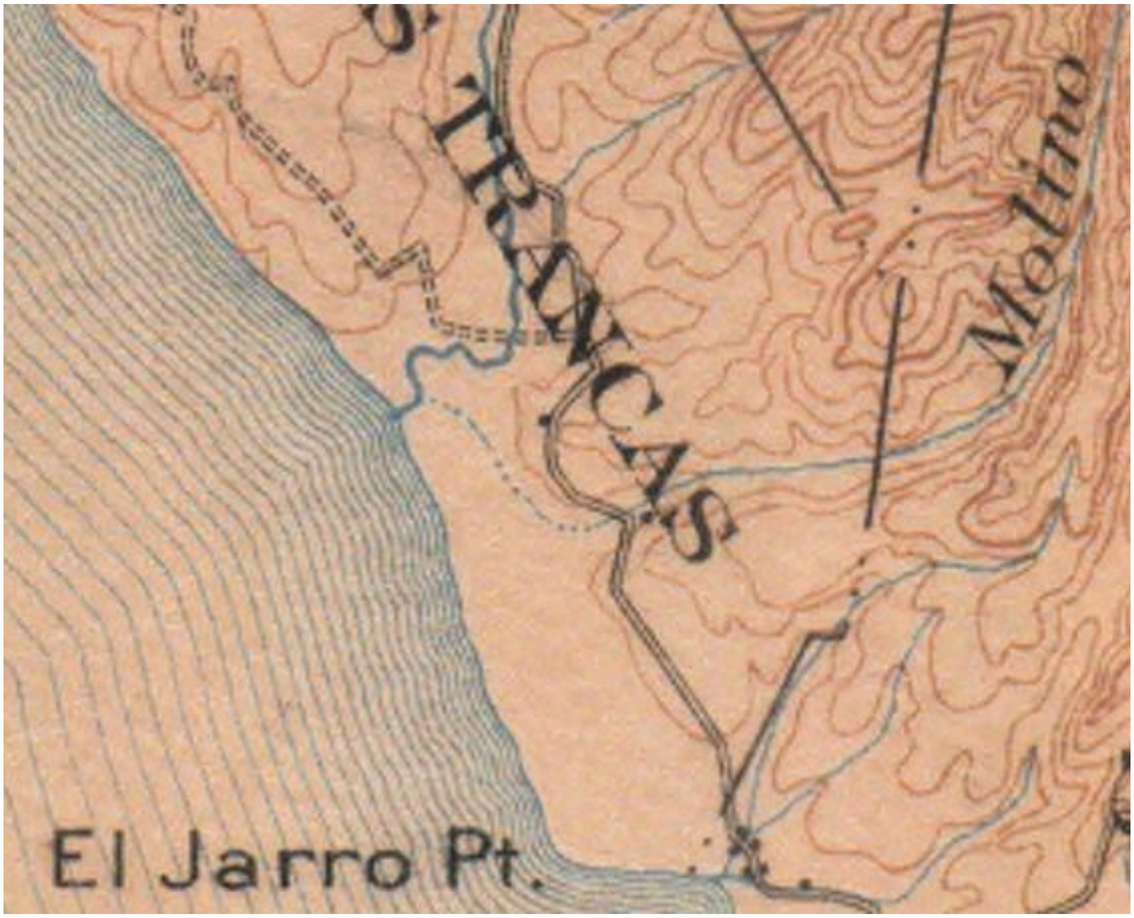

Figure 2. U.S. Coast Survey T-445 of Scott Creek by A.M. Harrison.

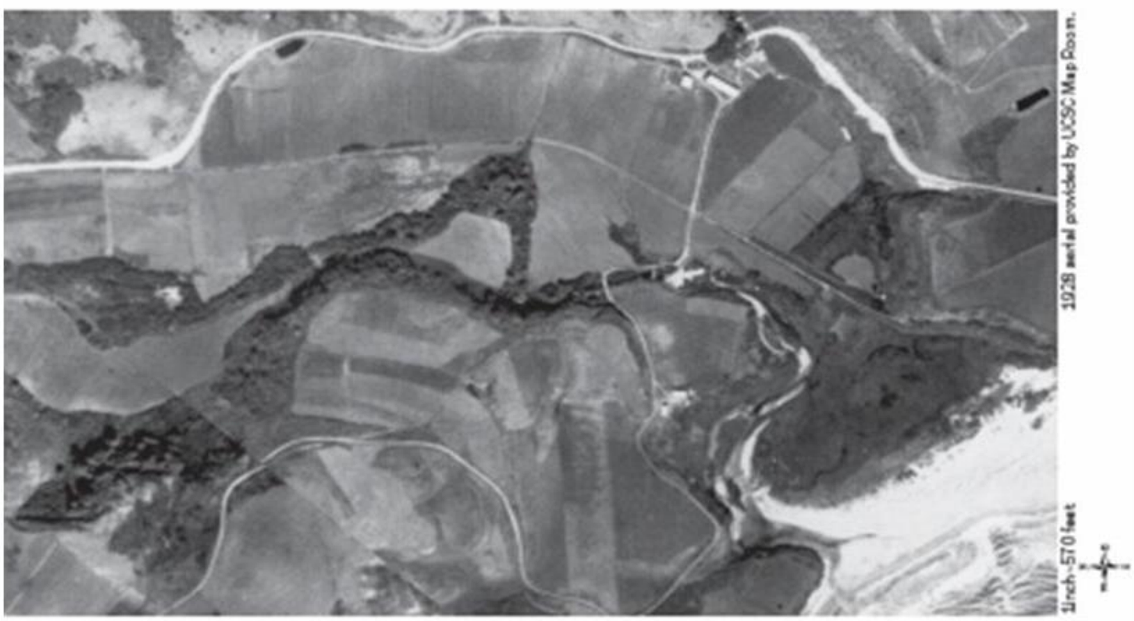

Figure 3. Scott Creek Lagoon in 1928, Santa Cruz County (Source: 2nd Nature Inc, 2006)

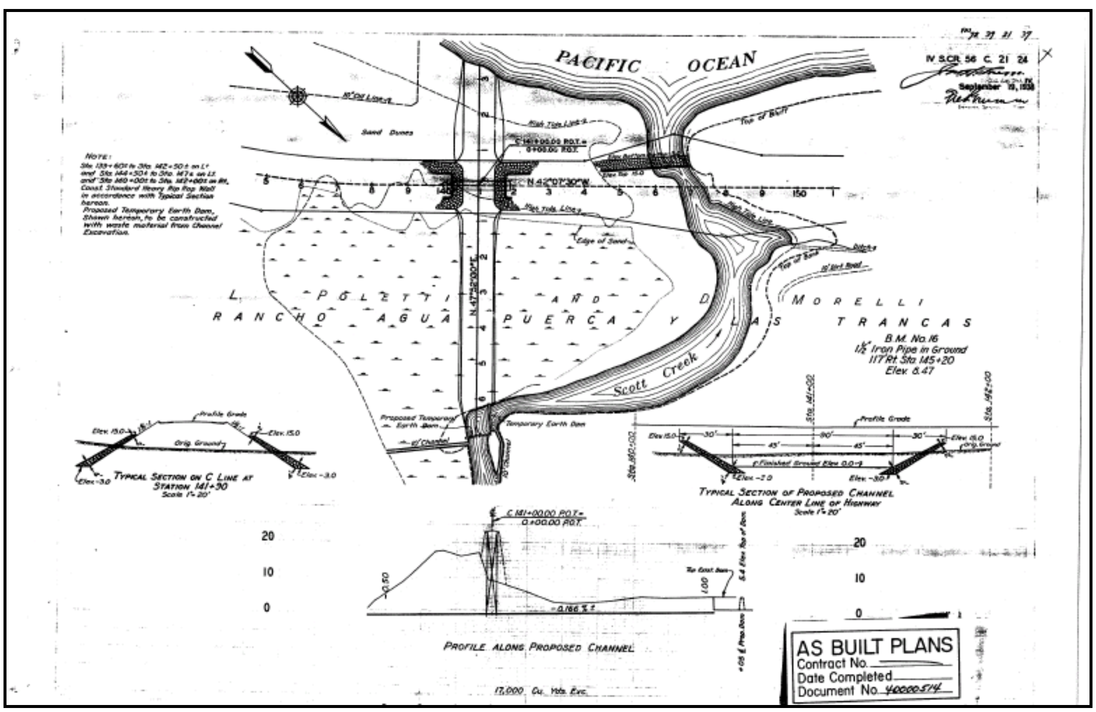

Figure 4. As built plans for Highway 1 Bridge on Scott Creek, Santa Cruz County.

Figure 5. Scott Creek Lagoon in 1941.

Isolated wetlands areas are now reportedly inundated during high flow events (Smith 2003) and potentially when high flow and high tides occur simultaneously. However, these areas have essentially been removed from the tidal influences in Scott Creek lagoon. Similarly, the levees have constrained the fluvial influence on stream channel conditions and isolated the single deep, pool habitat conditions within the lagoon (Smith 2003).

Information on the aquatic resources of Scott Creek lagoon is scarce prior to the late 1980's (Smith 2003, Bond 2003). Steelhead and coho salmon life history studies conducted in Waddell Creek during the 1930s occasionally referred to conditions within Scott Creek lagoon as being comparable (Shapovalov 1954). For example, Shapovalov and Taft report the timing of lagoon opening and closing in Waddell Creek to be essentially the same as that observed in Scott Creek (1933-1942). [Note that during a major portion of this time frame (1933-1939), Scott Creek did not have a bridge in the lagoon area, while a small county roadway bridged Waddell Creek lagoon, as discussed below].

Smith (2003, 2007) describes the "Coastal lagoon ecosystem" with reference to Scott and Waddell Creeks based on investigations beginning in the mid-1980s. Recently, the National Marine Fisheries Service (NMFS) Southwestern Fisheries Science Center (SWFSC) and the University of California at Santa Cruz have collaborated on a suite of rather intensive studies of Scott Creek and its lagoon. The studies address steelhead life history with a focus on lagoon rearing including discussion of tidally influenced conditions on steelhead population.

Smith (2003) describes Scott Creek lagoon as typically closed during the summer-fall period. The frequency and duration of the lagoon opening is critical to salmonid success in Scott Creek as it affects both upstream adult migrations and downstream juvenile migrations. The mouth needs to be open during coho salmon spawning migration (November to February) to allow adults access to spawning habitat. The later the mouth opens, the greater the effect on coho using the stream due to increased potential for straying or predation. For juvenile rearing, the lagoon should ideally close while inflow from Scott Creek is sufficient to maintain suitable depths and produce a freshwater lagoon. If the flows decrease before lagoon closure, resulting lagoon depths are likely to be shallow and marine water is likely to be dominant. Salinity stratification and ultimately high temperatures and low dissolved oxygen levels tend to reduce or eliminate suitable salmonid rearing habitat in the lagoon (Longier 2007). Bond (2006) reports substantial benefits to steelhead survival and population growth that is directly related to suitable lagoon conditions during the summer-fall period.

Figure 6. Scott Creek Lagoon, Santa Cruz County (A) 1972 and (B) 1987 (www.californiacoastline.org)

Figure 7. Scott Creek Lagoon, Santa Cruz County (A) 2002 and (B) 2004 (www.californiacoastline.org)

Figure 8. Scott Creek Lagoon, Santa Cruz County 2005 (www.californiacoastline.org)

Marsh habitat currently exists north of the leveed stream channel. The marsh can be inundated when the lagoon level is high during a closed condition. Some portions may be inundated during extreme high tides. Marshland and a pond to the south are essentially isolated from the tidal area and are only inundated by freshwater flowing through a tributary upstream of the pond (Smith 2003).

Smith (2003) highlights two conditions considered important to lagoon fish ecology: salt water acclimation, gradually preparing salmonids for marine life; and high flow/velocity refuge for species – life stages that are susceptible to entrainment (e.g., larval and juvenile tidewater gobies per Chamberlin 2006).

The marsh and ponded areas of the lagoon also provide habitat for California red-legged frogs as well as a diverse assemblage of birds. [Per Smith (2003), San Francisco garter snakes and western pond turtles do not occur in the Scott Creek lagoon]. The quality and quantity of these marsh-related habitats is related to tidal dynamics. Depth, vegetation and substrate conditions are governed by the periodicity and dynamics of tidal actions and can determine the suitability for these and other wetland associated species.

1.1.2 Waddell Creek

In 1770, a Spanish expedition made camp in the Waddell Creek valley, naming it Cañada de la Salud and noting the existence of a deep stream (Waddell Creek). The U.S. Coast Survey produced the earliest available maps of Waddell Creek in 1853, as shown in **Figure 9**. The map features clearly indicate the presence of a tidally influenced lagoon, tidal flat, and tidal marsh (closely spaced lines per Grossinger et al (2005)). Portions of the lagoon complex exceed 1,000 feet in width at some places. No development in the valley is apparent at the time of the survey, except a beach roadway and crossing.

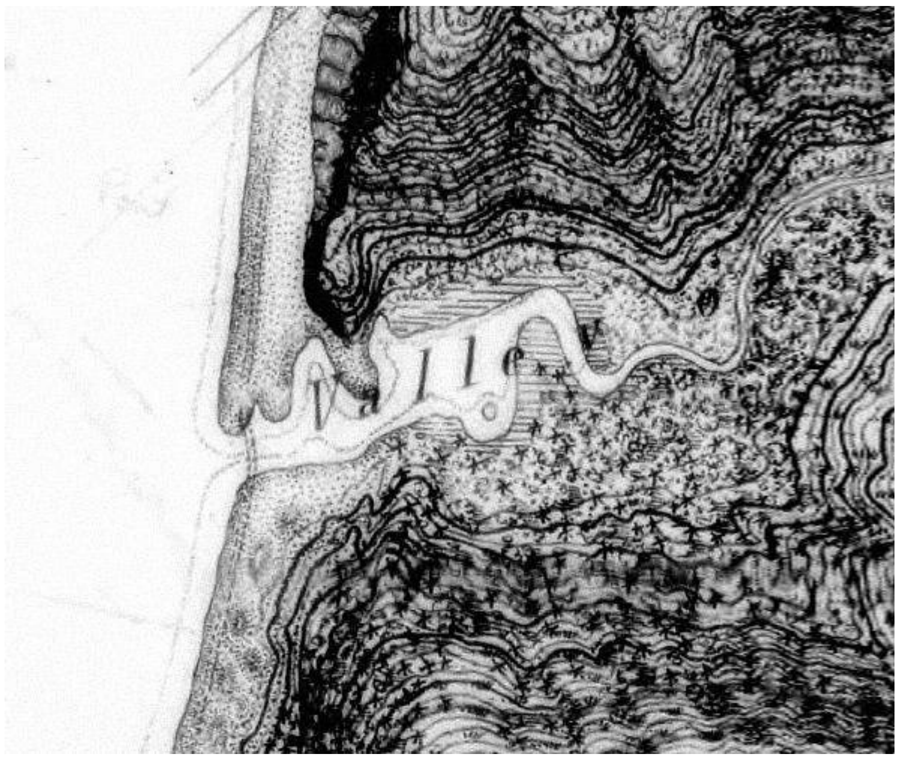

Figure 9. U.S. Coast Survey T-445 of Scott Creek by A.M. Harrison.

Per the as-built plans for the Highway 1 Bridge over Waddell Creek (**Figure 10**), the bridge was built in 1945 seaward of a pre-existing state highway bridge that had likely fixed the location of the creek and restricted the tidal interface. The highway bridge accommodated the stream alignment at the time with a span of about 181 feet. Overflow areas are called out on the as-built plans both landward and seaward of the bridge alignment. These areas likely held water when the lagoon was closed to the sea and were wetted during high flow events. High water level of 10.0 feet (above mean sea level) is indicated on the roadway profile drawing. The width of the high water line along the roadway alignment was approximately 500 feet. Assuming that the elevations on the plans reference mean sea level, the high water level called out would have exceeded extreme high tide by about 3 feet, which indicates that the tidal interface at the time of bridge construction would have been less that 500 ft wide. More recent aerial photographs of Waddell Creek lagoon are presented in **Figures 11-13**.

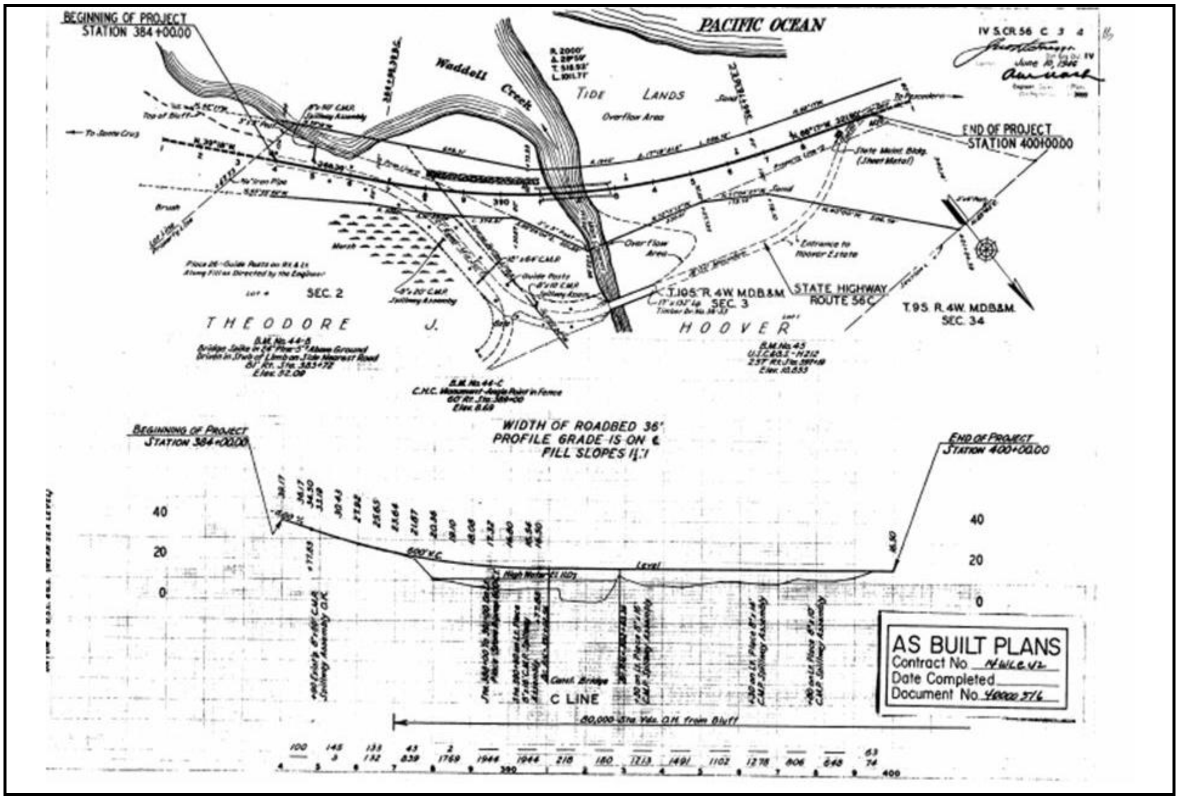

Figure 10. As-built plans for Highway 1 Bridge on Waddell Creek, Santa Cruz County.

Like Scott Creek, the lagoon at the mouth of Waddell Creek is seasonally open, although it appears that the Waddell lagoon has not closed permanently during the summer since 1994 (Smith 2003). Shapovalov and Taft (1954) report the lagoon closing annually during their study period (1933-1942). Waddell Creek was the subject of numerous studies conducted by the US Bureau of Fisheries and the California Department of Fish and Game (Numerous citations). The most definitive study was on the life history of steelhead and coho salmon reported by Shapovalov and Taft (1954). Surveys conducted by Smith (1990, 1993, 1994, 1996, 2000, 2002, 2003 and 2006) and the California Department of Parks (Rischbieter 2000) find conditions to be somewhat altered from those during the 1930s, including the construction of the Highway 1 bridge at the stream's mouth. It should be noted that the Highway 1 bridge replaced a bridge that existed upstream of the current alignment. The lower reaches of Waddell Creek were considerably developed during the late 19th and early 20th centuries, and included a planing mill, a small wharf, and several diversions and levees, as well as the road crossing.

Figure 11. Waddell Creek Lagoon, Santa Cruz County (A) 1972 and (B) 1979 (www.californiacoastline.org)

Figure 12. Waddell Creek Lagoon, Santa Cruz County (A) 1987 and (B) 2002 (www.californiacoastline.org)

Figure 13. Waddell Creek Lagoon, Santa Cruz County (A) 2004 and (B) 2005 (www.californiacoastline.org)

Smith (2003) reports the Waddell Creek lagoon to be persistently open, as stated above, behind a sandbar with a long channel to the ocean. The lagoon has been relatively brackish and shallower since the last time the lagoon was completely closed (1990). The reasons for the reported changes in lagoon conditions in the past 15 years are unknown. Bell et al. (2002) found evidence of increased infilling of the lagoon they identified as typical of the final stages of lagoon succession that may have been influenced by tectonic uplift and lowering of the water table.

Tidewater gobies rarely occur in the Waddell Creek lagoon (Smith 2003, USFWS 2005, 2006a). The distinct lack of velocity cover and high-flow refuge apparently results in sporadic colonization during low water years followed by extirpation during higher flow years.

Waddell Creek is relatively incised upstream of the bridge and even a full summer lagoon does not spread across much of the surface of the adjacent marsh (lagoon water does spread laterally through the sandy soils of the marshes adjacent to the lagoon). Deep water habitat is lacking when the lagoon is open. The stream channel within the lagoon is able to migrate and create scour pool(s) (Smith 2003). As in Scott Creek, these deeper sites may provide the only suitable habitat during periods of salinity stratification.

1.2 Applicable Investigations and Supportive Information

There are little data readily available concerning coastal lagoon dynamics on the north coast of California that may be considered directly applicable to Scott and Waddell Creek lagoons. Figure 14 shows representative tidal exceedence curves for the creeks, based on measurements at Point Reyes to the north and Monterey to the south. The curves represent the percentage of time water levels exceed the given elevation; for example Mean High Water (MHW) is exceeded approximately 10 to 15 percent of the time. Tidal datums are also indicated for reference.

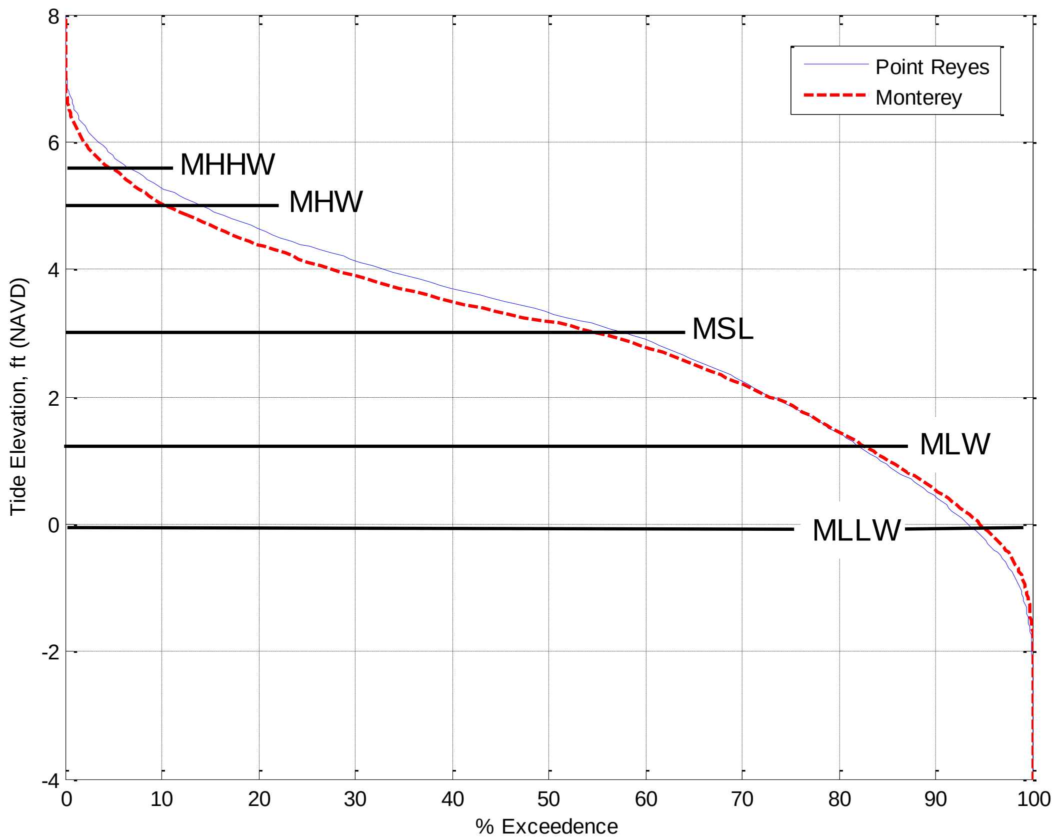

Figure 14. Tidal exceedence measured at nearby tide stations.

Figures 15 and 16 show LiDAR data collected by NOAA in 1998. Two images are shown for each location. In the topographic map on the left, light blue indicates areas potentially inundated at mean higher high water (MHHW), and dark blue areas inundated at mean sea level (MSL), based on the tidal datums shown in Figure 14. The image on the right shows a 3D rendering of site topography as available from the 1998 LiDAR data. In both figures, the creeks appear to be communicating with the ocean. Based on inundation at MHHW, there is very little tidal prism seaward of the bridges, mostly within the creek channel. The extent of tidal influence cannot be determined with the existing limited LiDAR data coverage of the creeks.

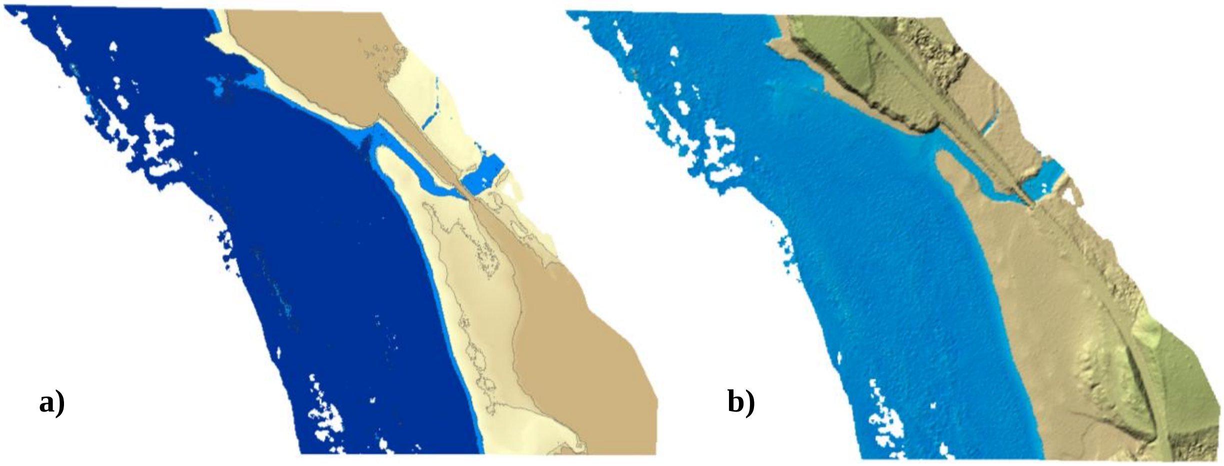

Figure 15. Scott Creek a) topographic tidal inundation map b) rendering of NOAA LiDAR data from 1998.

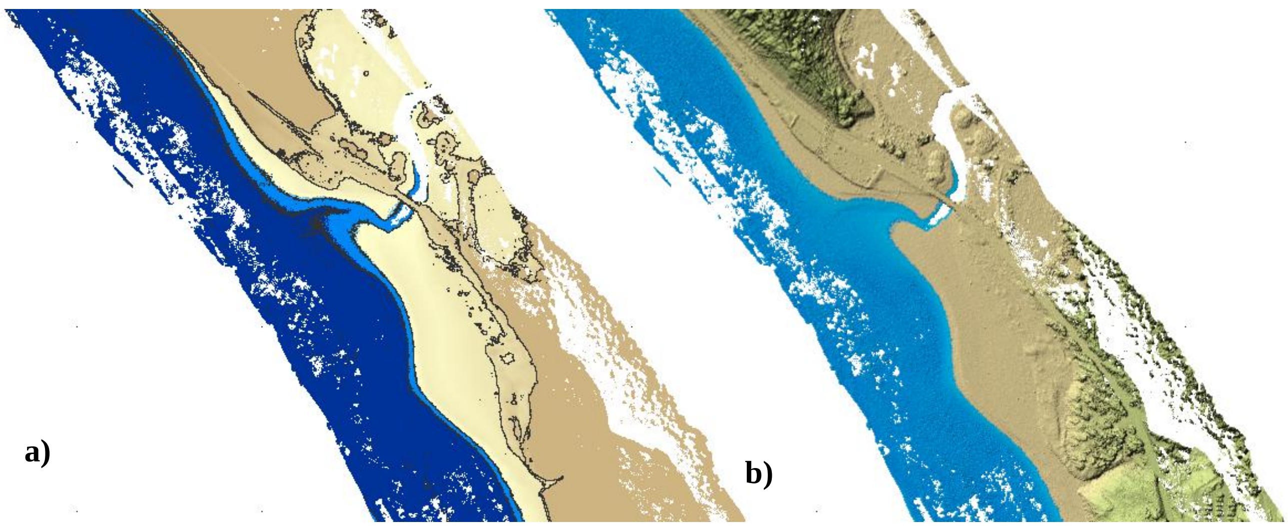

Figure 16. Waddell Creek a) topographic tidal inundation map b) rendering of NOAA LiDAR data from 1998.

Beyond limited information provided by the 1998 NOAA LiDAR data, information developed and reported on lagoons within the following waterways provide the majority of information applicable to describing and understanding lagoon systems like Waddell and Scott Creek's.

Garrapata Creek – Garrapata Creek lagoon, 10 miles south of Carmel, is a small, seasonal lagoon characterized as a dynamic system that is heavily influenced by ocean waves and tidal processes (Casagrande and Smith 2006). Flow to the lagoon is typically perennial; a barrier beach closes the lagoon from late summer to mid fall. Of note, this system is relatively unaffected by man-caused activities (i.e., not artificially breached, minor land development and water diversion in the watershed). The authors suggest that the wave action is relatively influential due to a lack of protection and that water quality and sedimentation, thus habitat conditions, are heavily influenced wave and tidal action. There is no discussion of specific fluvial or tidal influences on lagoon morphology; the primary focus being water quality.

Carmel River - Rather extensive measurements and analysis of lagoon conditions on the Carmel River, south of Scott and Waddell Creeks (James 2005) were used by Kraus et al (2008) to verify the breaching susceptibility index. Analysis of Carmel River lagoon dynamics show the conditions upstream of the barrier to be largely influenced by deposition and erosion related to runoff rather than tide. It also indicated that a geologic feature acts as a dam, impounding water upstream in the lagoon and preventing tidal flow into the lagoon until water surface elevations surpass the height of the "dam". As such, the lagoon is rarely tidally connected, only during exceptionally high tides.

Without similar data on elevation, hydrology, geotechnical conditions for Scott and Waddell Creek lagoons, the applicability of the Carmel River analysis is limited to conditions such as those described by Kraus et al (2008).

Russian River - Empirical investigations of the dynamics breaching and maintaining an open inlet on the Russian River Lagoon relate the constructive forces of barrier development (wave energy) with destructive forces (tidal prism and fluvial energy). SCWA (1993) concludes the tidal forces (historic and existing) are insufficient to maintain an open inlet and that the frequency and duration of an open inlet is reflected in the energy added from inflow (fluvial).

Stemple Creek - Stemple Creek watershed drains into the Estero de San Antonio within Bodega Bay has been evaluated to identify the hydrodynamics and geomorphology of the lagoon, and in particular, how the opening and closing of the mouth responds to sedimentation (MCRCD 1993). The analysis identifies information required to contemplate the results of different management actions and includes a discussion of the integrated influences of tidal and fluvial processes on the dynamics, morphology and ultimately management of the lagoon.

1.3 Specific Concerns Regarding Bridge Effects on Waddell and Scott Creek Lagoons

1.3.1 Timing of Barrier Closing and Opening

A primary concern of fishery agencies is the potential influence of bridge facilities on the timing of barrier opening and closure. The initial breach provides the first opportunity for migratory fish to enter, (adults) or leave (juveniles) the freshwater system. A delay in initial breaching can cause delay in adult immigration. For some species, like coho salmon, the delay can be critical. Predation, straying and delayed spawning are all potential results of a delayed breach that can decrease survival and ultimately coho production.

Juvenile salmonids rearing in the lagoon can be prematurely flushed to the ocean with early breaching. Since survival to adult is directly related to size at emigration, early emigration due to early breaching results in fish leaving at a smaller size and reduces their survival potential.

Bond (2006) determined that lagoon survival of juvenile salmonids in Scott Creek was related to water quality conditions during the fall that were directly affected by timing of lagoon closure versus extant flow conditions. If the lagoon closed while flow continued into the lagoon, the mean depth of the lagoon remained sufficient to provide suitable water quality for growth and survival. If the lagoon closed after flow had ended, the lagoon was shallow and high temperature and high salinity conditions would occur eliminating use of the lagoon for juvenile rearing.

1.3.2 Backwater and Similar Refuges from High Flow and Velocities

Larval and, to a lesser degree, juvenile tidewater gobies are highly susceptible to entrainment (Chamberlin 2006). Flow velocities resulting from inflow or tidal flow can carry the young fish out to the ocean. Goby populations are at high risk if cover or refuge from high velocity conditions is lacking. Even somewhat low velocity conditions associated with tidal flow in upper portions of lagoons can entrain larval gobies (Chamberlin 2006) suggesting that use of seasonally inundated marsh plains and similar habitat conditions are essential to goby survival. Conditions that exist within Scott Creek, primarily the isolation of most of the marsh plain due to channelization, are harmful to goby survival – the lack of suitable habitat is poorly understood and may be very vulnerable to changes in tidal or other changes in lagoon morphology and hydrology.

1.3.3 Increased Depth and Diversity of Morphology within Lagoon

The channelization of Scott Creek has essentially eliminated deeper water habitats that can support salmonid survival during periods of salinity stratification. In conjunction with structural complexity, such as large woody debris and rootwads, deeper areas can provide refuge from high flow conditions as well as increase carrying capacity. Coho salmon use in areas north of Santa Cruz County has been related to such conditions within the lagoon environment (Cannata 1998, Fisk 1958, Tschaplinski 1982, 1987, 1988). Although the issue in Scott Creek is primarily directed at the loss of deeper pools associated with the construction-related channelization, as discussed in the following sections, the influence of the existing bridge structure and approach on lagoon depth may be related to influences on morphology as well as frequency and duration of lagoon closure.

1.3.4 Non-Fish Habitat Conditions

California red-legged frogs, San Francisco garter snakes, western pond turtles and a variety of sensitive shore birds (e.g., snowy plover) depend upon marsh habitat in these two lagoons. (The garter snake may not occur within Scott Creek lagoon). The complex vegetation and sedimentation that sustains a freshwater marsh is integral to these species use. The sustenance of the marsh and its associated habitat conditions are dependent upon tidal overflow to marsh plains and ultimately the tidal prism.

2 General Affects of Bridges on Coastal Tidal Inlets

The large body of literature on tidal hydraulics and coastal processes contains comparatively little discussion of the particular problems of bridge crossings (TAC 2004). Both the Federal Highway Administration (FHWA) and the Transportation Association of Canada (TAC) do recognize the effect bridges can have on tidal waterways and have prepared a number of technical bulletins and design guides to address potential problems. Based upon the focus of these documents, the primary effect of bridges on tidal waterways is constriction (FHWA 2004, TAC 2004).

Constriction of a natural waterway opening (e.g., lagoon inlet) may modify the fluvial and tidal regime and the associated exchange.

In tidal waterways, the discharge is determined by the tide level and the waterway cross-sectional area. If the area is constricted or enlarged by channel scour, maximum flow rates will change.

General effects of tidal inlet constriction include (TAC 2004):

- Increased current velocities and scour potential in the constricted waterway opening,
- Increased phase difference (lag time) between exterior and interior tidal levels, and
- Reduced interior wave heights and tidal range.

In estuarine or stream-fed inlets, constriction can result in:

- Changes in tidal levels,
- Backwater effects during stream floods,
- Reduction in sediment transport downstream of constriction,
- Changing current velocities and directions including salinity effects,
- Concentrated velocities and scour, and
- Environmental, biological and water quality degradation.

Both the FHWA and TAC point to conditions that must be considered when a tidal inlet crossing is being designed. The purpose of their discussion is to identify and avoid harmful conditions in future bridge design. Since these conditions are also descriptive of effects bridges can have on tidal waterways, their description is used here to further identify bridge crossing properties that can affect tidal waterways.

TAC (2004) points out that at bridge openings where the bed of the waterway is essentially non-erodible, interior water levels and discharge through the constricted opening over a design tidal cycle must be accommodated. Where the substrate is easily erodible, it tends to adjust to the increased velocities by scouring. Per TAC (2004) guidelines, if the constriction is severe or scour is limited by a non-erodible stratum, it is reasonable to assume as a first approximation that the maximum natural tidal discharge (**Q_{max}**) will be significantly affected by the constriction.

$$\mathbf{Q_{max} = \pi P/T} \qquad \text{(Eq. 1)}$$

where P = tidal prism, and T is tidal period. Changes in Qmax will change the tidal amplitude and phase. (The effect of these changes as they apply to Coastal lagoons is discussed in detail in the following sections). Further, maximum discharge is related to inlet geometry as a function of cross sectional area and maximum velocity ((Vmax).

$$\mathbf{V_{max} = \pi P/(TA)} \qquad \text{(Eq. 2)}$$

where A is the cross sectional area of the waterway opening below mean sea level. Since the inlet width is fixed by constriction, either V_{max} or depth must be increased to accommodate the unconstricted Q_{max}.

FHWA (2004) identifies several techniques to evaluate hydraulic conditions of bridges in tidal waterways. The parameters influencing evaluation of these conditions can be considered potential bridge related effects to tidal flow.

If a bridge does not significantly constrict flow, the water surface is relatively level, and there is little apparent loss in velocity, then the tidal prism is assumed to be unaffected. Q_{max} is as defined above in Equation 1. Several factors that can account for changes in tidal prism but are unrelated to the constriction are discussed providing some insight as to when bridge constriction does not affect tidal flow. These include the effect of long, narrow interior waterways and inundation of the floodplain within the tidal reach. In a long, narrow lagoon or estuary, the interior tide is out of phase with the ocean tide, reducing the maximum flow through the constriction. If the tide inundates the interior floodplain, the ebb flow is slowed due to the shallow flow through vegetation. The tidal prism and tidal phase may modified and Q_{max} is less than that defined in the above equation.

A technique that treats the constriction more like a culvert, applies a discharge coefficient to account for exit and entrance losses and friction losses in the inlet channel (FHWA 2004). A coefficient of resistance is calculated to include head loss at the ocean and interior end of the constriction, and the friction losses along the channel. From this technique one can better define effects on tidal flow and tidal period. As the constriction increases, the backing up of flows entering the inlet (ebb and flood) increases, resulting in decreased V_{max}, and Q_{max}. Similarly, confined flow slowed by inlet friction, reduces V_{max}, and Q_{max} - the longer the constricted reach, the greater the reduction in flow.

One of the few reported investigations of the effect of bridging tidal inlets was conducted on Batticaloa Lagoon in Sri Lanka (Santharooban and Manobovan 2005). The investigation involved conceptual and empirical assessment of the effect of bridge-induced inlet constriction. The authors hypothesized that the constriction would create a backwater effect, impounding water during high flows, and increasing the overall resident period of water behind the constriction and therefore increasing sedimentation in the lagoon (**Figure 17**). They projected an increase in velocity (scour) at the inlet, and decrease in velocity (sedimentation) throughout the rest of the lagoon causing an overall decrease in lagoon depth. Ultimately the combined effect of impoundment, modified velocity distribution and increased sedimentation would change the spatial structure of the lagoon and perpetuate reduction in ability of fluvial or tidal sediment transport and accelerate lagoon filling. Overall, changes in hydrodynamics, morphology and water quality negatively affected habitat and biodiversity. Many coastal lagoons or small-scale estuaries in California have been subject to accelerated deposition and loss of storage volume due to a variety of land use activities, including constriction of the inlets due to road and railroad embankments (Goodwin and Williams, 1990).

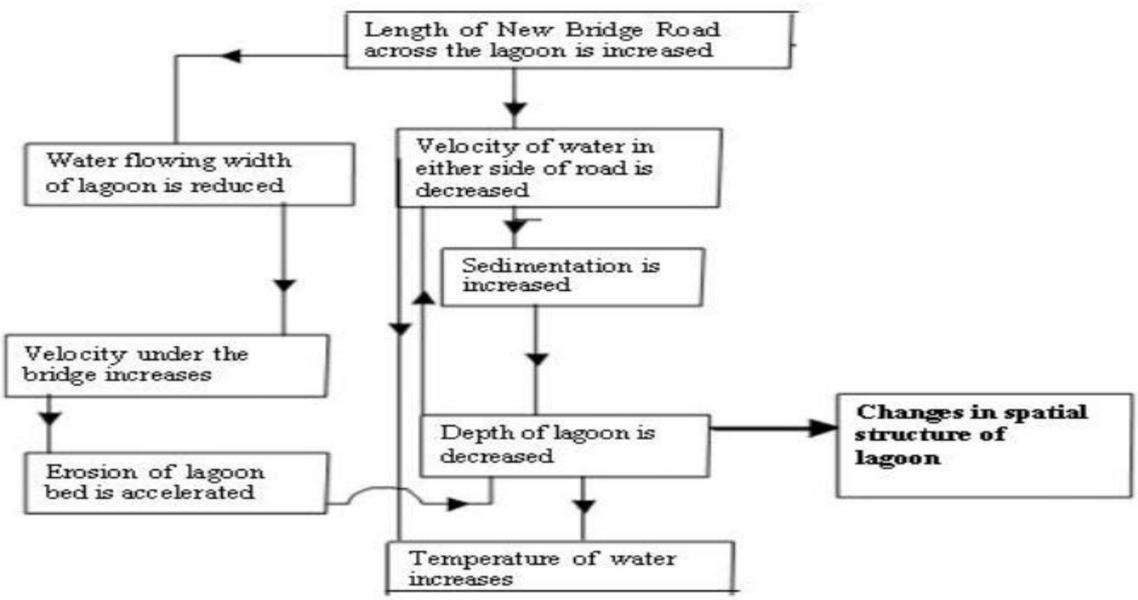

Figure 17. Flow chart of hypothesized effects of bridge on tidal inlet and lagoon (from Santharooban and Manobovan 2005)

As described above, the bridges constructed over Waddell and Scott Creeks filled portions of the tidal interface. At Scott Creek, levees initially built to divert the channel and facilitate bridge construction were left in place.

3 Potential Influence of Highway Bridges on California Coastal Lagoon Dynamics

The following discussions are largely based on several informative reports on the physical and biological nature of California's Coastal lagoons (USFWS 2006b, Kraus et al 2003,2008, SCWA 1993, Truitt 1992, Seabergh 2003). Some of the concepts and discussions were left unchanged from the original report for clarity.

The information provided in the previous section represents a substantial amount of the information presently available directly addressing potential, general effects of bridges on coastal inlets. In this section, we identify the salient effects of constriction (the principle effect of bridges on tidal waterways) on tidal hydrodynamics, lagoon morphology, and associated habitat elements (USFWS 2006b) including:

- Morphology
- Tidal influence (hydroperiod)
- Depth
- Velocity
- Temperature
- Salinity
- Dissolved oxygen
- Substrate
- Vegetation associations/cover types

3.1 General Discussion

The California coast contains several types of coastal lagoons. Lagoons can be tidal or non-tidal, saline, brackish or fresh, and with entrances that are always, never, rarely or periodically open. The most important factor determining the type of lagoon is the morphology and stability of the inlet channel connecting the lagoon to the ocean (Kraus and Wamsley 2003, SCWA 1993, Kjerve and Magill 1989). Opening of an inlet through breaching governs the depth, duration, and frequency of flooding in the lagoon, as well as tidal exchange and salinity (Kraus et al. 2008). As such, the relationship between bridge features and breaching is the fundamental issue to be considered to allow further assessment of the effect of bridge features on the critical issues listed above.

The inlet channel may always be open[1], never open or subject to periodic opening. Inlet channel conditions are dynamic, pursuing equilibrium between scour and fill generated by littoral (wave and tide) and fluvial (inflow) conditions. Wave energy continuously equilibrates the adjacent beach slopes, which typically results in sediment deposition within perturbations along the beach, such as the inlet channel. With beaches narrower and steeper in the winter due to wave action, the beach is more susceptible to breaching. Tidal energy is scouring at the inlet and depositing sediment landward (flood) and seaward (ebb) of the inlet. Fluvial events deliver sediment to the inlet and back-bay typically during storm events, and work with tidal ebbing to scour and maintain the inlet.

[1] Open herein means that the barrier is not formed and that surface water is connected between the ocean and lagoon.

The dynamics of small temporary open inlets play a key role in overall lagoon functioning. Intermittent breaching of the sand barriers of these systems leads to large changes in the physical-chemical environment, which in turn triggers major biological responses. The breaching process can also cause significant morphological changes because the strong breach outflows can scour large quantities of accumulated sediments from an estuary.

Man-caused actions that can change an inlet include (Seabergh 2003):

- Fill in part of the lagoon,
- Change in inlet channel dimension (cross section parameters), and
- Change in inlet channel length.

(Note, on Scott Creek, the levees and fill for the approach filled in part of the lagoon and the channelization changed (shortened) the channel length).

The following addresses the influence of confinement on coastal lagoons with a focus on the Central California Coastal region. As described above, constriction can involve reduction in the cross section area of the inlet opening and backwater conditions landward of the crossing. Response to these effects can be changes in flow and velocity through the inlet and lagoon, increased sediment deposition and overall decrease in lagoon depth – all of which can have substantial effects on the tidal hydrodynamics and lagoon morphology. Ultimately, depending upon the amount of constriction and the degree of response, the constriction can:

- Change inlet channel stability, and
- Change tidal prism reducing tidal power.

Interrelated with these changes are:

- Changes in the frequency and duration of inlet breaching and closing
- Change system from a frequently closed system to a permanently closed system,
- Decrease the extent of the lagoon including tidally maintained wetlands,
- Decrease lagoon depth,
- Alter water quality, and
- Alter tidal period.

3.2 Inlet Channel Stability

Coastal systems, especially barrier-inlet systems, are dynamic. Changes that take place in one element of this system will nearly always bring about a responding change in other elements. Inlet stability is a concept that defines the direction tidal inlet dynamics pursue to establish equilibrium – in this case a maintained open inlet. Ultimately, the various system elements will have a response that will affect and or be affected by the pursuit of inlet stability. As such, inlet stability is discussed from several perspectives that encumber conditions that can be related to constriction and the bridge related effects discussed above. The conditions include (SCWA 1993):

- Equilibrium Cross Sectional Area Concept
- Maximum Velocity Criteria
- Critical Width
- Escoffier Curve
- Wave power – Tidal Prism
- Littoral drift – Tidal Prism

Simply stated, inlet stability addresses the ability of an inlet to maintain itself in a state of "stable equilibrium" against the erosional and depositional forces of wave activity and associated littoral drift, which depends on availability of littoral sediment moving into the inlet, and the tidal prism.

Inlets are systems in dynamic equilibrium reflecting constantly changing energy forces. The two primary sources of energy, tides and waves, form a locally-unique balance that determines the specific geometric and functional characteristics of each inlet. As tides, waves, and sand transport seasonally vary, or as a result of longer-term influences, such as rising sea level or extreme flood-scour events, the inlet characteristics will change as well. This balance is referred to as a dynamic equilibrium to emphasize the point that as the opposing effects of the tides and waves vary in their cyclic patterns, a balance is being maintained that is reflected as a predictable inlet configuration.

Tidal movement through an inlet that is constrained by the geometry of the channels and the lagoon is analogous to water flowing through a pipe. Friction and other effects produce a change in energy balance and may cause sand to build-up in the inlet further changing the flow characteristics and affecting the inlet's stability.

3.2.1 Equilibrium Cross Sectional Area Concept

A fundamental geomorphic element of tidal inlet stability involves the relationship between the inlet cross sectional area and the tidal prism (Kraus 2000). Several relationships have been contemplated, all basically find the cross sectional area of the inlet (beach for barrier formed lagoons) to be directly related to tidal volume, as listed below (Kraus 2000):

- $A = C_1 P$ Le Conte (1905), O'Brien (1931, 1969) [e.g., $P = 5*10^4 A_c$ (O'Brien 1931)]
- $A = C_2 P^n$ Jarrett (1976)
- Closure curve Escoffier (1940, 1977)

- P/QG   Bruun & Gerritsen (1959, 1960)
- $VEe = C_3 P^m$ Walton & Adams (1976), Marino & Mehta (1986)
- $A_{Ee} = C_4 P^k$ Gibeaut & Davis (1993)

Where: A = min channel X-sectional area,

P = tidal prism,

QG = gross or total transport annually,

AEe, VEe = area, volume of Ebb shoal in equilibrium.

The equilibrium-area concept for tidal inlets has been a useful approach to understand the adjustment of an entrance channel's minimum cross-sectional area to the basic hydraulic and sedimentation characteristics of the inlet and bay it serves (Seabergh 2003). The concept for tidal inlets was originated by LeConte (1905). Based on field data from tidal inlets through sandy barriers along the western Pacific Coast, O'Brien (1931, 1969) determined a relationship between the minimum cross-sectional flow area of the entrance channel and the tidal prism. The relationship derived by Jarrett (1976) for Pacific Coast inlets demonstrates the relationship between tidal prism and inlet cross sectional area (18). The form of this equation is:

$$A_c = CP^n \qquad \text{(Eq. 3)}$$

where Ac is the minimum inlet cross-sectional area in the equilibrium condition, C is an empirically determined coefficient, P is the tidal prism (typically during the spring tide), and n is an exponent usually slightly less than unity. The empirical coefficients C and n are usually determined by the best fit to data. Recent work by Kraus (1998) derived the form of Eq. 3 by a process-based model that accounted for the dynamic balance between inlet ebb-tidal transport and longshore sand transport at the inlet entrance. Kraus (1998) derived an explicit expression for C in Eq.3. Hughes (2002) further verified the concept by confirming the relationship in the field and laboratory.

This analysis is used as a preliminary design tool to understand the inlet's response. Typically one-dimensional numerical or analytical models have been used to determine the inlet hydraulics in the initial approach.

3.2.1.1 Implications

The functional relationship between the tidal prism and the geometry of the inlet channel defines the tidal response to changes in inlet configuration. Changes in the inlet dimensions will cause adjustment by scour to reestablish the relationship or the tidal prism will be changed. Constriction would result in increased depth and/or a reduced tidal prism.

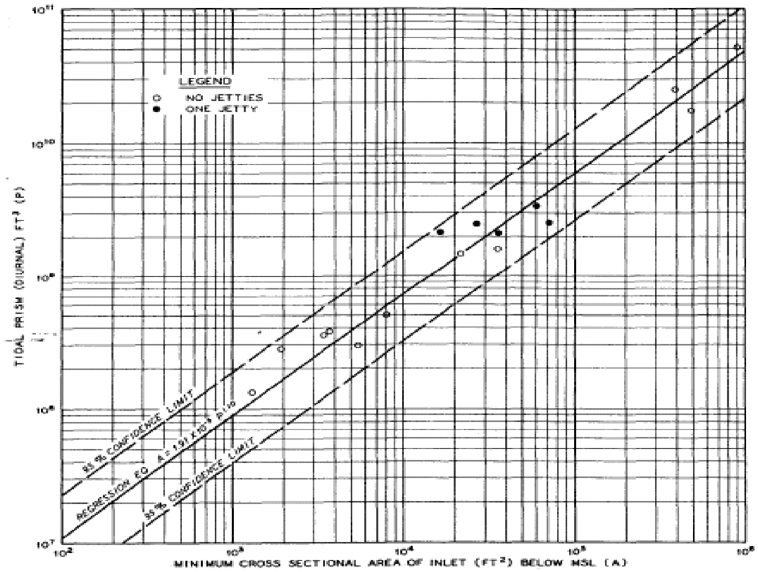

Figure 18. Relationship between cross sectional area and tidal prism for West Coast tidal inlets (Jarrett 1976).

3.2.2 Critical Section

The point in a channel where the cross-sectional area is a minimum is termed the ***critical section,*** the ***critical area,*** or the ***"throat"*** section (Truitt 1992). The critical section is not always where the top-width of the inlet narrows to a minimum since in erodible sandy material the channel depth may increase in proportion to reduced width so that the cross-sectional area is unchanged. The critical section can be considered the point controlling the entire inlet flow, analogous to a constriction in a pipe. The entire inlet can be replaced with an equivalent, geometrically regular channel represented by this critical cross-section to obtain an approximate analysis of channel conditions. Friction and other energy losses incurred in the channel can be applied to the cross section as an effective loss such that the total friction losses in the hypothetical site would equal those over the length of the actual variable-section channel. Investigation of a number of inlets has resulted in regression relationships directly between the critical throat area and the associated prism. When a bridge-related constriction determines the critical section, it potentially becomes the controlling factor of the tidal prism and related inlet and lagoon conditions.

3.2.2.1 Implications

Response to inlet channel constriction can be conceptually assessed by applying the cross section parameters at the critical section. When a bridge represents the critical section, the affect on tidal prism can be directly assessed as a function of the change in cross sectional area.

3.2.3 Maximum Velocity Criteria

For a tidal inlet to form and remain open (stable), the velocity of water moving out of the inlet must be sufficient to transport sediments deposited in the inlet; deposition from littoral drift and cross-shore transport driven by waves and wind. Thus a criterion of inlet stability is (Skou, 1990):

$$V_{max} > V_t \quad \text{(Eq. 4)}$$

Where: $V_{max\,x}$ = maximum velocity in inlet (critical velocity)

V_t = critical threshold velocity (to move D_{50})

D_{50} = mean sediment grain size

Byrne et al. (1980) discuss the results developed by various studies to produce a general approximation of conditions in oceanic inlets (Bruun, 1967; Jarrett, 1976). They observed that for a stable inlet channel:

$$V_{max} = 1.0 \pm 15\%\ \text{m/sec} \quad (3.28 \pm 15\%\ \text{ft/sec}) \quad \text{(Eq. 5)}$$

The calculated V_{max} (Table 1) is consistent with the theoretical value derived by Brunn (1978) and O'Brien (1969).

3.2.3.1 Implications

The velocity required to maintain open tidal exchange is a function of flow and cross sectional area. Reduction in cross sectional area without corresponding increase in velocity will increase sediment deposition and lead to lagoon closure. A persistent cross sectional area will reduce the tidal prism and tend toward a reduction in lagoon opening. Bridges can be considered persistent and depending upon the level of constriction to tidal prism, can cause reduction in tidal opening. The tidal prism in conjunction with flow provides the tidal power to maintain the opening. Reduction in tidal power due to loss in tidal prism will have proportional effect on closure. Given no overall change in flow due to the bridge facilities, the reduction in tidal prism will result in reduction in period and frequency of lagoon opening in proportion to the contribution to tidal power.

Table 1. Flow velocities required to maintain a lagoon entrance open to tidal exchange (SCWA 1993).

MEAN AND MAXIMUM VELOCITY CRITERIA

Flow velocities required to maintain a lagoon entrance open to tidal exchange.

VELOCITIES (M/S)	ALL INLETS	SEMI-DIURNAL	DIURNAL
Vmean, max	1.00	0.99	1.03
Vmean (Keulegan, 1967)	0.75	0.71	0.81
Vmean	0.77	0.70	0.87

Source: Bruun, 1978.

3.2.4 Escoffier Curve

Escoffier (1940) proposed a method of investigating the stability of an inlet based on the maximum inlet velocity for different cross-sectional areas. In this method, a bell-shaped curve of cross-sectional area A, versus maximum velocity ***V,*** is constructed for a given inlet. A sample curve (**Figure 19**) shows the delineation between stable and unstable inlets (Czerniak 1977). The cross-sectional area corresponding to the peak value of velocity is called the critical area ***A*.*** A change in cross-sectional area from the critical value will cause a change in the sediment flow capacity of the system, resulting in greater erosion or deposition rates (Skou 1990). For example, if a storm caused additional littoral drift material to enter the inlet and the cross-sectional area falls below ***A*,*** (left portion of the curve), then the sediment flow capacity will be reduced. Additional sediment will be deposited because the flow can no longer remove the same amount of material as before and the inlet will eventually close. On the other hand, if the cross-sectional area is greater than ***A*,*** the inlet is considered stable. Small changes in the cross-sectional area will be balanced by an opposing process, keeping ***A,*** in a narrow range (Skou 1990).

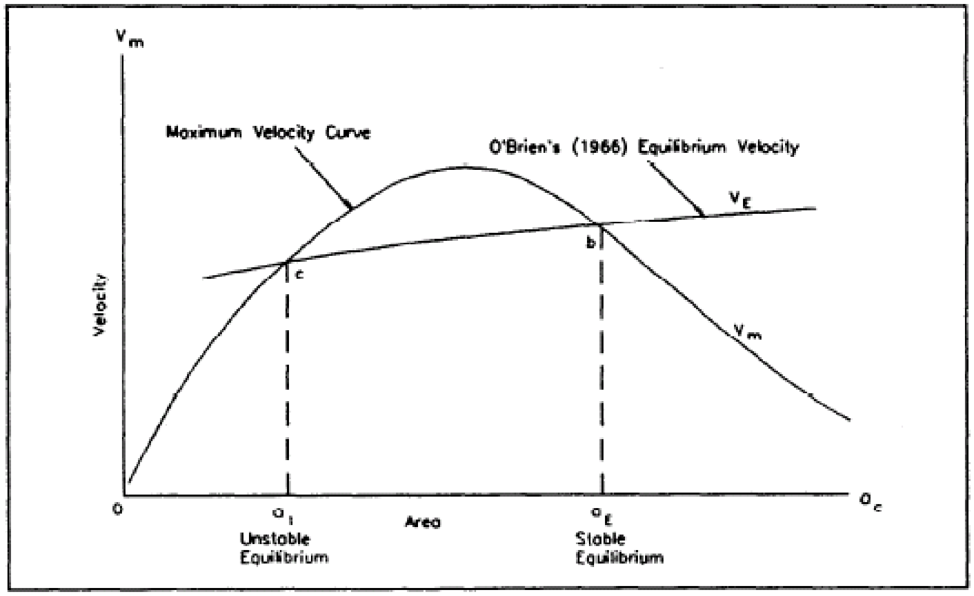

Figure 19. Escoffier curve showing the relationship between cross sectional area of tidal inlet and velocity through tidal inlet (Source: Seabergh 2003).

$$V_{\max} = c\left(\frac{A_c H}{2pL}\right)^{1/2}\left[\frac{(1+r^2)}{2} - r\right]^{1/2} \quad \text{(Eq. 6)}$$

$$r = \left(\frac{12054c}{M}\right)^2 \frac{A_C{}^3}{2pHL} \quad \text{(Eq. 7)}$$

Where:

V_{MAX} = mean velocity of peak tidal current (ft/sec)
c = Chezy's coefficient (ft0 . 5/sec) = R(1/6)/n
n = Manning’s roughness coefficient
A_c = cross-sectional area of inlet channel (ft2)
p = wetted perimeter of inlet channel cross-section (ft) (2Ba)0 . 5
L = length of channel (ft)
H = mean tidal variation in the ocean (ft)
M = water surface area in bay/lagoon at MSL (ft2)

Since V_{MAX} is a measure of sediment transport capacity, a small change in Ac will change the flow capacity of the inlet and lead to changes in erosion or deposition within the inlet (Skou 1990).

The Escoffier Curve demonstrates that as the area of the inlet channel is reduced by wave action, the ebb velocity is increased. According to Escoffier's theory, the scouring action in the inlet channel is proportional to the maximum ebb velocity. Therefore, an increase in the ebb velocity will increase the scouring in the inlet channel and the cross-sectional area will increase and move back towards the “stable” equilibrium value. However, if a wave storm decreases the inlet to less than the “unstable” equilibrium value, the maximum ebb velocity and scouring ability is reduced and the inlet area becomes smaller and smaller until closure occurs.

The relationship also describes the influence on non-tidal flow through the inlet. As flow increases with runoff, velocity increases and the scour and cross sectional area of the inlet also increases. In instances where land-generated flow and resultant velocities are high, a storm can increase the inlet to greater than the “unstable” equilibrium value, the maximum ebb velocity and scouring ability would be reduced and the inlet area would likely become smaller until the cross sectional area and velocity are within the equilibrium range. During periods of high storm induced runoff and accompanying high velocities, the inlet geometry is dominated by non-tidal conditions. Depending upon the magnitude and frequency of runoff , the influence of tidal action can range from minimal (as is likely the case at Scott and Waddell Creeks) to dominant..

3.2.4.1 Implications

The method used to generate an Escoffier curve involves calculating maximum velocities using Eq. 7 for a range of cross sectional areas that are applicable to the inlet being evaluated. The areas associated with velocities greater than the critical velocity of Skou (1990), per above, are in the range of dynamic equilibrium, and will maintain an open lagoon. The constraint related to the bridge include width, depth (limited by velocity and substrate erodibility) and energy loss (e.g., head loss, resistance, channel length), and lagoon dimensions. Again, this assessment is not intended to identify the conditions necessary to maintain an open inlet. Rather, they are used to describe the potential responses to the effects of a bridge within a tidal channel and the potential effect of the response(s) to lagoon and ultimately habitat conditions.

For example, if the constriction maintains a maximum cross sectional area that is below “unstable” equilibrium level, negative changes in lagoon area, perimeter, tidal prism and mean tidal elevation would affect the tidal prism as well as the amount and diversity of habitats. Reduction in area and elevation would reduce and potentially eliminate shallow, marsh habitats.

In cases where the tidal prism is such that ebb velocities are typically small relative to outflow velocities, further reduction in tidal prism by constriction or similar changes would be expected to affect inlet closure during prolonged periods of low flow. With severe channel constrictions that can back-up outflow and reduce velocities, bridge facilities could increase sedimentation, increase local scour (such as at the bridge piers) and compound effects of reduced tidal prism on lagoon dynamics and related habitat conditions, as discussed above (FHWA 2004, TAC 2004)

3.2.5 Wave Power - Tidal Prism Relationship

The wave environment incident upon a tidal lagoon beach provides the energy to move sediments into the tidal inlet by littoral drift or cross-shore transport (Kraus et al. 2002, SCWA 1993, Truitt 1992). Thus, the greater the wave energy incident upon the beach relative to the tidal prism, the greater the potential instability of the system. Johnson (1973) presented the relationship expressing an inlet closure parameter, C_w, based on the ratio of wave energy and tidal energy. The inlet will close at particular value of $C_w = C_{crit}$, giving the following stability criterion:

$$\frac{C_w}{C_{crit}} < 1 \quad \text{inlet remains open} \qquad \text{(Eq. 8)}$$

$$\frac{C_w}{C_{crit}} > 1 \quad \text{inlet will close} \qquad \text{(Eq. 9)}$$

$$Cw = \frac{E_\delta T_p W_c}{P(2c_{os})p} \qquad \text{(Eq. 10)}$$

where:

w = closure criteria parameter
Es = wave energy in ft*lbs/ft
TP = tidal period in seconds
wc = width of entrance in feet
P = tidal prism in cubic feet
$ç_o$ = tidal amplitude in feet0
p = unit weight of water in lbs/ft3

An alternative approach to Eq. 10 using the annual deep water wave power (Pw) correlates Pw to potential tidal prism (P). Johnson (1973) found that for a specific value of the Pw, there is a specific volume the P must exceed for the inlet to remain open. The relationship was applied to a diverse set of Pacific Coast tidal waterways (Table 2) (SCWA 1993). The results show most tidal waterways between San Francisco Bay and Point Conception (Santa Barbara) to frequently close primarily due to their small tidal prism. South of Point Conception, wave power is substantially less and relatively small lagoons remain open.

Goodwin (1993 referenced in MCRCD 1993) refined the definition of the closure criteria to take into account the additional role of stream flow in scouring on the ebb tide. The stream power is added to the tidal power.

3.2.5.1 Implications

The relatively high wave power along the Central California Coast suggests that only large lagoons can sustain perennial open inlets. The smaller the lagoon, the more often the inlet closes. As the tidal area decreases, the net effect of further reduction in tidal prism due to bridge constriction decreases.

3.2.6 Littoral Drift - Tidal Prism Relationship

Bruun (1962, 1978) empirically evaluated the relationship between the quantity of sediment input into the tidal inlet system and tidal prism (Table 3). His studies examined inlet stability as a function of the neap tidal prism (neap tide,ft^3), *PNEAP* , and sediment input towards the inlet channel from the ocean side of the lagoon (during one tidal period in ft^3), *QLS*. Conceptually, inlet channel flows must have the capacity to transport external sediment input (QLS) and sediment being transported through the creeks and rivers tributary to the lagoon to maintain an open inlet. This external sediment delivery to the channel is from littoral drift and bank erosion. Based upon his findings, Bruun (1962, 1978) established a stability criterion based upon the ratio of P_{NEAP} and Q_{LS} (Table 3). He also derived a relationship between cross-sectional area and littoral drift where: Q_{LS} = drift of sediment during one tidal period towards the inlet.

Table 2. Comparison predicted closure conditions of California coastal lagoons and estuaries based on tidal prism and wave power (from SCWA 1993)

Location		Potential Tidal Prism (106 ft3)		Annual deep-water wave power (1011 ft- lb F/ft/yr)	Closure condition
		Diurnal	Mean		
1	Smith River Estuary	35	24	303	(Infrequent)
2	Lake Earl	430	320	329	Frequent
3	Freshwater Lagoon	35	25	348	Always
4	Stone Lagoon	86	64	348	(Frequent)
5	Big Lagoon	240	180	348	(Frequent)
6	Eel Rover Delta	200	140	371	(Infrequent)
7	Estero Americano	22	15	(200)[a]	(Frequent)
8	Estero San Antonio	11	6.5	(200)	Frequent
9	Tomales Bay	1580	1070	209	Never
10	Abbotts Lagoon	17	11	307	Frequent
11	Drakes Estero	490	340	26	Never
12	Bolinas Lagoon	200	130[b]	117	Never
13	Pescadero	6.8	4.6	(200)	(Frequent)
14	Mugu, 1976	27	19	(100)	Frequent
15	Mugu, 1857	170	120	(100)	(Never)
16	Carpinteria	4.8[b]	1.5[b]	(50)	Infrequent
17	Agua Hedionda, 1976	80	55[b]	28	Never
18a	Batiquitos, 1985	20	13	(30)	Frequent
18b	Batiquitos, 1850	90	60	(30)	Never
19	San Dieguito, 1976	0.2	0.14	(30)	Frequent
20	San Dieguito, 1889	37	24	(30)	Never
21	Los Penasquitos, 1976	2	0.75	(30)	Frequent
22a	Tijuana, 1986	12.6[b]	4.8[b]	(100)	Infrequent
22b	Tijuana, 1977	14.8	8.3	(100)	Infrequent
22c	Tijuana, 1928	34.4	20.0	(100)	Never
22d	Tijuana, 1852	37.5	47.9	(100)	Never
23	Bolsas Bay, 1874	-	38	(30)	Never
24	Anaheim Bay	-	47	(30)	Never
25a	San Lorenzo River, c.	N/A	3.69	(200)	Frequent

Location	Potential Tidal Prism (106 ft3) Diurnal	Mean	Annual deep-water wave power (1011 ft- lb F/ft/yr)	Closure condition
25b San Lorenzo River, est.	N/A	17.4	(200)	-

Table3. Relationship between Neap tidal prism (P_{NEAP}) , longshore transport (Q_{LS}), and inlet stability (Brunn 1978)

Tidal prism : Longshore transport	Tidal Inlet Stability
150 < (P_{NEAP}/Q_{LS})	Conditions are very good, very good flushing and minor bar formation
100 < (P_{NEAP}/Q_{LS}) < 150	Good condition, an offshore bar formation is more pronounced
50 < (P_{NEAP}/Q_{LS}) < 100	Rather large bar by entrance, but usually a channel through the bar
20 < < (P_{NEAP}/Q_{LS}) < 50	Typical bar is breached by increased water discharge during storm and high runoff
(P_{NEAP}/Q_{LS}) < 20	Very unstable inlets, primarily overflow channels

$$\frac{P}{Q_{LS}} = \frac{A_c V \frac{T_p}{2}}{Q_{LS}} \qquad \text{(Eq.11)}$$

where: P = neap tidal prism (m3)
Ac = cross-sectional area (m2)
Tp = tidal period in seconds
V = mean velocity through inlet (m/s)

3.2.6.1 Implications

These simple criteria also indicate that the inlet channel could be maintained open to tidal exchange under most hydrologic conditions only if the longshore or cross-shore transport rate was reduced, or if the tidal prism is increased. A substantial increase in the tidal prism would require extensive dredging.

3.3 Frequency of Inlet Closure

3.3.1 The Physical Processes Associated with Lagoon Opening and Closures

Kraus (2003) and Kraus et al. (2008) clearly describe the process of lagoon closure along the wave-dominated West Coast. The rate of lagoon closure after the entrance is opened, either naturally or artificially, on a wave– dominated coastline will directly correspond to the rate of berm formation. The wave-built berm is an accretionary sedimentary feature located at the top of the beach-face (Komar, 1998). It forms through the deposition of sediment at the landward extent of wave runup, which typically results in vertical and horizontal growth in a seaward direction. The maximum wave runup height must directly determine the maximum possible berm height, but previous work has principally focused on relating the berm height to more widely measured parameters. For example berm heights appear to scale directly with wave height (offshore or breaker) and period (Takeda and Sunamura, 1982) and inversely with grain size (Okazaki and Sunamura, 1994). The studies of Bascom (1953) and Strahler (1966) found that berm growth is greatest when wave overtopping is taking place, which typically takes place during spring high tides due to an elevated still water level. When the wave overtops the berm crest it deposits the bulk of its sediment load atop the berm. Backwash volumes are also reduced when overtopping takes place resulting in a bias towards onshore sediment transport. Swash overtopping volumes are clearly important and are the focus of this paper.

3.3.2 Breaching (Channel Inlet Stability And Breaching Susceptibility Index)

Breaching potential is achieved if the water level on one side of a narrow barrier spit exceeds some critical elevation in relation to the crest of the barrier. Duration of higher water level is also a contributing factor. Breaching can happen by overtopping or seepage and liquification (Kraus 2003, Kraus et al. 2008).

Waddell and Scott Creek lagoons are barrier beach lagoons. As discussed by Kraus et al (2008), the breaching process of barrier beach lagoons on the coast of northern California can be described using a breaching susceptibility index where susceptibility (S) is related to the hydraulic gradient between the lagoon and the ocean:

$$S = h/L \text{ where}$$

h = the elevation difference between the water surface elevation in front of and behind the barrier and

L = the barrier width (shortest distance between the lagoon and the ocean)

They also conclude that:

- Along the California Coast, "barrier beaches commonly breach from the lagoon side through filling by groundwater inflow, runoff, river inflow, and direct precipitation that cause overflow at the lowest part of the barrier (Kraus 2008)".
- Barrier width influences breaching susceptibility. The narrower the barrier the greater the susceptibility.
- The head difference represents the destructive force promoting breaching, and the barrier width represents the constructive force resisting breaching.

3.3.2.1 Overtopping

A breach can occur if running surface water scours a trough between the sea and the body of water protected by the barrier. Breaching requires a certain duration of inundation and a strong flow. It is promoted by wave action and the presence of a pre-existing, localized area of low elevation in the barrier. The process can proceed from the seaward side or from the bay (estuary, lagoon, or river) side. Breaching from the seaward side occurs during periods of sustained high water level and powerful waves. From the inland side, a rapid rise in water level from a storm can incur overtopping. Wave setup and runup contribute to the inundation, and the presence of waves in the incipient breach will increase sediment mobilization and transport.

Kraus (2002, 2007) described the applicability of the breach susceptibility index to the US coasts (Table 4). The susceptibility as defined above showed breaching on the west coast to be low when considering wave power and overtopping as the breaching mechanism.

Table 4. Representative values of the breach susceptibility index (Kraus et al. 2002)

General US Coast Location	B = S^{10}/R for selected locations		
	Surge, S^{10} (m)	Diurnal Tide Range, R (m)	Susceptibility Index, B
New York, New Jersey	1.5	1.5	1.0
Florida (Atlantic side)	1.0	1.0	1.0
Louisiana, Texas	1.5	0.5	3.0
Northern CA, Oregon, Wash.	0.5	2.0 to 2.5	0.25 to 0.2

3.3.2.2 Seepage and Liquefaction.

If the barrier spit is narrow (**Figure 20**), seepage through the porous sediment caused by a difference in water elevation on the sides of the barrier can liquefy the sediment-water mixture, allowing large volumes of material to be transported quickly as slurry. This type of breaching usually occurs from the bay side because of the long duration of higher water level that is possible in an enclosed or nearly enclosed water body, and it is not necessary for the water level to have reached the top of the barrier spit.

Breaching potential is minimized if the barrier is high and wide. Barrier elevation and volume above mean sea level are key factors for resisting inundation and erosive wave attack during times of higher water level.

On the Pacific coast, breaching from the seaward side typically follows large storms preceded by a series of smaller storms that have created a depleted beach and dune. On the California coast, enclosed lagoons and mouths of small rivers tend to open after rainy season (Kraus et al. 2002), for which seepage and liquefaction are the dominant process. The breaching susceptibility index presented above, explains, in part why breaching can be an infrequent event on the Pacific coast.

Barrier spits enclosing lagoons can also breach by gradual rise in water level on the backside, likely through seepage and failure by liquefaction. Previous work (Joseph 1958) found that a critical water level in the enclosed Big Lagoon about 3-4 m above local mean sea level of the Pacific Ocean triggered breaching from the lagoon side. Barrier spits across Big Lagoon, Stone Lagoon, and Freshwater Lagoon are approximately of the same width and elevation, as all share the same littoral system (i.e., tidal power, littoral transport are similar so spit formation is similar). Breaching of the barrier spit across Big Lagoon occurs more frequently than at Stone Lagoon because Big Lagoon is fed by more streams. Rapid filling and more frequent reaching of critical water elevation at Big Lagoon are responsible for more frequent breaching there as compared to Stone Lagoon.

Kraus (2007) suggests that the breach susceptibility index for Pacific Coast lagoons is related to the difference between the surface elevation on the seaward side and the elevation on the interior side and the barrier breadth (L in **Figure 21**). Breaching essentially is a function of runoff and barrier breadth. Barrier breadth is a function of tidal (Kraus and Wamsley 2003) conditions during spit development near the tidal inlet.

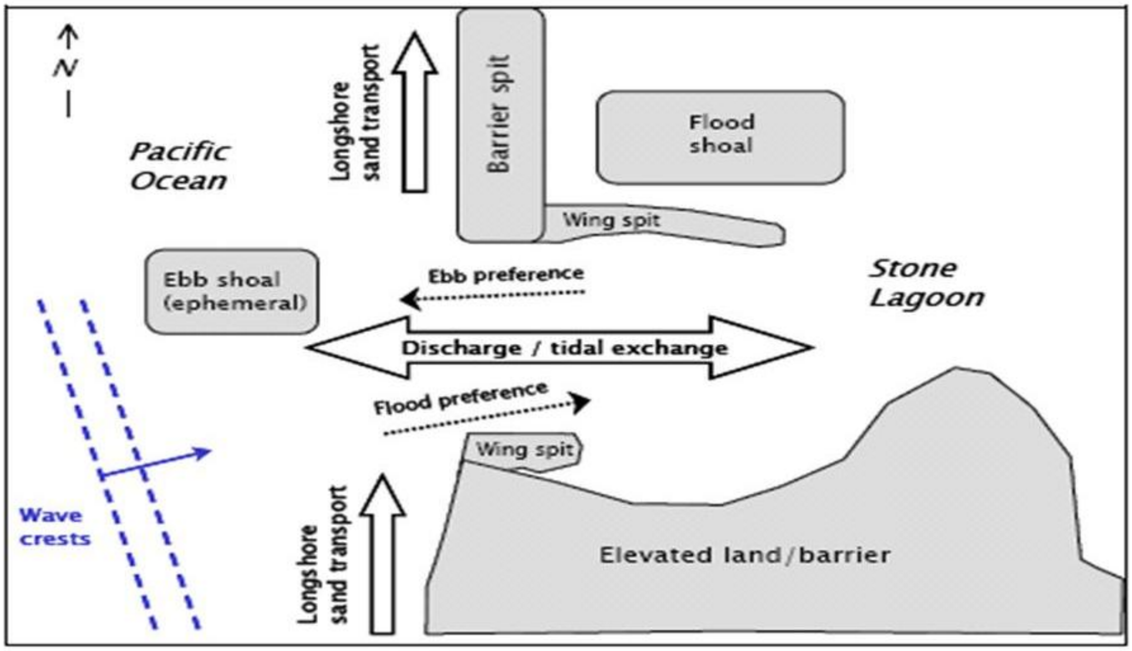

Figure 20. Transport mechanisms associated with tidal inlet dynamics (Kraus et al. 2002).

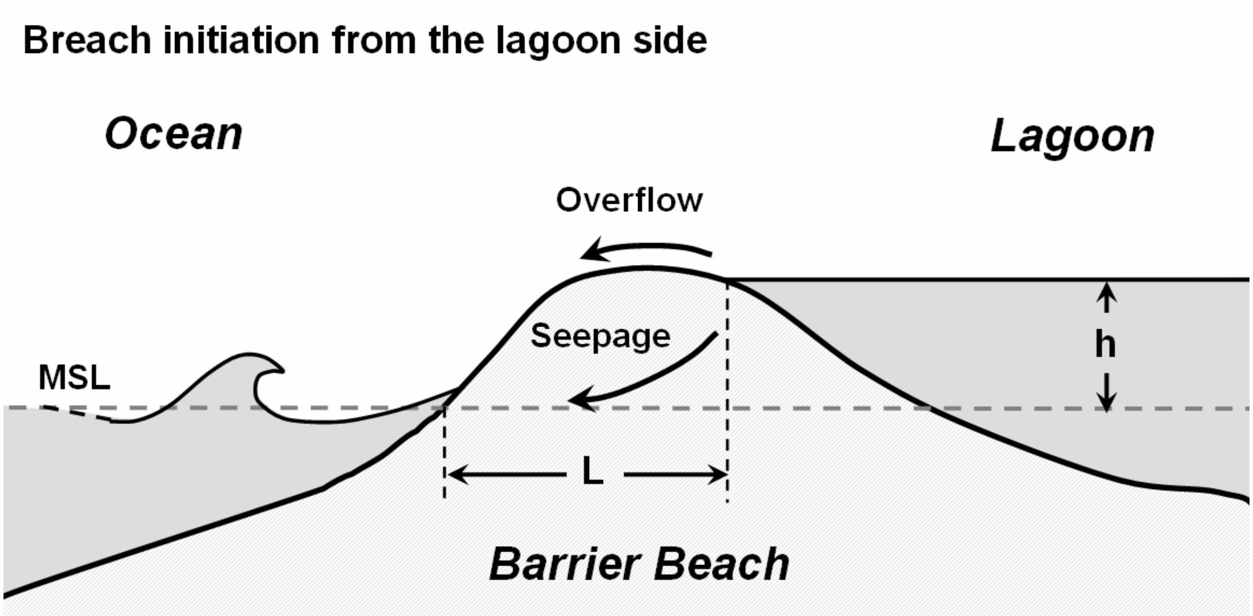

Figure 21. Schematic of tidal barrier cross section demonstrating breach initiation from the lagoon side (Kraus et al. 2008)

3.3.3 Inlet Opening Frequency

The frequency of natural breaching or artificial breaching following closure can be predicted by a simple mass balance model:

$$A\Delta Z = \left(Q - A_{jevap} - Q_s - Q_{GW}\right)\Delta t \qquad \text{(Eq.12)}$$

where:

A = the surface area of the lagoon (ft^2)

ÄZ = the change of water level in the lagoon (ft) during the time step *Ä*t(s)

Q = the freshwater inflow to the lagoon (ft^3/s)

Q_S = the seepage loss through the barrier beach (ft^3/s)

Q_{GW} = the loss or gain of water from the aquifer adjacent to the estuary (ft^3/s)

i_{evap} = the rate of evaporation from the estuary (ft/s)

3.3.3.1 Implications

Through the effect on tidal prism, the waters surface area can be effected by bridge related constriction and fill. A substantial change in area could result in sufficient change in water level fluctuation and therefore barrier breadth and the breach susceptibility index (Eq. 12). A decrease in the tidal prism, thus lagoon surface area, could increase the intra seasonal barrier breaching interval (i.e., the breaching interval following the initial breach).

3.3.4 Empirical Prediction of the Closure of the Entrance of the Estuary

The length of time that the estuary will be open to tidal exchange depends upon the following elements (SCWA 1993):

- *Wave Energy*. Wave energy governs the longshore and cross-shore sediment transport rate which acts to fill or close the inlet channel.
- *Sediment Availability*. Sediment available from the seaward side (foreshore) must be sufficient to fill the inlet channel.
- Beach Sediment *Size*. Large particles (e.g., cobbles or coarse gravel) require higher velocities (tidal flows in the inlet channel) to maintain an open channel.
- *Tidal Prism*. Volume of water that passes through the inlet channel in a tidal cycle and supplies most of the energy required to scour the inlet during non-storm events.
- *Freshwater Inflows*. River discharges that can supplement the tidal flows through the inlet channel and contribute to scouring.

Of these, the most important factors for lagoons along the central California Coast are wave energy, tidal prism, and freshwater inflows (PWA 2002).

3.4 Channelization of Tidal Waterway

Channelization within the tidal waterway can have different implications depending upon the geometry of the channel. Ricks (1995) describes the results of a relatively confining and steep channel built in Redwood Creek, Humboldt County, on the tidal dynamics and ultimately habitat elements of the creek's lagoon. The following is a summary of effects that may conceptually be linked to the channelization in lower Scott Creek.

- The channelization involved smoothing the roughness of the streambed, creating a trapezoidal channel with an increased hydraulic radius, and steepening the channel gradient, increasing mean velocity and frequency of mobilization of the bed material between the levees.
- Increased gradient also reduced the upstream extent of saltwater.
- The confined streamflow no longer flushes sediment from the adjacent slough areas.
- Over 50 percent of the lower estuary (between 0 and 4 ft above sea level) has filled with sediment or become isolated from the embayment.

- Overwash across the storm berm and transport by tidal currents are now the dominant processes delivering sediment from the nearshore zone to the "isolated" sloughs.
- The outflow channel from the embayment to the ocean follows a seasonal progression that influences substrate distribution, water quality, and embayed water volume.
- Accumulation of sediment has altered the seasonal progression of the outflow channel, thereby further restricting circulation and the volume of aquatic habitat.
- After high flows were confined by the levees, beach berm scour was limited and high berms were established.
- The water volume subjected to tidal fluctuations (tidal prism) decreased due to sediment deposition in the necks of the sloughs and the steep stream gradient constructed during channelization.
- Freshwater and potential estuarine habitats became shallow, and circulation between the embayment and sloughs was restricted.
- With a smaller tidal prism, the outflow channel functionally closes earlier in the season, and the embayment fills more rapidly, allowing water to flood adjacent land.
- The berm is artificially breached to preclude flooding reducing available aquatic habitat by as much as 75 percent.

3.4.1 Implications

Many of the effects of channelization exhibited in Redwood Creek may be ongoing in the Scott Creek lagoon. Loss of meanders and isolation of adjacent marsh plains from tidal flow are apparent. The effect on the tidal prism is obscured by the diversity and extent of effects in the lagoon due to various land use activities including the confinement and impounding effect of the bridge. It may be impossible to separate the effects of channelization from at a minimum the effect of the bridge. Any modification of either facility should be considered a potential change to all facilities and should require a clear understanding of the potential responses to the tidal system and associated habitats before any changes are implemented. The following sections enunciate the need to have targeted conditions and clear linkage between any modification and the tidal system to prevent conditions from getting worse.

4 Discussion

Bridge crossing in Coastal California lagoons can directly affect the lagoon in several ways. Changes in lagoon configuration resulting from tidal inlet constriction and partial filling appear most common. And, although channelization of lower stream reaches within the tidal area is not uncommon, the association of channels with bridges, as in Scott Creek, appears unique. These changes can substantially alter the tidal system by changing its geometry and ultimately the dynamics that influence many important elements of a tidal ecosystem.

Most lagoon attributes are affected by its tidal prism, including:

- Tidal inlet morphology and stability,
- Frequency and duration of lagoon opening,
- Water quality,
- Sediment, and
- Vegetation.

Constriction and filling (and channelization) resulting from bridge crossings affect the tidal prism and ultimately these attributes.

Tidal inlet morphology and stability depend on the interaction of the ocean tide at the inlet entrance with inlet channel geometry, back-barrier bay geometry, wave-generated processes, and morphology change induced by episodic storms. Depending on how these factors and processes combine, inlet hydrodynamics may include distortions to the tide that result in ebb- or flood-dominated currents, which in turn strongly influence the shape and extent of inlet ebb and flood scour and deposition. Inlet cross-sectional area, channel length, frictional drag, and geometry of the back bay influence tidal exchange. Small tidal inlets having narrow throat sections behave hydraulically as the balance between friction and the hydraulic pressure gradient along the inlet channel, influencing the tidal prism.

The periodicity and duration of lagoon opening governs the degree of tidal influence in the lagoon and adjacent marshes including the depth, duration and frequency of inundation. The lagoon can be saline, brackish or fresh depending upon the lagoon opening condition, the freshwater inflows, seepage through the barrier beach and losses due to evapotranspiration. The salinity distribution in the lagoon and marshes depends on the mixing processes, including tidal trapping, tidal pumping, and the effects of wind.

High freshwater inflows and a very porous barrier beach usually result in predominantly freshwater conditions in the lagoon. Lesser quantities of freshwater inflow and limited mixing in a deep lagoon can result in stratified conditions throughout the lagoon, including Scott Creek lagoon (Smith 2003) Stratification can lead to elevated water temperatures in the salt water and anaerobic conditions at the lagoon bed. Fish kills and a stressed ecosystem have been observed to be associated with these conditions (Largier 2007). If the lagoon inlet channel is closed and the freshwater inflows are small compared with the seepage losses and evapotranspiration, the lagoon can become hypersaline and hyperthermal.

The extent of the effects bridges have had on Scott and Waddell Creek lagoons cannot be determined without further evaluation, focused field measurements, empirical and/or mathematical modeling. However, the implied effects relative to the questions posed in the beginning of this document can be contemplated.

4.1 Frequency and Duration of Lagoon Opening

The beach- lagoon interface of both Scott and Waddell Creeks has been constricted by the bridge crossings. If the constriction has modified the potential water surface elevation upstream of the barrier, the breaching susceptibility will have changed and the timing of the initial breach and configuration of the inlet may be affected. Specific influences on tidal and fluvial dynamics and ultimately on the frequency and duration of the lagoon opening following the initial breach cannot be determined without further investigations as described below. The concerns expressed by fishery agencies relate to the timing of lagoon closure relative to migration (open lagoon) and summer-fall rearing (closed lagoon). Bridge induced change (e.g., reduction) in the tidal prism would potentially reduce the combined force of tidal and fluvial forces and shorten the duration of the lagoon opening. The concern that the lagoon would remain open after inflow declines forming a shallow, brackish lagoon is not likely directly affected by the bridges influence on tidal opening.

The bridge approachways have slightly reduced the effective breadth of the barrier beach, thus increasing breach susceptibility. The other factor influencing breach susceptibility (difference in elevation between the ocean and lagoon side of the barrier) is primarily influenced by inflow and could be affected by constriction that causes inflow to backup and increase in elevation behind the barrier. As such, the likely effect of the bridge constraints, if any, on initial breaching may be to cause a relatively earlier breach. However, the fixed location of the inlet reduces the ability of the inlet to overflow at the lowest point along the beach. At Scott Creek, the inlet is located at a point with a historically wider beach, thus reducing breaching susceptibility.

4.2 Water Quality Salinity Stratification

The bridge changes appear to improve the opportunity for early closure and development of a freshwater system. However, the concern with many lagoons that have reduced frequency and duration of tidal opening is the loss of tidal mixing and degradation of water quality and habitat (Elwany et al. 1998, Rinehart 2005, Larson et al. 2006, Largier 2007). Tidal restoration projects in the National Parks in northern California are aimed at increasing tidal prism to maintain open lagoons, supplemented by artificial breaching, to improve water quality and associated habitat conditions.

Bridge related channelization in Scott Creek has clearly eliminated the deeper areas associated with the pre-bridge channel configuration. Channelization has affected the scour associated with fluvial and tidal.

Here again, there is insufficient information to determine the effect of the bridge constraints on historic tidal opening and morphology. Current conditions that appear to decrease the frequency and duration of tidal opening may provide the conditions needed to sustain a substantially modified system. However, without a detailed investigation of the potential results of removing bridge related constraints, the current effect of the bridges on water quality and associated habitat conditions appears minimal or even positive.

4.3 Tidewater Goby Habitat

The issue of high flow event refuge for larval and juvenile gobies relates primarily to lagoon morphology as a function of tidal prism and sedimentation, and potentially fluvial related effects from previous development in the lower watersheds.

Although the conditions in Waddell and Scott Creek lagoons that appear to reduce or eliminate high flow refuge are likely related to channelization and channel incision – not to tidal dynamics in this case – they may be exacerbated by the reduction in tidal prism. Reduction in tidal prism can reduce the tidal range and depth in the lagoon. The frequency or occurrence of tidally inundated marsh plains during high tide events would diminish and the maintenance of shallow, off-channel habitat that can typically provide high flow refuge.

4.4 Steelhead and Coho Salmon Habitat

Issues regarding steelhead and coho salmon use of the lagoons include:

4.4.1 Adult Upstream Migration

Timing of lagoon opening needs to accommodate upstream adult migration. Coho salmon begin migration during November and are known to migrate into these streams as late as February (Shapovalov and Taft 1954, Smith date unknown). Steelhead can enter anytime between December and May. Typically, the earlier the opening occurs within this period, the better for coho and potentially steelhead. Unobstructed passage into the stream from November through March would be preferred.

The effect of the bridge induced conditions on lagoon breaching and seasonal closure (i.e., frequency and duration of opening) appears compatible with adult migration. As described above, the initial breaching is not considered to be affected by bridge related conditions. The frequency and duration of closure has likely increased, which could affect migration during dry years when tidal prism may have maintained a longer period of opening. Further investigation is needed to address this issue.

4.4.2 Smolt (Kelt) Downstream Migration

Juvenile migration from the lagoon to the ocean, versus to the lagoon, is likely occurring from fall through spring when the lagoon is typically open, at least intermittently. The bridge effect on lagoon closure, as described above, likely decreases frequency and duration of opening and possibly restricts out migration. It is expected that the fish that are ready to migrate during fall are simply delayed. Delay could negatively affect survival if lagoon conditions worsen during the fall, or if timing of migration affects survival, as discussed by McKeown (1984). Fish that are not ready to leave until late in the season may be confined to the lagoon for another season. The tradeoff between extended lagoon residence and larger size at migration and ultimate survival to reduced survival associated with another season in the lagoon is unknown.

4.4.3 Rearing and Smolt Adaptation

The current influence of lagoon closure on steelhead rearing in Scott Creek lagoon is well documented (Smith 2003, Bond 2006, Hayes et al. 2007). Juvenile coho have not recently been observed in the creek's lagoons. Juvenile coho salmon are known to rear successfully in lagoons (Shapovalov and Taft 1954). Shapovalov and Taft (1954) report that most coho salmon juveniles in Waddell Creek left the stream as yearling and spent little or no time in the lagoon. Coho rearing in Navarro River has been associated with complex structure (e.g., woody debris) and cooler water. As suggested by Smith and others, the absence of coho rearing, especially over-summer rearing, in the Scott and Waddell lagoons may be due to water temperatures.

Lagoon morphology may also influence lagoon use by both steelhead and coho salmon juveniles. The absence of deeper habitat and structure can be linked to changes in fluvial and tidal dynamics that are affected by bridge conditions. However, the specific relationships among fluvial and tidal dynamics, morphology, breaching and closure, water quality and marsh habitat development and maintenance in a modified or "restored" Scott or Waddell Creek lagoon is unknown. Backwater effects could increase sedimentation and decrease scour. Improving scour by reducing constriction at the bridge and constraints from channelization in Scott Creek would increase depths and increase the tidal prism improving habitat structure and increase tidal mixing. But, the consequence of increasing opening duration on the freshwater habitat supporting enhanced growth during the summer-fall period cannot be answered without further investigation, field data collection, and application of more sophisticated analyses.

4.4.4 Non Fish Resources

California red-legged frogs (CRLF), San Francisco garter snakes, and western pond turtles all primarily use freshwater reaches of the marsh. The influence of bridges on development and maintenance of tidal marsh is related to decreased tidal prism and increased sedimentation. Channelization in Scott Creek has certainly affected the tidal marsh dynamics. The specific effects of the bridges on the marshes and their habitats requires more detailed assessment and analyses as described below.

5 Further Investigations

The introductory quote by Joshua Collins speaks to the need for clear management direction especially regarding Coastal lagoons. The dynamic nature of these systems, the potentially large scale response to change and the varied nature of their value to diverse interests requires enunciation of the desired character before effects can be clearly defined. For example, restoration to a pristine system may not be compatible with optimizing anadromous fish habitat.

The tools needed to identify physical responses and potentially biological responses to lagoon modification are available. However, basic physical measurements of lagoon dynamics are not available. Any assessment of alternatives must be founded on a better understanding of the existing system, based in part of on-site field data. Depending on the level of required detail, changes in lagoon conditions can be modeled to define long term change in morphology to short term changes in water quality. The process of identifying further investigations, especially as they relate to design of potentially substantial modification to the lagoons, really becomes first a question of what is the desired outcome.

An additional consideration for the project is the rise mean sea levels that will occur over the life of the project. NOAA has published sea level rise trends for Point Reyes and Monterey tide stations. If present trends continue, sea levels at Scott and Waddell Creek are expected to rise 0.6 to 0.8 feet in the next century (NOAA 2008). Others have suggested that sea levels along the California coast may accelerate in the next century to more than 2 feet/century (Cayan et al. 2006). Such an increase suggests that the lagoon-bridge-ocean relationship will continue to evolve even if no change occurs in bridge design, including increased vulnerability to coastal storms, higher rates of beach erosion, and more frequent saltwater inundation landward of the bridge crossing.

The USFWS (2006b) has identified linkages between tidal habitat conditions and tidal elements using various analytical tools to guide tidal restoration projects targeting limiting habitat factors or other, related habitat conditions for tidewater goby. In essence, the linkages provide a means to identify bridge related effects on tidal conditions and thus habitats by reversing the relationship from habitat oriented to tidal element oriented. The enunciation of effects on tidal elements can then be linked to habitat effects.

The list of analytical tools, their data requirements and applications prepared by FWS (2006b) are presented here (Appendix 1) to identify the types of information needed and the effort involved in order to succinctly identify current effects of Highway 1 bridges on Scott and Waddell Creek lagoons, but more informatively, to identify the response of tidal conditions and related habitats to potential changes in bridge configurations and other actions intended to "restore" these lagoons.

6 Conclusions and Recommendations

Quantitative information about the dynamics and physical characteristics of Waddell Creek and Scott Creek lagoons prior to construction of the existing bridges is very limited. Recent efforts to assess the biological productivity of the two creeks provide useful information about the significance of the lagoon habitat, yet have produced few physical measurements of critical parameters such as water levels, flow rates, and salinity distribution. Still, it is apparent from the limited data available that the bridges have altered creek and lagoon dynamics in the following fundamental ways:

1. Tidal range landward of the bridges has likely been only slightly decreased by reduced cross sectional areas of the existing tidal interface (bridge span) as compared to historical conditions. In combination with a slightly decreased tide range, isolation and filling of tidally influenced areas has reduced the tidal prism. The actual reduction in the tidal prism caused by the bridges is unknown due to a lack of both historic and recent tidal and topographic information. Analysis of topographic data suggests that at present very limited areas, primarily within the main creek channels, are still subject to direct tidal exchange. Conceptually, the reduced tidal prism may result in more rapid lagoon closure following a breach.
2. General lagoon dynamics have been altered by the presence of a physical barrier between the beach and lagoon systems. Conceptually, the bridge abutments limit wave overtopping and introduction of sea water landward of the highway during strong storm events. The abutments have also altered the natural cross shore transport during severe storms and exchange of wind blown sand between the active beach, dunes, and lagoon. These impacts are expected to increase as sea levels continue to rise. Further, the abutments have altered local hydrology by impeding seaward flow during flood events.
3. Channel migration and equilibrium has been affected by modifying channel geometries, gradients, and fixing the physical location of the channels connecting both lagoons to the ocean. The channel mouth must now migrate from a fixed point seaward of the bridge, limiting its ability to adjust to changing beach conditions. At Scott Creek, the channel must meander seaward of the bridge along the active beach to the more narrow beach at the north. Upstream land use has also likely contributed to an altered lagoon system, in combination with the bridge effects.
4. Straightening and confining the downstream reach of Scott Creek has resulted in an increased hydraulic gradient and decreased channel diversity.

Prior to conducting further studies or adopting an approach to bridge replacement, the current understanding of the existing system must be improved. Changes to the lagoon functions resulting from new bridge configurations can then be evaluated and compared to the existing and historical conditions. The following steps are recommended:

- Perform field work to fill critical data gaps and refine knowledge of the existing coupled creek-lagoon-beach system. This work should include, at a minimum, LiDAR topographic mapping of the dry beach, lagoon, and lower watershed; traditional bathymetric and topographic surveys of the creek cross section, profile, and adjacent disconnected wetland areas; bathymetric beach profile surveys extending seaward from mean higher high water to depth of closure (~40ft); collection of continuous water level, stream flow rate, and salinity measurements seaward and landward of the existing bridge alignment, preferably covering periods of open and closed lagoon conditions; collection and laboratory analysis of surface sediments within the creek and along the outlet channel; collection of nearshore wave height and direction.
- Apply field data to estimate existing tidal prism and perform 1D tidal analysis of both lagoons/creeks. Initiate a wave shoaling and transformation study based on offshore data to conceptually estimate the significance of wave impacts along the bridge abutments and non-tidal seawater exchange. This task would also prove useful for locating the new bridge alignment and providing necessary protection against scour and extreme storm events.
- Compile creek hydrology data from stakeholders and perform 1D hydraulic studies defining flow rates for extreme events and seasonal flows. Calibrate hydrologic model with stream flow measurements and characterize creek geomorphology.
- Define lagoon management goals by agencies responsible, including NMFS, DFG, the Coastal Commission and County of Santa Cruz. This action may require alternative analysis using both empirical and numerical methods to better define implications associated with goals and objectives.
- Conduct a feasibility study to identify the larger scale restoration needs to meet management goals for these two lagoons and integrate bridge design as appropriate.
- Conduct detailed evaluation of the potential physical responses of the lagoon to alternative bridge designs in context of the management goals using field data. Demonstrate proof of concept for final design with rigorous and calibrated numerical modeling supported by field work described above.

Numerical modeling is now commonplace for projects of similar magnitude and considered by most of the coastal engineering profession as the industry standard for assessing complex coastal processes. Having gathered the recommended field data and performed basic analysis of tidal prism, creek hydraulics and geomorphology, conducting a 2D modeling for both lagoons would provide insight into the anticipated physical impacts and responses for a range of alternative designs. According to FWS (2006b), two-dimensional hydrodynamic modeling can provide daily, seasonal, and annual fluctuations in water depth, depth-averaged velocity, depth-averaged temperature and salinity, and sediment transport/deposition dynamics at point locations within a plane in a tidal environment. Hydraulic characteristics (water depth and depth-averaged velocity/shear stress) are determined as a function of cross-section characteristics, input hydrograph data, long-term tidal data, and hydraulic control structure characteristics. Several 2D numerical models (e.g., DELFT3D, MIKE21, RMA/SED2D) can simulate unsteady depth-averaged flow dynamics and sediment transport simultaneously, which provides insight into lagoon breaching dynamics. As with 1D numerical models, 2D numerical models can simulate the effects of various obstructions such as bridges, culverts, weirs, tide gates, spillways, levees, and other floodplain structures on flow dynamics, and additional modules can simulate time series of salinity and temperature in the same fashion as 1D models, but with spatial variability.

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8 Appendix A

Appendix Table 1. Approaches to evaluation of tidal dynamics including addressed variables, data needs, and level or detail and effort, from Guidelines for tidewater goby habitat restoration prepared by Stillwater Science for the US Fish and Wildlife Service (FWS 2006)

Approach		Variable Addressed	Data Needs	Considerations/Limitations	Application
1D Numerical Modeling (continued)	Hydraulic Routing	• Hydroperiod • Depth • Vegetation • Velocity	• Elevation/storage capacity relationship (high-resolution topographic data) • Long-term tidal data at the inlet • Channel/hydraulic control structure characteristics (dimensions, roughness estimates) • Watershed hydrograph • Initial water surface	• Availability of long-term tidal data, hydrology data, and topographic/bathymetric data • Potential cost associated with topographic/bathymetric data • Potential effort associated with constructing a hydrograph (i.e., additional hydrologic modeling) • Potential cost associated with calibration data – need to monitor water surface elevation data under existing conditions	MORE COMPLEX – maximum water surface elevation within a tidal area for specific tide elevation-storm event combination
	Steady/ Unsteady Flow	• Hydroperiod • Depth • Vegetation • Velocity • Temperature/ Salinity	• Hydraulics • Cross-section characteristics (dimensions and spacing, channel/floodplain roughness) • Input hydrograph • Long-term tidal data • Hydraulic control structures (dimensions, roughness) • Temperature/Salinity • Hydraulics data • Initial temperature • Meteorological data (wind speed, wind direction)	• Availability of long-term tidal data, hydrology data, meteorological, and topographic/bathymetric data • Potential cost associated with topographic or bathymetric data collection • Potential cost associated with model purchase • Potential effort associated with constructing a hydrograph (i.e., additional hydrologic modeling) • Potential cost associated with calibration data – need to monitor water surface elevation, salinity, and temperature data under existing conditions • High level of expertise needed for modeling	COMPLEX – daily, seasonal and annual fluctuations in water depth, depth-averaged velocity, and depth-averaged temperature/salinity at point locations along a tidal channel

Approach		Variable Addressed	Data Needs	Considerations/Limitations	Application
1D Numerical Modeling (continued)	Hydraulic Routing	• Hydroperiod • Depth • Vegetation • Velocity	• Elevation/storage capacity relationship (high-resolution topographic data) • Long-term tidal data at the inlet • Channel/hydraulic control structure characteristics (dimensions, roughness estimates) • Watershed hydrograph • Initial water surface	• Availability of long-term tidal data, hydrology data, and topographic/bathymetric data • Potential cost associated with topographic/bathymetric data • Potential effort associated with constructing a hydrograph (i.e., additional hydrologic modeling) • Potential cost associated with calibration data – need to monitor water surface elevation data under existing conditions	MORE COMPLEX – maximum water surface elevation within a tidal area for specific tide elevation-storm event combination
	Steady/ Unsteady Flow	• Hydroperiod • Depth • Vegetation • Velocity • Temperature/ Salinity	• Hydraulics • Cross-section characteristics (dimensions and spacing, channel/floodplain roughness) • Input hydrograph • Long-term tidal data • Hydraulic control structures (dimensions, roughness) • Temperature/Salinity • Hydraulics data • Initial temperature • Meteorological data (wind speed, wind direction)	• Availability of long-term tidal data, hydrology data, meteorological, and topographic/bathymetric data • Potential cost associated with topographic or bathymetric data collection • Potential cost associated with model purchase • Potential effort associated with constructing a hydrograph (i.e., additional hydrologic modeling) • Potential cost associated with calibration data – need to monitor water surface elevation, salinity, and temperature data under existing conditions • High level of expertise needed for modeling	COMPLEX – daily, seasonal and, annual fluctuations in water depth, depth-averaged velocity, and depth-averaged temperature/salinity at point locations along a tidal channel

Approach	Variable Addressed	Data Needs	Considerations/Limitations	Application
2D Hydrodynamics Numerical Modeling	• Hydroperiod • Depth • Vegetation • Velocity • Temp/ Salinity • Substrate	• Hydraulics • High-resolution topographic data • channel/floodplain roughness • Input hydrograph • Long-term tidal data • Hydraulic control structures (dimensions, roughness) • Temperature/Salinity • Hydraulics data • Initial temperature • Meteorological data (wind speed, wind direction) • Sediment transport/deposition • Sediment input rate • Initial suspended sediment concentration • Critical velocity • Settling velocity • Erosion coefficient • Dispersion coefficient	• Availability of long-term tidal data, hydrology data, meteorological, and topographic/bathymetric data • Potential cost associated with topographic/bathymetric data collection (very high resolution data required) • Potential cost associated with model purchase • Potential effort associated with constructing a hydrograph (i.e., additional hydrologic modeling) • Potential costs associated with calibration data – need to monitor water surface elevation, salinity, and temperature data under existing conditions • Very high level of expertise needed for modeling • Potential cost associated with overall modeling effort	VERY COMPLEX – daily, seasonal, and annual fluctuations in water depth, velocity profiles, and temperature/salinity profiles at point locations within a grid in a tidal environment

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09/28/2007 01:16 PM

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cc

bcc

Subject
Scott/Waddell study

Wow, this report seems very thorough and I have learned a ton reading it. I have a bunch of comments that probably don't so much point out errors as just reflect inexperience with the subject matter and may just require some explanation from Mr. Snider to clear things up for me. I do want to make sure that the assumption that tidal influences are the most important factor is accurate, and therefore directs further investigations in the right direction. If you guys can spare some time to talk about it before we submit comments, then maybe you can clear up some of these issues for me and we can get rid of some of these comments.

The recommendations are great. My only reservation is that the recommended 2-D analysis seems like it's for tidal channels and marshes with fixed tidal inlets--do they consider fluctuating inlet elevations (sandbars)? Also, do they consider other hydrologic inputs, such as creeks, which are likely major contributors to the form and function of these wetlands? I have to assume they do since they are from tidewater goby habitat mitigation guidelines, but I don't know that they do for a fact. These wetlands were probably infrequently open to tides even in pre-bridge conditions. We don't even know how much if any of the wetlands are below high tide lines--is the marsh more of a creek floodplain or a tidal plain?. If they aren't, then the only hydrologic inputs are wave overwash and the creek. I suppose that the recommended further studies would determine this, but it seems that the current study could make an initial evaluation (we should have topographic data) instead of assuming that tidal prism is the big factor.

In general I think there is too much focus on tidal prism as the primary factor in maintaining deepwater habitat. Intuition tells me that the historic deep channel along the north bank was maintained by creek flows instead of tidal flux. Most of the analysis treats the wetlands as equivalent to tidal, such as in a bay, but they are much less frequently tidal. They share plant communities with tidal wetlands, but this is due to the salts that are deposited in the soil during less frequent saltwater influxes than the daily tides. These types of lagoons are rarely subject to daily tidal flux, even in pre-bridge conditions. Tidal prism is obviously the primary factor in tidal wetlands such as Elkhorn Slough, which has a permanently open inlet below mean sea level, and can store massive amounts of water at high tide. However the Scott Creek and Waddell creek lagoons are rarely tidal, and I doubt that the volume of salt water entering these small lagoons in historic conditions was ever enough to significantly scour the main channels during ebb flows. Seems to me that more often, scouring flows were caused by either 1) freshwater buildup behind the berm, and/or saltwater overwash resulting in a breach and rapid ebb, or 2) winter flows in the creeks. I am inclined to feel this way because these events occur more frequently than open tidal inlets , I see little tidal influx in similar lagoons, and the large main channels would naturally be sized to handle channel-forming creek flows, which are of a much greater volume and velocity than tidal flows in these small lagoons. The historic (and maybe existing) main channels were probably too big to allow tidal ebb velocities that would scour the channel given the limited tidal storage capacity of the estuaries. In addition, buildup behind a berm will store more water with (creating more scour potential) than would a normal high tide behind an open inlet. Buildup behind a sandbar may store water much higher than a high tide, creating a greater head. Berms can build up much higher than a high tide line due to wind and wave energy. Judging from the 1928 aerial at Scott Creek, the main channel was the only deepwater habitat for fish rearing and oversummering, so the factors that maintained this channel's dimensions are probably the most important to determine.

pg. 36 concludes "If the existing spans represent 20 to 30 percent of the historic tidal opening, the tidal prism is only 20 to 30 percent of its pre-bridge magnitude." This conclusion can't be made without an analysis of channel cross section at the constriction, which requires knowing the depth, not just width, of the channel. No such measurement was attempted. The conclusion also assumes that the channel depth at the constriction (bridge) has not scoured in response to reduced width, which would compensate for the lost cross-sectional area. It may be that even in pre-bridge conditions, the inlet depths were such that tidal influx was infrequent and small, and that the current channel hasn't changed the frequency or volume at all. Again, there is too much assumption that the tidal prism is the most important factor at these wetlands and that it has been altered significantly by the bridge.

pg. 36 says "Similarly, the extent of the marsh area in lower Scott Creek that was removed from tidal action by channelization has substantially reduced tidal prism capacity." Again, this is the case only if those wetlands are below the high tide elevations--maybe they are, but no attempt was made to determine this. The levees have also reduced the storage capacity for creek flows, which might flood the wetlands during normal winter flows if not for the levees. This could provide scour potential as well and is not really analyzed. We don't really know this without knowing the elevations.

pg. 32: "Fish kills...have been observed..." Please clarify whether they have been observed at Scott Creek or other locations.

pg.32. paragraph 3: I assume that the 70% and 80% tidal inlet restriction numbers were arrived at by measuring historic channel width below the high tide line such as that shown on figure 1. Tidal inlet coefficients in all of the formulas discussed were defined by areas below mean sea level, not the high tide line. Given this, I'm not sure that "tidal inlet" is an accurate term for the channel cross sections where 70% and 80% losses of width were incurred, since probably none of those cross sections were below mean sea level.

No discussion of channel elevations below the bridge relative to mean sea level or mean high tide, whether the bridge constriction creates an artificial channel height at the constriction, and whether this channel elevation at the constriction plays a role in the altered tidal prism.

All of the formulas discussed ignore sediment deposition, velocities, and flows created by the creek itself.

pg. 33 says "As described above, the initial breaching is not considered to be affected by bridge related conditions. The frequency and duration of closure has likely increased..." while Pg. 32 says "Late opening, after February, may be influenced by the bridge effects. Breaching is not directly related to constriction and fill here, but tidal range could be affected by bridge conditions and potentially change the geometry of the barrier (breadth) and influence initial breaching....The change would likely increase breaching susceptibility as the breadth is likely to decrease due to bridge conditions...The likely effect of the bridge constraints on initial breaching would be to cause a relatively earlier breach." These seem contradictory to me; pg 32 says the bridge condition indirectly affects initial breaching, while pg 33. says the bridge does not affect initial breaching.

Pg. 34, first paragraph: If I understand what this sentence is trying to say, then it should read "...which could affect migration during dry years, when [, before the bridge was built, the] tidal prism may have maintained a longer period of opening." Also, it seems a key piece of the recommended analysis following this sentence is, again, the elevation of the constriction at the bridge, which would be necessary to calculate the cross section of the constriction below mean sea level or even high tide lines. A comparison of that cross section to the predicted historic cross section (depth, not just width) may shed some light now on the tidal prism changes.

Pg. 34 says "The absence of deeper habitat and structure can be linked to tidal dynamics that are affected by bridge conditions." This conclusion makes sense if you accept that the tidal influence is the primary factor in sediment transport. It seems to me that the levees probably affected deepwater structure more than the bridge. Most similar, small, unbridged lagoons in Big Sur and SLO County are closed naturally for most of the year, and therefore have no tidal influence for much of the year, and still maintain deepwater habitat (e.g. Arroyo de la Cruz, San Carpoforo, Little Sur River). And when there is tidal influence, the lagoons are too small to hold the kind of tidal prism that creates scouring flows mid-lagoon during the ebb flows. I am more inclined to believe that the deepwater habitat in the main channel would be maintained by creek flows if there were natural sinuosity, which would create secondary and tertiary currents during storm events to scour the channel. I could see the smaller estuary channels being maintained by tidal influence or other means of buildup behind the sandbar, but not so much the main channel because it's cross section is more likely a function of creek flows. If the main channels were partially below mean sea level or the high tide line, however, then I could see the tidal prism, more than creek flow, affecting their depth. But again there is no analysis of either historic or current channel elevations at the constriction.

pg. 34: "CRLF may benefit from seasonal brackish conditions." Any citation or further clarification for this?

Gary Ruggerone/D05/Caltrans/CAGov
09/26/2007 03:42 PM

To
Dave_Hacker@dot.ca.gov
cc

Subject

Dave:

Thought you might be interested in this draft technical memorandum that has been prepared for the Scott & Waddell Bridge projects by the HQ fish passage on-call consultant. We are providing comments back to the consultant by 10/10/07 so if you have any comments, let Chuck or I know prior to then.

[attachment "Tech Memo-Implications Hwy Bridge Crossings(09 24 07)fdraft.doc" deleted by Dave Hacker/D05/Caltrans/CAGov]
Gary

Lyn Wickham/D05/Caltrans/CAGov

11/14/2007 02:59 PM

To
Steve DiGrazia/D05/Caltrans/CAGov@DOT
cc
Chuck Cesena/D05/Caltrans/CAGov@DOT, Michael Sandecki/D05/Caltrans/CAGov@DOT, Dave Hacker/D05/Caltrans/CAGov@DOT, Gary Ruggerone/D05/Caltrans/CAGov@DOT, Lance Gorman/D05/Caltrans/CAGov@DOT, Kelly Mcclain/D05/Caltrans/CAGov@DOT
bcc
Subject
Re: Fw: Scott/Waddell report

History:
This message has been forwarded.

Steve,

I have a number of concerns with the consultant's report and have provided two sets of comments on it (attached). I'll try to summarize for you those that haven't been addressed in the most recent version of the report.

The majority of the report and its references pertain to estuaries of a different nature (larger and always open) than those at Scott and Waddell Creeks.

The report emphasizes the effects of tides on the estuaries and gives very little consideration to the effects of the creeks. Many of the references point out that creeks can have significant effects on estuaries of the type we're looking at.

The report makes unfounded assumptions about how much of the beach between the ocean and the estuaries could allow for the formation of an inlet channel between the two. Geotechnical data would be needed to actually determine the length available for inlet formation. We have virtually no geotechnical data on either creek because the Preliminary Investigations, which would include that information, are unavailable for both bridges.

Based on the unfounded assumptions discussed above, the report makes equally unfounded references to the possibility that the inlet channel widths, and consequently the estuaries, might have been reduced in size by up to 80%. There is nothing in the historic data we have (as-built plans and aerial photographs) which would indicate that the channels were ever that much larger than they are now.

The report does not adequately address how to estimate the length of the beach that would naturally be available for inlet formation, how important it is to keep that entire length open to allow for inlet channel meander, or what the natural width of the inlet would be. I consider these issues to be the main concerns in determining an appropriate bridge length to program for.

The report recommends that our next step should be to develop detailed models of the estuaries. The modeling described is used to establish the inner workings of the estuary for a known inlet channel configuration. It would not help us to determine how wide the inlets should be or how much beach length should be allowed for meander. The proposed modeling may be appropriate at a later stage in the project in order to fine-tune our design, but I it would be a mistake to pursue it now.

I believe that other members of the internal team share some of my concerns. The consultant addressed some but not all of my concerns in the most recent version of the report, labelled as a final draft. I don't know if any further changes can be expected. The main purpose of the report was to bring some consensus to the stakeholder group regarding the extent of the proposed bridge replacements so that we can program the project. So far, the only consensus the report has developed is amongst those of us in disagreement with its methods and results. Chuck and I have discussed the possibility of showing the stakeholder group the report along with our comments. This is a very undesirable option, but if it's our only choice, I prefer it to showing them the report without our comments and with our implicit approval.

I think we could make a reasonable estimate of maximum bridge length based on some of the techniques discussed in the references for the report. We might need some additional data, such as geotechnical studies. I don't know if we have resources to develop those at this stage. I'm also concerned that anything we do in-house will not be considered valid by the stakeholder group. If we have any funds for more consultant work, I would strongly suggest that we look into whether we could get even a cursory recommendation from Dr. John Largier at UC Davis. He was recommended to me by Dr. Nicholas Kraus, one of the sources frequently cited by our current consultant. According to Gary, HQ has had an interagency agreement with UC.

We should meet internally to discuss how to proceed. I spoke with Lance this afternoon about funding. His understanding of it from Kelly is that we could use bridge funds for replacement in kind at the same location, possibly increasing the length by an additional span. Anything beyond that is out of the scope of that program. He said we would either have go to HQ to get special permission to use the bridge funds or use SHOPP funds. He suggested that if we wanted a representative from Maintenance, Kelly would be the best choice.

Let me know if you have any questions (or if you're just sorry you asked).

Lyn

Tech Memo Comments 101507.doc More Tech Memo Comments 110107.doc

To
Lyn Wickham/D05/Caltrans/CAGov@DOT
cc

Subject
Re: Fw: Scott/Waddell report

Lynn

Can you describe, in laymans terms, your concern? I would like to keep track of it in the project file.

Steve

To
Chuck Cesena/D05/Caltrans/CAGov@DOT
cc

Dave Hacker/D05/Caltrans/CAGov@DOT, Michael Sandecki/D05/Caltrans/CAGov@DOT, Steve DiGrazia/D05/Caltrans/CAGov@DOT
Subject
Re: Fw: Scott/Waddell report

From the brief review I gave the new document, it looks as if a good number of my comments weren't addressed, particularly and most importantly my objection to recommending 2D modeling as the next step. If HQ prepares a new task order, I can only hope it won't be for modeling.

To
Steve DiGrazia/D05/Caltrans/CAGov
cc
Lyn Wickham/D05/Caltrans/CAGov@DOT, Michael Sandecki/D05/Caltrans/CAGov@DOT, Dave Hacker/D05/Caltrans/CAGov@DOT
Subject
Fw: Scott/Waddell report

FYI
----- Forwarded by Chuck Cesena/D05/Caltrans/CAGov on 11/13/2007 11:26 AM -----

To
Chuck Cesena/D05/Caltrans/CAGov@DOT, Gary Ruggerone/D05/Caltrans/CAGov@DOT
cc
William.Snider@hdrinc.com
Subject
Scott/Waddell report

Good afternoon. I'm sending a copy of the final report under the current Task Order. I believe that HDR addressed the issues identified as critical changes. We intend to prepare a new Task Order to provide an opportunity to address other issues and to assist presenting the report to agencies and stakeholders should resources be available. We are aware that we will have some cuts due to the current state financial situation.

[attachment "Tech Memo-Implications Hwy Bridge Crossings(11092007)fdraft.pdf" deleted by Lyn Wickham/D05/Caltrans/CAGov]

Richard E. Hill, SEP
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Tech Memo Comments
L Wickham
10/15/07

General:

- Provide a glossary. A table of contents would also be helpful.
- In particular, the term tidal inlet or opening should be well-defined and it should be consistently made clear whether the actual tidal inlet or the area where it might potentially form is being discussed. My understanding of the tidal inlet is that it is the actual channel between the ocean and the estuary, whereas the length of beach adjacent to the estuary and between rock outcroppings could be considered the potential area where the tidal inlet could form. This report often seems to refer to the full length of beach between outcrops as the tidal inlet, without any qualification that it is only the potential area where the inlet might develop. Neither the actual tidal inlet width nor the potential area where it might occur are know with any certainty at either creek in their condition before the bridges were constructed. The natural inlet width can only be roughly estimated from what little data we have (as-built plans and aerials). The area of potential tidal inlet could be determined through a geotechnical study, but that data is not currently available. Any statements made regarding tidal inlet should be qualified and lack of data to determine it acknowledged.
- I don't find listings for the references noted in the text as Krause 2003, SCWA 1993, Krause 2000, Kraus 1998. Some of these seem to be crucial to the report and I would like to be able to find them. Many citations to references by Kraus are misspelled as Krause.
- Most of the references and other sources which were listed and which I could find address navigable inlets into large waterbodies and do not seem applicable to Scotts and Waddell Creeks.
- The emphasis of this report seems to be on the tidal influences on estuaries with open inlets. My impression is that the main concern of the stakeholder group is when and how the inlet opens and closes, which doesn't receive as much attention. I attempted to review as many of the references as I could find and made my own search for more, so I realize that there isn't a great deal of research on this subject. However, I have found more in-depth discussions of aspects of this subject than are covered in this report and I think it is worthwhile to pursue it further.

p.2, Scott Creek: The discussion should make it clear that the entire original opening was filled and a new 160' long one created. The potential tidal inlet is estimated to be 500'. I am unaware of any geotechnical data which would allow such a determination. I also see no correlation with the as-built plans that might help to provide an estimate. Provide more detail on where this estimate comes from and how accurate it is likely to be.

p. 7, Waddell Creek: The report describes the bridge as crossing a "900 foot wide tidal opening including a 181 foot-long span." This sentence should be clarified to convey that there is a 181-foot long bridge within a 900-foot wide area of potential tidal opening. Also, as for Scott Creek, clarify the manner in which the opening length was determined.

p. 10, Rise in Sea Level: Clarify how the term *freeboard* is being used in this context. I take it to mean the height between MSL and the soffit of the bridge, but it is generally used to mean the height between design water surface elevation and the soffit.

p. 15, pp. 1: It is stated that the bridges "include filled portions of the tidal inlet." It should be clarified that it is the approaches, not the bridges, that fill portions of the potential, not necessarily the actual, tidal inlet.

p. 16, General Discussion: The main discussion addresses the mouth dynamics of inlets, leading one to believe that the term *channel* refers to the inlet channel between the ocean and the lagoon. In the notes on Scott Creek, the channel referred to is the entire main channel of the creek running through the estuary. The comments on Scott Creek should be reconciled with the rest of the discussion.

p. 32, Frequency and Duration of Lagoon Opening: "The inlet areas of both lagoon systems have been constricted by the bridge crossings. The inlets opening may have been reduced by as much as 80 percent in Waddell Creek and 70% in Scott Creek." These statements need to be substantiated. As previously noted, there is very little data on the tidal inlets before the bridges were built. What data we have seems to indicate that the channels to the ocean at both creeks were not drastically different, at least in width, than what is provided by the existing bridges. To state that the inlet openings might have been reduced by as much as 80% is unfounded. It may be that the potential area of inlet location has been reduced that much, but not the actual inlet width.

p. 35, Conclusions and Recommendations: "The bridges and raised (filled) approaches traversing the lagoons of Waddell and Scott Creeks have clearly altered the fundamental elements of lagoon dynamics. The tidal prism has been reduced due to constriction and fill." Again, these statements require substantiation. Particularly in the case of Waddell Creek, for which the current bridge provides less constriction than the previous one. If the discussion is intended to extend to all man-made features affecting the estuaries, distinctions between those features should be made. While it seems clear that the tidal prism at Scott Creek has been reduced by fill, it is less clear that it has been affected by constriction or that the Waddell tidal prism has been reduced by either factor.

p. 36, Conclusions and Recommendations: "If the existing spans…" I don't find enough evidence of this assertion to warrant discussing it. Regarding modeling, all of the models described seem to be useful only in determining the characteristics and behavior of the lagoon if the inlet is already open. I don't see any indication that modeling will help to understand when the inlet will open and close or how wide a natural inlet would be. I consider these issues to be of primary importance. In fact, I would think that determining the natural inlet width would be crucial to any modeling. My recommendation would be to spend our time and resources further studying the breaching/closure process rather than on the suggested modeling.

More Tech Memo Comments
L Wickham
10/22/07

General:

The main concern of this phase of the project is to determine an acceptable minimum bridge length at each creek so the project can be programmed. The bridge length should be adequate to allow the estuary to function optimally for the various species of concern. It may be that many studies will need to be done to fully define optimal conditions, but the bridge length could be estimated as the maximum inlet channel width needed to accommodate the anticipated needs.

It seems clear from the resources gathered by the consultant that the channel width will vary seasonally. The channel is likely to be open in the winter when the creek is running and closed periodically in the summer. The channel width immediately after the first breach of winter is related to the volume of water in the estuary immediately prior to breaching. The width during significant creek flows will likely to be similar to that of the creek. The width when creek flows have diminished will depend on the tidal prism. A range of possible widths could be estimated and the largest used for the bridge length.

The size of the tidal prism used in the above calculation could be assumed as the maximum size indicated by the high water marks shown on the as-built plans, which represent conditions before the bridges were constructed. There will likely be a great deal of consideration given to the appropriate size of the tidal prism, but it seems reasonable to the consider pre-highway condition as the maximum expected size.

I think a reasonable estimate of channel width and therefore bridge length could be developed using existing information (as-built plans, aerial photographs, topography) and the empirical equations presented in some of the references, particularly the PWA analyses of Estero de San Antonio and the Russian River. Some additional data may need to be collected, such as tidal information and perhaps some topography. If we do any further studies at this phase, the focus should be on collecting the information necessary to use the empirical equations rather than developing mathematical models.

Specific comments on the Tech Memo in relation to some of its references and other sources follow.

Notes on *Estero de San Antonio Enhancement Plan*, PWA 1993

p. 4:

Conclusion number 8 notes that scour due to winter floods allowed some recovery of the tidal prism, thus indicating influence from fluvial processes.

p. 14:

An equation is given which takes stream power into account when determining tidal power, and consequently the closure relationship. This equation could be useful.

p. 15:

It is definitively state that "closure conditions can be greatly affected by streamflow."

Notes on *Russian River Estuary Study*, PWA 1992

p. 31:

The hydrologic conditions within the lagoon can be predicted if the opening characteristics of the inlet channel, the tributary flows entering the lagoon, and the detailed bathymetry of the lagoon are known. Mathematical models are used to predict the flow and mixing processes in the system.

This supports the idea that models used to determine conditions within the lagoon are applicable only when the inlet channel characteristics are already known. Our current interest is in determining the inlet channel characteristics. Modeling of the lagoon may be useful at later stages, but not at this one. The PWA study discusses methods that might be used to determine inlet characteristics on p. 32.

p. 32:

Under present conditions, the entrance of the Russian River remains open during the winter months when flows in the river are high and the barrier beach cannot form in the inlet. During periods of low river flows or intense wave action, the estuary entrance will close. An approximate estimate of the diurnal tidal prism is 1,750 acre-feet and for the mean tidal prism is 1,300 acre-feet (Table 4.1) in 1992. Historic records indicate that this tidal prism is approximately the same or less than conditions in 1876 which is insufficient to maintain the estuary open under all wave and flow conditions.

This paragraph illustrates that the role of the tidal prism is to keep the estuary always open, if that is possible or desired. It makes clear that fluvial energy has a large effect on when the estuary is open if it is of the type that closes periodically. In the case of Scotts and Waddell Creeks, the lagoons have not historically been always open and therefore are not always influenced by tidal prism.

p. 34:

The discussion on the Escoffier Curve points out that it should be used only when "Water entering and leaving the estuary through channels other than the inlet are negligible." That is, the method can be applied only when there is no fluvial inflow and does not address the effects of fluvial energy. It is useful only for estuaries that are open under all conditions. This method and several others referred to in this study and the Tech Memo are all intended to describe conditions when an estuary is always open. The methods are associated with research done on maintaining navigable tidal inlets. None of them helps to determine when an estuary opens and closes, the main concern of this project. They also have no bearing on the size of the tidal channel is when fluvial energy is present.

p. 58:

During the six observed closures in 1992, none occurred when the river discharges exceeded 700 ft3/s. The lagoon does not close during the wet season months, implyingthat there is a critical river discharge above which the estuary will not close.

It seems likely this is the case at Scotts and Waddell as well.

p. 60:

Using the wave power ratio might be a place to start, but considerable data must be collected in order to determine the initial estimate. It isn't clear from any of the discussion on frequency of inlet closure (p. 44 - 61) what the procedure would be to actually predict the frequency.

p. 175:

The size of the channel formed across the barrier beach is a function of the volume of water released from the estuary.

This seems to be a reasonable method to pursue in determining appropriate channel/bridge width. It could be estimated by establishing the desired maximum water surface elevation, which would allow calculation of the volume. The exact relationship between volume and channel size isn't given but could be researched.

Notes on *Carmel River Lagoon Management Plan*, PWA 1999

p. 107:

Increases in the magnitude and frequency of overbank flows entering the proposed new South Arm channel will promote periodic scouring of organic debris and sand accumulating in the South Arm lagoon. The enhancement of the natural scouring processes during high water events will maintain the geometry of the lagoon channel and ensure relatively deeper, fresher water for aquatic species in this portion of the lagoon.

This supports the idea that fluvial processes affect deep water habitat.

Critique of the **HDR** September 24, 2007 **draft**
Assessment of the Effects of Highway 1 Bridges on Scott and Waddell Creek Lagoons

Mike Sandecki - October 31, 2007

The HDR analysis was initiated to determine the impact of the bridges and bridge approaches on the Scott Creek and Waddell Creek coastal lagoons. Existing information was to be collected and annotated in a bibliography, and supplemented by on-site reconnaissance investigations. Where this approach was insufficient to determine the impacts of the bridges, any additional studies that would be required to determine the impacts would be identified. This assessment does not meet those requirements.

The HDR analysis emphasizes an "open inlet" lagoon scenario, and makes a cursory finding of the impact of the bridges on that condition. The HDR analysis would be more useful if a greater effort was made to evaluate how bridges may affect inlet opening and inlet closure, and to focus on documented evaluations and management recommendations for similar types of lagoons in California. The initial summary of bridge impacts and the influence of tidal prism volume should be revisited. Ultimately any influence of bridges on inlet functioning should be linked to habitats in each lagoon.

Suggested Analyses

A suggested revised draft might include studies of the impact of the highway on other possible lagoon conditions, including the effect of the bridge on the opening of a closed inlet, and the effect of the bridge on the closing of an open inlet (the effect of the highway is probably limited in the closed inlet scenario).

<u>The effect of the bridge on an open inlet</u>

When the lagoon inlet is open, scour from tidal currents tend to maintain the inlet. The importance of tidal prism volume to the Scott and Waddell lagoons appears to be overemphasized. Many of the references cited in the HDR analysis relate to large, deep embayments with permanently open inlets and significant tidal volume. Comparisons of lagoons that are geographically distant and geomorphically dissimilar to Scott and Waddell do not appear to be very relevant.

The papers I reviewed discuss the diminishing role of tidal forces as lagoons mature and fill with sediment. Both Scott and Waddell appear to be mature lagoons, mostly filled, with insufficient tidal volume to keep either lagoon open for extended periods, and with insufficient freshwater influx to breach the opening more than once or twice during the rainy season. The lagoons at Scott and Waddell are shallow, emphemeral lagoons with seasonal inflow of freshwater. Bell, in fact, characterizes the Waddell embayment as a saltmarsh.

HDR indicates that the present bridge span width reduces the opportunity for tidal exchange. It states that prior to highway construction, the entire length of beach along the lagoon was potentially subject to tidal exchange. Most lagoon inlets in California have relatively small openings somewhere along the barrier beach (and are unaffected by highway construction). The actual inlet dimensions prior to highway construction should be compared to the condition limited by bridge width to assess changes in tidal exchange.

An evaluation of the topography relative to high and low tide elevations should be identified as a fundamental information requirement for each lagoon. How much tidal influence is expected at each lagoon seems the most relevant question, and after that, whether or not that volume has been diminished or increased by the bridges would be a follow up question.

The historic physical character of each lagoon inlet should be investigated in a more comprehensive fashion. An exhaustive search for archival maps and aerial photos should be accomplished. The historical dimensions of the inlet openings should be used to evaluate where a bridge might change tidal volume, and whether or not the change is significant.

The effect of the bridge on the opening of a closed inlet

Lagoons that are open intermittently generally open and close seasonally, dependant on a number of interrelated factors. The process of opening a closed inlet is relatively straightforward (and at the same time somewhat unpredictable). The lagoon fills with freshwater provided from a river or creek until it overtops the beach.

There are a number of factors involved in the overtopping process that control when that threshold is reached. The most significant of these appear to include 1) The volume of freshwater delivered to the lagoon from the watershed and seepage losses of lagoon water through the beach barrier, and the consequent elevation of the water surface in the lagoon and 2) The relative elevation of the beach where the breach occurs to that water surface.

The highway may affect these factors in several ways, and each of these need be addressed. The bridge opening may limit the elevation of the lagoon height at the breach location by restricting flow. The bridge location may control the elevation of the lagoon height by directing the inlet to a fixed location along the barrier. The fixed location of the bridge may restrict progressive channel meandering in shallow lagoons or in tidal creeks, limit channel and hydraulic complexity, and affect potential pool depths. It also appears to be possible that the highway may inhibit seepage, raising the lagoon water surface elevation.

To get a handle on the water surface elevations, the actual size of the inlet opening, rather than the entire width of the sand spit, should be compared to current and possible bridge span dimensions. The issue of where to place a bridge along the barrier, and whether or not to leave the bridges where they are currently, should be evaluated in light of the factors listed above. How far inland into the lagoon from the natural beach barrier the highway crosses is another highway design factor that may be helpful to consider.

The effect of the bridge on the closing of an open inlet

The closing of an open lagoon inlet appears to be more complex. The empirical equations that describe the process are also more complicated. But basically, a threshold is crossed where the inlet is suffocated by sediment transported by littoral ocean currents or, in smaller lagoons, carried by high-energy onshore ocean waves. The literature investigating lagoons in California shows that most lagoon inlets close seasonally. This is generally a result of the inadequacy of the tidal prism and freshwater inflow to scour and maintain the inlet.

Highway design features that may influence this process are similar to those that induce a breach, but also will require the evaluation of any highway feature that changes the tidal prism volume.

Existing Literature on Lagoons

A more precise interpretation of the literature should be a primary concern for future analyses. For example, Smith does not state that Waddell Creek has "maintained persistent surface flow between the lagoon and the ocean" since 1994, but rather states that the lagoon has "not closed permanently in summer" – the normal time for seasonal closure - since 1994. Bell did not find "increased infilling" of the lagoon or infilling that is "influenced by tectonic uplift and lowering of the water table." Instead, Bell found evidence of progressive infilling over a 3,000-year period in Waddell lagoon. She also sees evidence of uplift and changed water elevations in organic detritus preserved in the soil column. Elevated rates of lagoon sedimentation are evident in other coastal lagoons such as Estero de San Antonio in Marin County (Williams and Cuffee, 1993) but are not evident in Bell's work at Waddell. No evidence of "persistent surface flow" or "increased sedimentation" can correctly be surmised from the references that I was able to access.

Only relevant references and investigations should be used to identify data needs and future investigations needed. The characterization of Estero lagoon and the Russian River estuary by PWA both provide good examples of the basic analyses that could be applied at Scott Creek and Waddell Creek.

Computer Models

In the investigation of the Russian River estuary, PWA emphasizes the use of empirical equations over mathematical models to characterize the breaching process. They state that computer models require extensive field data and are "still in the research phases of development." The recommendation for modeling in the HDR analysis appears to address only the role of tidal forces in maintaining an open inlet. It is unclear that the type of modeling proposed would be sensitive to the questions that need to be addressed.

There is no attempt by HDR to identify basic concerns a computer model (or future studies) would need to resolve. Perhaps a matrix showing advantages and disadvantages of each highway design on different species needs to be prepared for comparison purposes and a starting point for future discussions.

My recommendation is to forgo an expensive, complicated computer modeling effort in favor of a comprehensive geomorphic evaluation and application of empirical equations to find solutions.

Gary Ruggerone/D05/Caltrans/CAGov
10/10/2008 10:56 AM

I reviewed the September 2008 Draft report "Implications of Highway Bridge Crossing Effects on Coastal Lagoons" prepared by HDR Engineering. I have the following comments:

Overall: The draft report provides additional background information on the Scott and Waddell watersheds and more detail on the fluvial processes and their effect on lagoon formation. The report does a good job of identifying additional data needs necessary to fully understand address the effects of the bridges on the creek and lagoon dynamics.

Page numbering- The title page is identified as page 1. Then 4 pages later, the Introduction is also identified as page 1. The multiple page appendix does not have page numbers.

Specific comments:
Page 1- 1. Introduction- 4th paragraph states "Based on the knowledge that **little empirical information** has been acquired on the dynamics and associated physical features of these lagoons.....". While Page 7-Background- states "Recently National Marine Fisheries Service (MNFS) Southwestern Fisheries Science Center (SWFSC) and University of California Santa Cruz have collaborated on a **suite of rather intensive studies** of Scott Creek and its lagoon. The studies address steelhead life history with a focus on lagoon rearing including **discussions of tidally influenced conditions** on steelhead population". These two statements seem to be somewhat contradictory.

Page 2- 1.1.1 Scott Creek- 1st paragraph, 5th sentence reads "A tidal marsh is also faintly indicated on the south side of the creek with closely spaced dashed A road, agricultural development, and a low water crossing of Scott Creek are also shown." I suspect a word is missing after the word "dashed" and that there should be a "." to start a new sentence with "A road, ..."

Page 12- 1.1.2-Waddell Creek- 5th sentence reads "It should be noted that the Highway 1 bridge **replace** a bridge and **filled** approach that existed upstream of the current alignment." I suspect that the sentence should read "replaced a bridge and fill approach".

Page 15- Carmel River- 3rd sentence reads "It shows that a geologic feature establishes acts as a dam,....". I suspect that the word "establishes" should be removed, or additional words should be added to clarify.

Page 21- 1st sentence states "As described above, the bridges constructed over Waddell and Scott Creeks filled portions of the **tidal interfaced**." Shouldn't that be "**tidal interface**"?

Page 40- 4.1 Frequency and Duration of Lagoon Opening, 2nd paragraph, 1st sentence states "Late opening, after February, **may be influenced by the bridge effects the tidal range was affected** potentially changing the geometry of the barrier (breadth) and influencing initial breaching (Breach Susceptibility= Elevation difference/Barrier breadth)." Confusing sentence.

Page 3 paragraph 2 – missing the word yards between 500 and wide in the next to last sentence.

Page 11 paragraph 1 – the phrase “(closely spaced lines per)” seems to be missing something.

Page 15 paragraph 2 – In the Garrapata Creek section the second sentence reads …a barrier beach closes the lagoon closes from late summer to mid-fall.

Page 20 Figure 15 – what does the M or D after each inlet condition descriptor mean?

Page 24 paragraph 3 – refers to Eq.3 several times. Does this stand for equation 3? Where is the list of equations, or whatever Eq, 3 stands for.

Page 27 paragraph 3 – refers to Eq.7. Again, what does this stand for?

Page 30 paragraph 2 – refers to Eq.10.

Page 40 paragraph 2 – As Gary mentioned, there is a very confusing sentence to start this paragraph. It seems like an importance sentence as the next sentence states that the barrier breath is likely to be decreased due to bridge conditions, That seems counter intuitive to me and perhaps that first sentence holds the key to understanding the second. The final sentence in this paragraph states that the likely effect of the bridge constraints, if any, would be to cause a relatively earlier breach. But on page 41 in the second paragraph of section 4.4.1 it states that the initial breaching is not considered to be affected by bridge related conditions. Because of the “if any” in the first conclusions, you could say they are saying the same thing. But they seem just dissimilar enough to raise questions.

Page 42 paragraph 3 – About the fourth sentence it reads” Backwater effects could ber”

Page 43 paragraph 2 – First sentence reads… “is the project rise…”, this should probably read “the projected rise”?

Page 44 paragraph 1 – it reads “…dynamics and physically…”. Should it be “…dynamics and physical…”

Page 45 last paragraph – The first sentence has a comma and not a period.

Scott and Waddell Creek Bridges 0F9900
Comments on Highway Bridge Crossings Draft Report
L Wickham
10/15/08

General: The report should be thoroughly edited to resolve the many sentences that are unclear or incomplete.

p. 11, Waddell Creek: The high water elevation is identified as 11.0 feet on the as-built plans. The datum is given adjacent the roadway profile as "USC&GS (Mean Sea Level)."

p. 15, Carmel River: The discussion of the Carmel River lagoon states that "…the lagoon is rarely tidally connected, only during exceptionally high tides." The report makes a connection between this lack of tidal connectivity and a geologic feature acting as a dam. Neither of these statements seems to be supported by the James 2005 reference.

p. 20, Figure 14: This figure is confusing and seems to contradict both itself and the hypothesis described in the paragraph above on p. 19. The diagram indicates that increasing bridge length across the lagoon will lead to both increased sedimentation and accelerated erosion of the lagoon. Provide further explanation or eliminate the figure.

p. 22, pp. 1: "Wave energy is predominantly delivering sediment to the inlet…" This is true during the summer, but in winter, waves tend to erode the beach (Williams, P. and C. Kelly Cuffe. 1993 Geomorphic and hydrodynamic analysis for the Estero de San Antonio enhancement plan).

p. 23-39: Discussion is mostly unchanged from previous drafts and predominantly addresses estuaries with minimal fluvial flow. For example, the Escoffier Curve should be used only when "Water entering and leaving the estuary through channels other than the inlet are negligible." That is, the method can be applied only when there is no fluvial inflow and does not address the effects of fluvial energy (PWA. 1992 Russian River Estuary Study). Much of this information may not pertain to Scott and Waddell Creeks, which appear to be significantly affected by fluvial flow.

p. 33-34: This statement on p. 33: "On the California Coast, barrier beaches commonly breach from the lagoon side…" is in direct conflict with one on p. 34: "On the Pacific coast, breaching typically occurs from the seaward side." Reconcile.

Highway 1 @ Pescadero Creek, looking upstream