APPENDIX H: CHARACTERIZATION OF GENERAL RESTORATION ACTIONS

Introduction

The restoration strategies are composed of restoration actions. In this appendix, we characterize many of the types of large-scale restoration actions, using a uniform set of criteria, that are included in the restoration strategies. The purpose of this action characterization is to provide a narrative summary of pros and cons associated with potential large-scale restoration actions (by reach), to facilitate a better understanding of the different types of restoration actions and to support broad-level comparisons of actions.

The criteria used to evaluate each potential action are presented below. The ranking of "positive," "neutral," or "negative" is specific to each criteria, and should not be compared across criteria. These rankings are provided to ensure that the gamut of potential characterizations are included for each criteria. Because each criteria requires significantly different consideration for evaluating the criterion however, these rankings are not directly comparable.

It is difficult, and potentially misleading, to distill complex information about a proposed restoration action into a single designation of positive, neutral or negative. The narrative descriptions of each characterization provide the most information regarding the potential to achieve the restoration objective as well as the uncertainties associated with the action.

In many cases, several characterizations may be appropriate for the proposed action, sometimes even with conflicting outcomes. For example, a single action might have multiple consequences, some synergistic (positive) with other actions, while other consequences may conflict with other actions or objectives (negative). When applicable, this is explained in detail in the narrative characterizing the action. Finally, negative characterizations are not intended to automatically exclude the action when developing a final restoration strategy. In other words, an individual action may be worthwhile even if it receives negative ranks on some criteria.

Criteria

Ecosystem Restoration: Is action intended to protect or restore natural processes, functions, or conditions of the San Joaquin River system below Friant Dam?

Positive: *Restoration*: Action is expected to protect or recreate processes, functions, or conditions believed to be typical of the natural processes, functions, or conditions of the San Joaquin system.

Positive: *Rehabilitation*: Action is expected to create processes, functions, or conditions believed to be more typical of natural conditions than of current conditions, but falling short of full restoration.

Positive: *Substitution*: Action is expected to protect or create conditions believed to have been present elsewhere in the natural system, but no longer accessible or restorable.

Neutral *Intervention*: Action is intended to artificially provide some of the benefits of a natural process or function, rather than restoring the process or function itself.

Neutral *Non-restorative*. Action is neither intended to protect or restore natural processes, functions, or conditions, nor expected to cause processes, functions, or conditions to move further from a natural state.

Negative *Anti-restorative:* Action is expected to cause conditions or processes to move further from natural conditions or processes.

The "big-picture" goal of the project, as expressed in the mutual goals statement, is restoration at the ecosystem level; this criterion is intended to convey the extent to which an individual action fits this philosophy. An action may well advance the goals of the plan without being intrinsically restorative itself. For example, a ring-levee around Firebaugh is not a natural feature, and does not restore any natural condition, and would therefore receive a neutral or negative score on this criterion; it could well be a very desirable action in itself, however, and could increase the feasibility of other, restorative, actions. Conversely, an action which is restorative in intent might well be incompatible with the broader project goals.

The distinction between "rehabilitation" and "substitution" is not always clear; for example, an action might propose to create critical habitat in places where it did not exist historically, say by supplying consistent flows in channels that would be naturally dry much of the time, in order to fill a function once provided by portions of the river above Friant Dam.

The word "intervention" is used here as a label for technology-based solutions. Construction of a fish hatchery, or mechanical gravel gleaning, would be examples of "intervention" rather than "restoration." It is possible for interventions to play a useful role in an overall restoration strategy, where critical natural processes cannot be feasibly recovered.

Sustainability: Is action intended to protect, restore, or create self-sustaining processes?

Positive *One-time intervention*: Action is expected to establish a permanent goal, or to establish or jump-start a self-sustaining process.
Positive *Conservation:* Action is expected to protect a currently functioning process.
Neutral *Interim measure:* Action is expected to provide benefits during a transition period, after which other measures are expected to provide benefits of a similar kind.
Neutral *Low maintenance:* Action is expected to require re-application after exceptional events, or at long time intervals, or to require light on-going activity which can be subsumed under an identified pre-existing commitment of resources.
Negative *High maintenance:* Action is expected to provide a temporary benefit, which must be repeated at frequent intervals, will require an ongoing commitment of dedicated resources.

This is another "big picture" criterion, and closely related to the first. The ultimate goal of the project is a healthy, naturally-functioning ecosystem. From a practical point of view, too, a self-maintaining system is clearly preferable to a museum exhibit requiring eternal maintenance.

Synergies and Conflicts: How will action interact with other proposed actions, or with broader environmental goals?

Positive *Synergy:* Action is expected to enhance the effectiveness of other actions.
Neutral *Compatibility:* Action is expected to coexist with other actions.
Negative *Conflict:* Action is expected to reduce or negate the effectiveness of other otherwise desirable actions.
Negative *Hazard*. Action poses some credible risk of generating significant new problems.

This is a potentially difficult criterion to apply, because the concepts of “synergy” or “conflict” are only meaningful in the context of the whole suite of actions under consideration. In some cases these interactions are generic. For example, an action which would provide channel-altering flows in Reach 1 for geomorphic benefits in November or December would be expected to conflict with the habitat requirements of developing chinook salmon embryos; an action which provided similar flows in April or May might benefit outmigrating smolts. In other cases, actions may be tied closely to one another by design, or represent conflicting approaches to the same problem.

The concept of “hazard” is intended to capture a kind of risk different from that considered under the “Confidence” criterion below. The risk considered here is that of an action backfiring, rather than merely failing to achieve its goal. For example, the introduction of a new species into an ecosystem, such as the recent introduction of the Chinese leaf beetle (*Diorhabda elongata*) into the Owens Valley to control tamarisk, always poses some risk of permanently transforming the system in unforeseen ways.

This category is one in which it can be appropriate for a single action to receive multiple ranks. This is further explained in the associated narrative.

Societal/Infrastructure Impacts: How will action affect human systems?

Positive	*Ancillary benefits*. Action is expected to provide corollary benefits for human systems, such as downstream flood control, water quality, water supply, or land-use.
Neutral	*No significant impacts*. Action is not expected to have significant impacts on human systems, or expected impacts are easily mitigated.
Negative	*Ancillary costs*. Action is expected to have adverse impacts on human systems, or to require extensive mitigation.

This criterion is similar to the “synergies and conflicts” criterion, except that the synergies and conflicts are extended to non-ecological considerations, such as human health and safety (e.g., flood control, drinking-water quality), local economics (e.g., land-use, tax base, tourism), and “quality-of-life” (e.g., community character, culture, recreation).

This category is one in which it can be appropriate for a single action to receive multiple ranks. For example, an action which enhances flood control might adversely affect land use. This is further explained in the associated narrative.

Confidence: Is action likely to achieve target goals?

Positive	*High confidence*. Action has high probability of success.
Neutral	*Typical*. Action has probability of success typical of actions receiving serious consideration in similar contexts.
Negative	*Low confidence*. Action has low or unknown probability of success

This criterion, and the next, attempt to address the three-way interaction of costs, benefits, and risks. This particular factorization is intended to separate essentially “scientific” questions about how likely an action is to yield its intended result, from “practical” questions of how benefits compare with costs.

The "probability of success" of an action is in general a matter for professional judgment. The basic questions considered are whether there is broad consensus on the underlying conceptual model, and whether similar actions have succeeded in other locations.

Cost-effectiveness: Does action make efficient use of resources?

Positive	*Efficient*. Action has high expected benefit, or is expected to yield multiple benefits, relative to the commitment of resources or assets required.
Neutral	*Typical*. Action has expected benefit typical of actions receiving serious consideration in similar contexts.
Negative	*Inefficient*. Action has low expected benefit, relative to the commitment of resources or assets required.

This criterion assesses the cost versus benefit (although at a more qualitative level than a true "cost/benefit analysis"). The basic question is whether the action under consideration is expected to produce greater benefits for a comparable level of investment, or comparable benefits at a lower level of investment, than other actions. As with the "synergies and conflicts" criterion, the narrative discussion may draw comparisons with other specific actions to explain the rank given.

The previous criterion, of probability of success, affects the ranking given to this criterion as well. If the total number actions to be implemented were infinite, only the expected value of the benefit of an action would enter into a manager's decision. In practice, however, the number of actions is limited. A manager might be willing to try an action having only a small probability of success, if the potential benefit is sufficiently large, and the cost sufficiently small, but unwilling to stake the future of the program on a single action with equal chances of achieving either spectacular success or utter failure. What is really involved here is not simply a "cost/benefit ratio," but the economists' concept of "utility."

Flexibility: How does action affect future flexibility?

Positive	*Fungible*. Resources or assets committed to action can be exchanged for other ecosystem resources or assets, as priorities evolve.
Positive	*Proactive*. Action consists of securing ecosystem assets, to preserve the viability of other actions not taken immediately.
Neutral	R*eversible*. Action can be abandoned if expected benefits fail to occur, or if priorities shift, and the state or functioning of the ecosystem will quickly revert to a condition comparable to the pre-action condition, with little or no further commitment of resources.
Negative	*Remediable*. Action can be abandoned if expected benefits fail to occur, or if priorities shift, but significant additional commitment of resources will be needed to reverse changes in the state or functioning of the ecosystem.
Negative	*Irreversible*. Action is expected to create changes in the state or functioning of the ecosystem which cannot be feasibly reversed.

This criterion addresses the question of what happens when an action fails to achieve its intended goal, or if project goals are changed in response to changes in public values or scientific knowledge. Can the assets invested in the action be recovered and redirected? Are the assets simply gone? Will it be necessary to "pour good money after bad" to undo the effects of what a future generation deems to have been a mistake?

Strategic Value: How will the action be received by the general public, and by other decision makers?

Positive	*Leveraged*. Action has the potential to leverage an initial public investment into a larger effort for ecosystem benefits.
Positive	*Ripe*. Action can be achieved in the near term, without significant technical or regulatory obstacles.
Neutral	*Neutral*. Action has no components requiring unusual strategic attention.
Negative	*Impractical*. Action might well be beneficial, but implementation would require basic changes to the existing regulatory framework, or a feasible technology for implementation has not yet been identified.
Negative	*Provocative*. Action may be beneficial, but is likely to alienate some current program participants, or generate significant backlash among currently neutral parties, making the implementation of other efforts more difficult.

This is the least "scientific" criterion of all, but one which needs to be addressed. Actions which have only modest benefits at the ecosystem scale, but which produce visible effects in a short time, can help to build public support for the program. On the other hand, moving too rapidly in politically-sensitive areas, or proposing novel new strategies with too little attention to local concerns, could alarm potential allies, who might feel compelled to block unrelated actions to protect their own long-term interests.

Adaptive Management: Does action contribute to ideal of adaptive management?

Positive	*Active adaptive management*. Action is accompanied by monitoring, with predetermined criteria for assessing success or failure or for modifying the implementation on the basis of monitoring results. In addition, the action is structured to aggressively accelerate the rate of learning, e.g., by incorporating rigorous tests of alternate conceptual models into the implementation design.
Positive	*Passive adaptive management*. Action is accompanied by monitoring, with predetermined criteria for assessing success or failure or for modifying the implementation on the basis of monitoring results. In contrast to active adaptive management, passive adaptive management is more concerned with quantifying success or failure than with discriminating between alternate conceptual models.
Neutral	*Static program component*. Benefit of action so well understood that monitoring is unnecessary; or action required for reasons unrelated to expectations of success or failure, and not subject to future review.
Negative	*No learning potential*. Action is of unknown or unconfirmed effectiveness, and proposed monitoring is unlikely to provide assessment of effectiveness.

The ideal of adaptive management is to simultaneously advance the project goals while collecting information that will improve the efficacy of future efforts.

The basic problem is that the goals of management can be inconsistent with the requirements of good science. This is because managers naturally want to make conditions uniformly "good," under the current state of knowledge about what constitute "good" conditions, whereas scientists need to see a broad range of conditions, both good and bad, in order to actually advance the state of that knowledge. Special attention is needed to prevent management from becoming locked forever into sub-optimal strategies based on initial best-guesses.

Though there is a general goal of using an adaptive management approach in implementing the SJRRP, adaptive management is not applicable in all cases. For example, it may not be worth employing an adaptive management approach if the value of the information to be gained does not compare favorably with the additional cost or risk of designing and treating a particular restoration activity as an experiment.

Cost Estimates

This document includes rough, preliminary estimates of the scale and cost of several key restoration actions. For example, estimates of cut-and-fill volumes of material accompany large-scale channel and floodplain modifications, as well as levee alterations, to provide a sense of scale and to facilitate the comparison of restoration actions. Similarly, this document provides several estimates of the land acreage associated with large-scale restoration actions. These volume and acreage estimates also form the basis of cost estimates. The purpose of these volume and cost estimates is to help reviewers gauge the relative level of effort and cost associated with key restoration actions and to facilitate the comparison of actions. These estimates are planning-level, reconnaissance estimates that rely upon simplifying assumptions. As such, they should not be treated as cost proposals.

Costs were estimated for the following restoration actions:

- Land or easement acquisition costs associated with levee setbacks and the creation of a floodway in different reaches
- Isolating the active channel from floodplain gravel pits within the floodway to prevent stranding
- Isolating the active channel from pits by building dikes to separate off channel pits from the active channel and constructing 3-stage channel through in channel captured pits
- Gravel augmentation at selected riffles in Reach 1A
- Riffle creation in Reach 1A
- Re-routing the channel around Mendota Dam
- Reconstructing the channel in Reach 4B

The cost estimates included in the restoration actions below are based on preliminary estimates of project features and associated quantities. These costs estimates provide a basis for the comparison of the cost impacts of different restoration actions.

General criteria used in developing the cost estimates for restoration actions are listed below. These criteria have been taken from recent restoration and levee projects completed on major river systems in the Central Valley. Quantities are based on:

- Soils maps to determine suitability of soil materials for levee construction.
- Army Corps of Engineers criteria for embankment material.
- Levee cross-sections per Reclamation Board standards (major levee systems).
- Land encompassing project improvements and local borrow sites to be owned by project stakeholders.
- In addition to earthwork costs, levee construction unit costs include interior (landside) drainage improvements and culverts, patrol road base, fence relocation, irrigation system replacement, access and security provisions, and hydroseeding.
- A contingency of 20 percent is added to levee embankment quantities due to shrinkage, waste and uncertainties in preliminary volume estimates.
- A contingency of 35 percent is added to spawning gravel quantities due to shrinkage, waste and uncertainties in preliminary volume estimates.

- Both engineering / surveys and construction management costs are estimated at 5 percent of construction costs.
- Contractor indirect costs include insurance, bonds, construction management, and mobilization at 6 percent.
- Levee material has a separate cost item for conditioning when excavated on-site.

Summary List of Actions

Potential Large-Scale Restoration Actions for River-wide
1. Preserve existing patches of riparian vegetation
2. Manage non-native invasive plant species
3. Eliminate barriers to fish passage
4. Screen diversions
5. Conduct horticultural restoration at key areas

Potential Large-Scale Restoration Actions for Reach 1
6. Create a floodway
7. Fill floodplain pits to prevent stranding
8. Add gravel to existing riffles
9. Mechanically disturb and remove fine sediment from spawning gravels
10. Build a functioning, multi-stage channel through large gravel mining pits
11. Create alternative channel alignment around gravel pits
12. Create additional spawning habitat
13. Reconnect side channels with the mainstem

Potential Large-Scale Restoration Actions for Reach 2
14. Create a floodway
15. Setback left bank levee in Reach 2B
16. Create floodplain ponds to restore native fish
17. Develop a bypass channel around Mendota Pool and Dam
18. Reconnect Lone Willow Slough with the mainstem
19. Screen diversions on Mendota Pool

Potential Large-Scale Restoration Actions for Reach 3
20. Create a floodway

Potential Large-Scale Restoration Actions for Reach 4
21. Reconstruct a multi-stage channel in Reach 4B1
22. Investigate alternative fish migration pathways in Reach 4B1

Potential Large-Scale Restoration Actions River-wide

Action 1. Preserve existing patches of riparian vegetation.

Preservation of existing habitat can be a cost-effective means of meeting restoration goals for vegetation and wildlife, and can provide more immediate ecosystem benefits as compared to restored lands, which generally require time for vegetation to establish and mature. Remnant riparian vegetation occurs throughout the planning area, generally as isolated patches. Preserving these habitat patches can provide anchors from which to build broader corridors of contiguous vegetation.

Criteria	Characterization of Action
Ecosystem Restoration	*Restoration*. This action aims to protect conditions believed to be typical of the San Joaquin River corridor.
Sustainability	*Conservation*. Existing stands of riparian vegetation occur in remnant patches throughout the planning area. Actively conserving these areas can protect their value as habitat and provide building blocks for other restoration actions.
Synergies and Conflicts	*Synergy*. Preserving existing riparian vegetation protects its value and function as habitat for wildlife species. Also, the restoration of riparian vegetation via planting or natural recruitment can build from conserved habitat to form broader and more contiguous vegetation corridors that can better support the movement of wildlife species.
Societal/ Infrastructural Impacts	*Ancillary benefits*. Preserving existing patches of riparian vegetation can help protect adjacent managed lands by stabilizing river banks and trapping sediment from flood flows. Existing patches of vegetation can also provide a buffer between land use activities and river processes, and they provide scenic landscapes. *Ancillary costs*. Preserving existing patches of riparian vegetation may require purchasing private land from willing sellers, but these purchases would likely cause few disruptions to existing land uses if such land currently supports riparian vegetation.
Confidence	*High confidence*. There is comparatively little uncertainty in the value of existing habitat.
Cost-effectiveness	*Efficient*. Preservation of existing patches of vegetation is cost-effective because comparatively little effort is required to restore land.
Flexibility	*Proactive*. Conserving patches of riparian vegetation protects against the potential loss of existing habitat. Because preservation requires no action that causes a change from the present state, this action is also reversible.
Strategic Value	*Leveraged.* Preserving existing patches of riparian vegetation can stimulate interest in restoring lands between these patches to form broader and more contiguous corridors of vegetation. *Ripe*. The San Joaquin River Parkway Trust has been successful in purchasing lands from willing sellers within the river corridor to preserve and restore riparian habitats, demonstrating that this type of action is ripe.
Adaptive Management	*Passive adaptive management*. Monitoring of existing patches of vegetation can support periodic assessments of its value and function as habitat.

Protecting existing riparian habitat provides one of the most cost-effective measures for restoring the San Joaquin River, because once implemented, such actions require comparatively little maintenance or monitoring to ascertain whether intended objectives have been achieved. Preserving patches of existing vegetation is a vital strategy to employ early in a restoration program, before potential changes in land use degrade the value of current habitat.

Action 2. Manage non-native invasive plant species.

The San Joaquin riparian corridor, like most California landscapes, is host to many non-native and invasive plant species. CDWR (2002) mapped existing vegetation along the San Joaquin River, and 50 percent of all plant species identified were non-native and invasive species. Exotic plant species can alter the structure and dynamics of natural ecosystems. Non-native plant species can impact native wildlife by displacing native vegetation that is used for nesting or as a food source. Once established, non-native plant species can alter nutrient cycling, energy fixing, food web interactions, and fire and other disturbance regimes, to the extent that the native landscape is changed. Though it is generally infeasible to completely eradicate an alien species, it is important to manage their abundance and distribution to provide conditions conducive to native plant establishment.

Criteria	Characterization of Action
Ecosystem Restoration	*Restoration*. Management of non-native and invasive plant species attempts to restore historical conditions.
Sustainability	*Low to High Maintenance*. Depending on the plant species and its current abundance and distribution, maintenance and management of non-native and invasive species will be low to high maintenance. For example, plant invasions that are limited spatially are generally easier to manage, as compared to more widespread invasions. In most cases, repeated measures and vigilance will be required to manage non-native plant species.
Synergies and Conflicts	*Synergy*. Reducing the abundance and distribution of non-native plant species will support efforts to preserve and restore native vegetation by reducing competition. Reducing the extent and spread of non-native plant species, and increasing the extent of native plant species, will likely improve habitat quality for various wildlife species. *Conflict*. Managing non-native plant species can include the application of herbicides or other chemical treatments, which can also endanger nearby native vegetation. Thus, methods used to manage non-native and invasive species will have to consider potential impacts to native species.
Societal/ Infrastructural Impacts	*Ancillary benefits*. Many non-native plant species currently interfere with socioeconomic activities. For example, aquatic invasive plant species can clog water diversions and negatively affect recreation. Human benefits that are provided by non-native plant species (e.g., bank stabilization) can generally be provided by restored native plant species.
Confidence	*Low confidence*. Though it is possible to control non-native plant species locally, it is difficult to know how effective such efforts will be in the long term. The duration of the benefits of control and management actions are often uncertain, because of the potential for re-colonization of a managed area by non-native plant species.
Cost-effectiveness	*Typical*. Considerable effort, resources, time, and money can be required to effectively manage non-native and invasive species.

Criteria	Characterization of Action
Flexibility	*Reversible*. Because non-native invasive species become established so readily, abandoning this action will likely result in a pre-action condition. Since many of these non-native and invasive species are found on other San Joaquin River tributaries, such as the Tuolumne and Merced rivers, as well as the fact that these species are often spread by humans, it is likely that the non-native plant species could easily re-invade areas from where they have been eradicated.
Strategic Value	*Ripe*. General public awareness of the effects of non-native plant species seems to be growing, stimulating more interest in control efforts. The San Joaquin River Parkway Trust is actively planning to manage non-native and invasive plant species. Also, a large-scale mapping effort by CDWR (2002) provides vital information about the location of non-native plant species in the river corridor, which provides a valuable tool for developing a basin-wide strategy for managing non-natives.
Adaptive Management	*Passive adaptive management*. Because the threat of non-native invasive plant species re-establishing in areas along the river corridor is great, monitoring will be required to assess any re-introductions to areas where non-native plants have been cleared. *Active adaptive management*. There is generally a poor understanding of the local conditions and mechanisms that confer a competitive advantage to non-native plant species, so management efforts may provide an opportunity for examining the combination of forces and conditions that stimulate the recruitment and establishment of non-native plant species.

Reducing the extent of non-native plant species, and preventing their spread, will be a continual battle, but it will be an essential component of a restoration program for the San Joaquin River. The value and duration of efforts to restore aquatic and riparian habitats in the San Joaquin River will be diminished without complementary actions to manage the abundance and distribution of non-native plant species. The vegetation mapping conducted by CDWR (2002) provides a valuable tool for developing a basin-wide strategy for managing non-native plant species in the San Joaquin River corridor.

Action 3. Eliminate barriers to fish passage.

This action focuses on eliminating infrastructural barriers to fish passage along the San Joaquin River and bypass channels. These key pieces of infrastructure include (from upstream to downstream): Chowchilla Bifurcation Structure, inlet facilities associated with a new Mendota Pool bypass channel (Strategies 2 and 3 only), Mendota Dam (Strategy 1 only), Sack Dam, Sand Slough Control Structure (Strategy 2 only), and Mariposa Bifurcation Structure (Strategy 2 only). These pieces of water supply and flood routing infrastructure will need to be retrofitted with fish passage facilities or replaced with structures having alternative designs that can facilitate fish passage. This list does not include all potential barriers, but identifies the largest ones. An analysis of all potential barriers was conducted by JSA (JSA 2001). JSA identified several additional physical barriers, including culverts, road crossings, etc., as well as depth and velocity barriers which would also need to be eliminated, but are not the focus of this action. In addition to providing enhanced benefits for fish, retrofitting and redesigning infrastructure that currently impedes fish movement will also facilitate passage and routing of sediment to preserve sediment continuity.

Criteria	Characterization of Action
Ecosystem Restoration	*Intervention*. Because of their importance to the water supply infrastructure of the San Joaquin River, some barriers will have to remain in place. However, passage over these barriers is also required to meet the objective of restoring salmonid populations to the San Joaquin River. This action will rehabilitate the river channel to a state similar to historical conditions, while leaving important infrastructure (dams, bypass structures and channels, etc.) in place.
Sustainability	*One-time to low maintenance*. This action will require a one-time cost to retrofit each of the barriers/dams with adequate ladders or other passage facilities. Once replaced or retrofitted, these barriers will require periodic maintenance and inspection to ensure their function.
Synergies and Conflicts	*Synergy*. This action is a necessary step in establishing a self-sustaining salmon population in the San Joaquin River. Providing passage will ensure adult salmon will be able to reach upstream spawning grounds and that juvenile salmon will be able to migrate downstream. Eliminating barriers will also provide opportunities for native fish to disperse downstream. *Conflicts*. It is possible that potential predatory fish will congregate at fish passage facilities, thereby creating a predation risk for outmigrating juvenile salmon.
Societal/ Infrastructural Impacts	*Ancillary Costs (short-term)*. In the short-term, there will be ancillary costs associated with retrofitting and replacing barriers to fish migration. In addition, some infrastructure may need to be off-line during the construction and retrofitting process, causing even more ancillary costs as a result of this action. *No significant impact (long-term)*. The goal of this action is to provide passage while maintaining current water diversion and supply capabilities. As such, in the long-term, no significant impacts are expected to infrastructure from retrofitting or redesigning these structures to allow fish passage.
Confidence	*High*. Fish ladders and passage facilities are a common addition to many Central Valley dams and water control structures. Most of the structures in the planning area are small enough that fish passage facilities can be expected to provide the expected passage benefits. *Low*. Providing passage facilities that meets the needs of native resident fishes is poorly understood, and because the needs and behavioral patterns of these fish are generally less known than salmonids, our confidence in designing passage facilities suitable to accommodate these species is lower.
Cost-effectiveness	*Typical*. This action is an integral step to restoring a self-sustaining salmonid population in the San Joaquin River. The cost-effectiveness of this action is typical of other actions that would be required in order to achieve this objective. In order to maintain water supply infrastructure, proving passage via ladders, etc. is the most cost-effective means for achieving both water supply as well as fish passage.
Flexibility	*Remediable*. Although constructing and retrofitting barriers will require a

Criteria	Characterization of Action
	significant investment of time and money, the action is reversible. The costs of retrofitting, however, would be lost through this process, and could therefore not be applied towards some other asset.
Strategic Value	*Neutral*. There is a general public desire to restore a *self-sustaining* population of salmon, as indicated by the mutual goals statement. Achieving self-sustaining populations of salmonid and other fish species will require providing passage past structures, which should not be controversial because the approach is to preserve the water supply infrastructure.
Adaptive Management	*Passive*. Monitoring the use of passage facilities by both salmonids and native resident fish will allow us to (a) assess species-specific suitability to the passage facility (particularly for native resident fish), (b) track the potential threat of increased predation on juvenile salmonids found near the fish passage facilities, and (c) provide a means to count the number and timing of fish moving past the barrier (see Appendix I, Section 2.3.3).

Barriers to passage currently found throughout the planning area impede movement by both juvenile and adult salmonids, as well as native resident fish. In order to establish a self-sustaining population of salmon in the San Joaquin River, it will be necessary to improve passage conditions by constructing ladders and providing pathways through or around these barriers. Therefore, this action would be implemented under all of the restoration strategies. This action is intended to maintain all existing water supply capabilities, although some interruption of service may be required during the construction and retrofitting stage.

Actual passage facilities will depend on the barrier or structure. Cost estimates for these structures were developed by JSA (2001). A summary of the costs associated with providing passage over the key infrastructure identified above is presented below. Additional infrastructure, including culverts, road-crossings, etc., may also need to be retrofitted. Costs described below therefore likely underestimate the total cost required to provide adequate fish passage from Merced River to Friant Dam.

Barrier (from upstream to downstream)	**Cost**	**Options for fish passage**
Chowchilla Bifurcation Structure	$510,000–$3,810,950	Fish passage options at Chowchilla Bifurcation Structure (RM 216.1) include constructing backwater weirs ($510,000–$3,000,000) and fishways ($1,668,300–$3,810,950), and modifying barrier operations.
Mendota Pool bypass channel (inlet and outlet) (Strategies 2 and 3 only)	$139,200–$5,205,200	Fish passage options at Mendota bypass channel (RM 204.7) include replacing ($2,324,000–$5,205,200), and maintaining ($139,200–$187,200) the existing fishway.
Mendota Dam (Strategy 1 only)	$510,000	Fish passage options at Mendota Dam (RM 204.7) include constructing backwater weirs ($510,000).
Sack Dam	$290,500–$960,000	Fish passage options at Sack Dam (182.0) range in cost from $290,500–$960,000 and include constructing backwater weirs or fishways, and modifying barrier operations.
Sand Slough Control	$139,200–$39,000,000	Fish passage options at Sand Slough Control

Barrier (from upstream to downstream)	Cost	Options for fish passage
Structure (Strategy 2 only)		Structure (RM 168.5) range in cost from $139,200–187,200 for regular maintenance, to $1,494,000-$39,000,000 for fishway and backwater weir construction.
Mariposa Bifurcation Structure (Strategy 2 only)	$510,000–$540,000	Fish passage options at Mariposa Bifurcation Structure (RM 147.6) include removing the drop structure ($540,000), and constructing backwater weirs ($510,000) and creating additional roughness in the streambed ($22–104 per boulder).

Action 4. Screen diversions.

There are hundreds of water diversions in the planning area, each of which could present an entrainment risk to the larval and juvenile life history stages of numerous fish species. These diversions will need to be assessed for the entrainment risk they pose to restored fish species.

Criteria	Characterization of Action
Ecosystem Restoration	*Intervention.* The action is designed to provide a substitute for a continuous migration route to and from the Sacramento-San Joaquin Delta by eliminating false pathways for fish to become entrained in. This action will not completely restore the migration corridor, but will prevent stranding of migrating smolts in irrigation channels or flood bypass channels.
Sustainability	*One-time intervention.* The installation of diversion screens would be a one-time intervention *Low maintenance*. Although installation of the screens will only have to occur once, regular maintenance and inspection will be required on the screens in order to maintain effective function.
Synergies and Conflicts	*Synergy*. Screening diversions may enhance the effectiveness of other restoration actions with the objective of establishing a self-sustaining, viable population of salmonids in the San Joaquin River. Because this action will enhance conditions during the migration of juvenile salmonids, this action is synergistic with actions that improve spawning conditions in Reach 1, including augmenting gravel, improving spawning habitat, providing pulse flows for outmigration, and removing barriers to migration. Restoration strategies call for the reconnection of the mainstem channel with side-channel and backwater habitats to provide rearing habitats for fish species. These side-channel and backwater areas are, however, typical locations for diversion structures. Screening diversions is therefore synergistic with reconnection of side-channel and backwater habitats by providing safer conditions for the fish that will be rearing in these areas. *Hazard*. Predatory fish may congregate in the vicinity of screened diversions because of the potentially suitable prey source. The significance of this predation risk is not currently known. In addition, diversion screens could present another form of infrastructure that resists the restoration of

Criteria	Characterization of Action
	some geomorphic processes.
Societal/ Infrastructural Impacts	*Ancillary costs.* Though the installation of the fish screens would not affect the ability to divert water, the construction and maintenance of fish screens represents an added responsibility for water diverters. Fish screens can also become clogged by debris, which can disrupt water supply operations until the screen is cleared.
Confidence	*Typical*. There is information available regarding screening criteria and effectiveness. If screens are designed, installed, and maintained properly they can successfully limit entrapment of migrating smolts. *Low*. It is not adequately understood if increased predation at diversion screens could potentially offset the positive effects of screening.
Cost-effectiveness	*Typical*. The cost of adding screens to diversions of various sizes are described below. *Inefficient*. The relative cost of installing and maintaining screens is high. The population-level effect of reduced smolt entrainment by screens is unknown, as is the potential for increased predation in the vicinity of diversion screens.
Flexibility	*Remediable*. Screening diversions has no ecosystem-level impact except to provide "safer" conditions for fish passage. The action is reversible and screens could be abandoned, although at a significant cost.
Strategic Value	*Neutral*. Because of the costs associated with screening and the public support that would be required, there is no inherent strategic value to this action.
Adaptive Management	*Passive*. Monitoring of pre- and post-screen installation conditions, as well as monitoring of equivalently-sized diversions with and without screens could provide valuable information regarding the population-level effect of diversion screen benefits. In addition, predatory fish abundance at diversion screens should be monitored.

There are approximately 100 diversions on the mainstem San Joaquin River; however, the individual and cumulative risk of these diversions to fish populations is unknown. Most diversions in the project area are located at channel margins and on side-channels – areas where some fish species, such as juvenile salmonids, often occupy. Screening diversions can require a significant investment of resources, which can reduce the resources available to support other types of restoration actions. Prior to the construction of any fish screen, each diversion should be assessed for its entrainment risk. In addition, the potential to consolidate diversions and reduce the number of potential diversion points should be examined. Consolidation of diversions could reduce the cumulative risk posed to fish populations and reduce the number of potential fish screens.

Cost considerations. The diversions in the planning area (aside from the Mendota Pool diversions, which are treated separately in Action 19) range from 1 to 600 cfs, with an average diversion of 12 cfs. The U.S. Bureau of Reclamation's Anadromous Fish Screen Program provides cost information on various diversion screens constructed in the Central Valley (USBR 2002). Analyzing the cost of these completed diversion screens, a range of $4,000,000 to $15,000,000 can be approximated for diversions transporting between 200 and 300 cfs ranges. California Department of Water Resources estimates that simple screens for lower capacity diversions may cost from $5,000 to $10,000 per cfs diverted (CDWR 1995). In general, the larger or more complex the required screening system, the higher the cost. Additional costs may also result from construction requirements to meet National Marine Fisheries Service and California Department of Fish and Game screening criteria (CDFG 1997, NMFS 1997).

Action 5. Conduct horticultural restoration at key areas.

Horticultural restoration can enhance the benefits of the naturally recruited riparian corridor by increasing the width of the corridor, providing an important initial seed and propagule source to stimulate natural regeneration, and hastening the establishment of riparian habitat patches along the river corridor, which increases the diversity and complexity of available habitat for wildlife. This restoration activity is primarily recommended in areas where there will be significant floodplain reconstruction and/or levee setbacks, and in strategic areas throughout the project area where horticultural restoration is both likely to be sustained (given site conditions) and likely to provide plant-community-specific benefits.

Criteria	Characterization of Action
Ecosystem Restoration	*Restoration.* This action will provide conditions that recreate processes and functions that existed naturally before much of the land was developed for agriculture.
Sustainability	*Low to high maintenance*. Initial planting can require a relatively large labor effort and some areas may require watering, fertilization, weeding, etc., although target areas will be identified based upon the potential for natural recruitment and/or other suitable conditions so as to minimize maintenance. In addition, monitoring would need to be conducted to ensure that non-native species do not become established in the re-vegetated areas.
Synergies and Conflicts	*Synergy*. The action is synergistic with efforts to promote natural riparian vegetation recruitment by providing an initial seed and propagule source to enhance natural recruitment. The action is also synergistic with conservation and habitat connectivity efforts by providing contiguous habitat patches, increasing the riparian corridor width, and improving habitat conditions for multiple wildlife species.
Societal/ Infrastructural Impacts	*No significant impact*. The action is not expected to interfere with human systems.
Confidence	*Typical*. The soil, groundwater, and inundation conditions required by some plant communities are well known. For others, experimental development of horticultural restoration protocols may be necessary.
Cost-effectiveness	*Typical*. Costs of maintenance and set up can be initially high, but are likely to yield high benefits by the time the vegetation becomes adequately established in providing habitat cover, and seed and propagule sources.
Flexibility	*Remediable.* The potentially significant resources that can go into a horticultural restoration project cannot be easily used for another purpose. Planted areas could be abandoned, but it could take some time and effort to return those areas to the state they were in prior to restoration. If woody vegetation was able to establish, vegetation removal may be somewhat more difficult than if restored areas were abandoned during the seedling stage.
Strategic Value	*Ripe*. There are no significant regulatory obstacles to horticultural

Criteria	Characterization of Action
	restoration. Acquiring conservation easements or fee-title purchases of areas where planting would take place would be the only significant obstacle.
Adaptive Management	*Active adaptive management*. Monitoring of the action could provide opportunities to assess the recruitment, regeneration, growth, and habitat value of several restored vegetation community. In addition, horticultural restoration could be designed as an experiment to test various physical habitat conditions, planting schemes, watering frequency, etc. to best re-colonize restored areas.

Because horticultural restoration can be used to "jump-start" the restoration process and begin to provide habitat value before natural recruitment establishes plants, this action is considered as part of all restoration strategies.

Cost considerations. The cost per acre for horticultural restoration along the San Joaquin River was developed through discussions with local experts and by adapting the costs to conduct such restoration in other Central Valley rivers and ecosystems. While the prices incorporated into our cost estimate included a variety of restoration activities, we feel they offer a reasonable range of what could be expected for the San Joaquin River. Based upon the cost estimates from other Central Valley rivers, we have calculated an average cost of $10,000 per acre for horticultural restoration of riparian, oak woodland, and other mid- to higher-elevation sites on the San Joaquin River. Our cost is meant to account for seed and cutting collection, propagation, planting, protective measures, and three years of maintenance and/or monitoring. This cost assumes that horticultural restoration would be conducted on sites between 20 and 200 acres, and it does not include grading. Most horticultural restoration on the San Joaquin River would occur on former agricultural fields that have been placed under easement or purchased from willing landowners.

Costs for horticultural restoration can vary significantly depending on conditions such as local topography (e.g., a site might require grading prior to planting), site accessibility, use of container stock versus cuttings or seed, amount of infrastructure that needs to be put in place for irrigation, length of time irrigation is required, maintenance costs such as weed control and protection from herbivory, and duration of maintenance and monitoring. As stated above, our cost estimates are for the restoration of mid- to high-elevation vegetation types; wetland restoration could be quite a bit more expensive depending on the level of site grading required, potential for natural revegetation, type of plants used, and necessary maintenance.

Potential Restoration Actions for Reach 1

Action 6. Create a floodway.

A restoration action for Reach 1 includes defining a floodway where the river channel would be allowed to reconnect with its floodplain, and where the preservation and restoration of river processes and habitats would be focused. Much of the land adjacent to the river channel in Reach 1 is publicly owned, which reduces the amount of private land that would need to be purchased from willing sellers to complete the floodway. An examination of recent aerial photographs indicates an approximate floodway width of 700 feet in those sections of Reach 1 where the river is not artificially constrained by human activities or infrastructure. Consequently, a floodway that is 700 feet wide would be a potential target for Reach 1.

Criteria	Characterization of Action
Ecosystem Restoration	*Rehabilitation*. A 700-foot-wide floodway in Reach 1 is likely smaller than historical conditions, reflecting the effects of the reduced flow regime imposed by Friant Dam.
Sustainability	*One-time intervention*. The action would primarily involve the purchase of privately owned parcels from willing sellers within the targeted floodway corridor. The actual alignment of floodway boundaries is flexible. The San Joaquin River Parkway Trust has been purchasing parcels adjacent to the river channel for conservation and restoration in Reach 1, already contributing to the dedication of a floodway.
Synergies and Conflicts	*Synergy*. By providing space for the restoration of river processes, this action supports many other restoration actions, including: re-connecting the channel with its floodplain through more frequent inundation; reconnecting side-channels with the mainstem to enhance fish rearing habitat; increasing the area available for natural riparian vegetation recruitment; and improving flood routing and storage.
Societal/ Infrastructural Impacts	*Ancillary benefits*. By dedicating space for the river to re-connect with a portion of its historical floodplain, the floodway can improve flood routing and storage, and reduce flood damage to managed lands adjacent to the river. In addition, a publicly-owned floodway improves recreational opportunities along the river. *Ancillary costs*. Defining a floodway will involve, in part, purchasing private land or conservation/flood easements from willing sellers, which can disrupt current land use practices. Also, some infrastructure (e.g., haul bridges and culverts) will be incompatible with the restoration of river processes.
Confidence	*Typical*. Restoration plans for other Central Valley rivers have incorporated the concept of a defined floodway within which river processes will be restored.
Cost-effectiveness	*Efficient*. Defining a floodway supports multiple ecosystem benefits, including floodplain rearing for fish, riparian vegetation recruitment, and flood routing and storage. In addition, a significant portion of floodplain land in Reach 1 is already publicly owned. *Typical*. Land costs in Reach 1 (especially Reach 1A) are some of the highest in the river corridor.
Flexibility	*Fungible/Reversible*. The action would primarily involve the purchase of

Criteria	Characterization of Action
	privately-owned parcels from willing sellers within the defined floodway corridor. These purchased parcels could support or be managed for other land uses if expected benefits fail to materialize. *Proactive.* The action is a precursor to other restoration actions and would provide the environment and conditions necessary to successfully implement a variety of actions.
Strategic Value	*Leveraged/Ripe*. The San Joaquin River Parkway Trust has been active for several years in acquiring lands adjacent to the river in Reach 1.
Adaptive Management	*Static*. Dedicating land to the restoration of river processes does not require monitoring per se. However, providing space for the restoration of river processes provides a necessary pre-condition to support active experimentation.

Restoring the San Joaquin River ecosystem will require dedicating space where the restoration of river processes and habitats are allowed and encouraged. Providing this space where the river can connect with a portion of its historical floodplain will require re-locating some current land use practices that are incompatible with the restoration of river processes. Dedicating land to river restoration is an important pre-cursor to many other restoration activities. The definition of a 700-foot-wide floodway in Reach 1 is a loose guideline. There will likely be sections of Reach 1 where it will not be possible to achieve the targeted floodway width because of existing infrastructure. Similarly, there will be opportunities in Reach 1 where it will be possible to define a wider floodway.

Cost considerations. It is difficult to estimate the cost of a potential floodway in Reach 1 because of differences in the value of lands adjacent to the river channel, as well as potential differences in the cost of conservation and flood easements. For example, the San Joaquin River Parkway Trust estimates an average cost of $20,000 per acre for some floodplain land in Reach 1; however, lands that have been mined for gravel in Reach 1 would likely be considerably less expensive.

A reconnaissance-level GIS analysis of landownership in Reach 1 suggests that a floodway of approximately 700 feet would encompass nearly 13,000 acres of land in Reach 1 that is currently in private ownership. (Some of this area could potentially fall under State Lands Commission claims and easements, which would reduce this estimate of privately-owned land). If we assume that half of this land is purchased at a price of $20,000 per acre (high value land) and the other half is purchased at a price of $3,000 per acre (flood easement and/or low-value land), then the total estimated cost of creating a floodway in Reach 1 would be approximately $150 million. This rough cost is balanced by the potential ecosystem and flood management benefits, as well as potential flood damage reduction.

Action 7. Fill floodplain pits to prevent stranding.

There are numerous floodplain pits in Reach 1 that present a potential stranding risk to juvenile salmonids. With the release of higher flows to the San Joaquin River to satisfy various ecological objectives such as riparian recruitment, many of these small floodplain pits will be accessed by flows, which increases the potential for juvenile salmon to become trapped in the pits as flows recede. Maps in Appendix A identify most of these floodplain pit areas within a potential floodway for Reach 1 (Action 6). These maps also identify potential sites for floodplain re-grading that could provide material for filling pits in Reach 1.

Criteria	Characterization of Action
Ecosystem Restoration	*Intervention*. This action is intended to reduce a potential stranding hazard to juvenile salmonids and create new rearing habitat in the upper reaches of the San Joaquin River. *Rehabilitation.* Filling the pits will re-create floodplain surfaces that likely resemble historical conditions.
Sustainability	*One-time intervention*. Once the floodplain gravel pits have been filled, there should be little requirement for any maintenance. Large flow events may deposit fine sediments on the created floodplain surfaces, and subsequent re-grading may be necessary, but in general, the action should be self-sustaining and require only one-time intervention.
Synergies and Conflicts	*Synergy*. Filling floodplain pits, in conjunction with the release of higher flows from Friant Dam, should increase the amount of inundated floodplain that will be available to support rearing by juvenile salmon. *Conflict*. Filling floodplain pits may reduce the amount of wetland habitat that is currently available in Reach 1.
Societal/ Infrastructural Impacts	*No significant impacts*. Small floodplain pits in Reach 1 provide few social benefits, so filling them will likely have little impact on human activities.
Confidence	*High Confidence*. The principal goal of filling these small floodplain pits is to reduce the risk of stranding for juvenile salmon rearing in Reach 1. Filling the pits is very likely to reduce stranding risk.
Cost-effectiveness	*Typical*. Filling floodplain pits will generally require an initial, one-time investment that is likely to provide lasting benefits by reducing the risk of stranding for juvenile salmon rearing in Reach 1. However, it is currently unclear how significant a threat these floodplain pits pose to juvenile salmon. Monitoring of these pits following the recession of high flows could support a better assessment of their threat as a source of mortality for juvenile salmon.
Flexibility	*Remediable*. Re-claiming floodplain pits can simply be abandoned; however, additional effort would be required to re-create some of the wetland habitat that may be associated currently with floodplain pits.
Strategic Value	*Neutral*. The scale of borrow material required to fill in numerous floodplain pits could necessitate the acquisition of a mining permit. Filling in the pits may also require revisions to SMARA restoration plans. Depending upon the location of a given floodplain pit, Reclamation Board and Section 404 permits may be required.
Adaptive Management	*Active adaptive management.* Because several floodplain areas would be re-graded, areas could be designed differently to test the microhabitat preferences of salmonids in the San Joaquin River. Substrate, slope, and area of inundation could be manipulated to determine which criteria are most important for rearing fish. *Passive adaptive management*. Ongoing management and monitoring would be required to ensure that floodplain habitats do indeed create

Criteria	Characterization of Action
	conditions that enhance habitat value and promote rapid growth in juvenile salmonids. Habitats could be monitored for production of macroinvertebrates, growth of juvenile fish, use and access of areas, possible stranding, and duration of inundation.

It is unclear how significant a stranding risk floodplain pits in Reach 1 will pose to restored populations of chinook salmon. Prior to large-scale filling of pits, monitoring following high flows should be used to assess the relative risk of floodplain pits as a source of mortality for juvenile salmon rearing in Reach 1.

Cost considerations. Cost estimates for this action were estimated by breaking Reach 1 into three haul distance zones to estimate the cost of filling the pits. The three zones are delineated as follows:

- Zone 1: Friant Dam (RM 267.5) to the downstream extent of Cobbs Island (RM 258.0)
- Zone 2: downstream stream extent of Cobbs Island (RM 258.0) to Highway 99 (RM 243.2)
- Zone 3: Reach 1B Highway 99 (RM 243.2) to Gravelly Ford (RM 229.0)

Potential borrow sites were identified close to pits that require filling to reduce the haul distance. A per unit cost was estimated for each of the three zones under two scenarios: (1) free fill material; and (2) purchased fill material. These two cost options reflect different assumptions about whether potential borrow sites are publicly owned as part of a floodway (Action 6). Purchasing fill material added $4.80 to the per-unit cost. The tables below show the cost components for the different zones in Reach 1; the first table assumes that fill material can be secured free of charge because of public ownership; the second table assumes that fill material must be purchased.

Estimated costs for filling floodplain pits without charge for source material

Cost Component	Zone 1	Zone 2	Zone 3
Haul rate (operator) ($/hr)	70.00	70.00	70.00
Haul distance (mi)	1.0	2.75	2.75
Haul rate (cy/hr)	31.9	23.6	23.6
Haul costs ($/cy)	2.19	2.97	2.97
Excavation ($/cy)	1.00	1.00	1.00
Grading ($/cy)	1.00	1.00	1.00
Materials ($/cy)	0.00	0.00	0.00
Total haul costs ($/cy)	4.2	5.0	5.0
Fill required for action (cy)	459,230	75,422	25,472
Cost with 20% for loss and shrinkage of material	$2,314,519	$452,532	$152,632
Site preparation	$117,000	$22,500	$18,000
Total estimated cost*	$3,385,000	$661,000	$238,000

*Includes contingencies, contractor costs, engineering services, and construction costs

Estimated costs for filling floodplain pits with charge for source material

Cost Component	Zone 1	Zone 2	Zone 3
Haul rate (operator) ($/hr)	70.00	70.00	70.00
Haul distance (mi)	1.0	2.75	2.75
Haul rate (cy/hr)	31.9	23.6	23.6
Haul costs ($/cy)	2.19	2.97	2.97
Excavation ($/cy)	1.00	1.00	1.00

Cost Component	Zone 1	Zone 2	Zone 3
Grading ($/cy)	1.00	1.00	1.00
Materials ($/cy)	4.80	4.80	4.80
Total haul costs ($/cy)	9.0	9.8	9.8
Fill required for action (cy)	459,230	75,422	25,472
Cost with 20% for loss and shrinkage of material	$4,959,684	$886,963	$299,551
Site preparation	$177,000	$22,500	$18,000
Total estimated cost*	$7,067,000	$1,266,000	$443,000

*Includes contingencies, contractor costs, engineering services, and construction costs

The total estimated cost for filling in all floodplain pits in Reach 1 (aside from the large gravel mining pits through which a channel must be re-constructed) ranges from $4,284,000 to $8,776,000, depending on the cost of fill material. Again, it may not be necessary to fill all floodplain pits in Reach 1, depending upon the stranding risk they pose to juvenile salmon.

Action 8. Add gravel to existing riffles.

Reconnaissance-level field observations indicate that gravel depths in some riffles in Reach 1 may not be adequate to support salmon spawning. Augmenting these locations with spawning-sized gravels would likely increase their value as spawning habitat. Periodic high flows would likely scour gravel from some of these riffles, which would necessitate periodic gravel augmentation after high flow events. Prior to large-scale gravel augmentation, it will be important to observe the distribution of spawning by adult salmon, so that gravel can be placed in riffles that will likely be used for spawning.

Criteria	Characterization of Action
Ecosystem Restoration	*Rehabilitation.* This action is expected to mimic spawning conditions that were typical of the San Joaquin River before construction of Friant Dam, but the action does not restore the natural processes of sediment transport that delivered spawning-sized gravel to potential spawning riffles.
Sustainability	*Negative.* This action will require repeated application after high flows scour spawning sized gravels from the topographic controls.
Synergies and Conflicts	*Synergy.* This action is expected to increase the effectiveness of other actions to restore a viable, self-sustaining population of spring- and fall-chinook salmon. The addition of clean gravel will likely improve salmon survival–to-emergence, and it may also enhance aquatic invertebrate production.
Societal/ Infrastructural Impacts	*Ancillary costs.* This action is expected to increase the amount of salmonid spawning in the upper portion of Lost Lake Park, which could require limitations on local recreational activities during the spawning season. *Ancillary benefits.* This action could increase quality of life issues as spawning salmon could become part of the community character and could potentially draw tourists interested in observing spawning salmon.
Confidence	*Typical.* This action is expected to succeed; however, it is acknowledged that the spawning salmon will most likely not use the entire augmented riffle, but will select certain patches that meet their specific requirements of depth, velocity, and particle size distribution. To determine potential

Criteria	Characterization of Action
	augmentation locations that will provide the greatest benefit to spawning, it will be important to monitor the distribution of salmon spawning. The duration of the benefits of augmented gravel are unclear, because it is uncertain where gravel may be scoured with the release of high flows.
Cost-effectiveness	*Typical*. Gravel augmentation of spawning riffles will likely provide habitat benefits between periods of high flows; however, it will be important to supplement spawning riffles where adult fish are pre-disposed to spawn. Periodic replacement of scoured gravels will be necessary.
Flexibility	*Reversible.* If the expected benefits of this action fail to materialize, it will be possible to abandon the effort, and the channel will likely return to its pre-treatment state.
Strategic Value	*Leveraged.* Expected spawning at the augmented riffles may generate public support for ecosystem restoration goals and may leverage an initially small effort into a larger effort to restore additional habitat. *Provocative.* Although this action is beneficial for restoring a viable, self-sustaining population of salmon, recreational use of Lost Lake Park during the spawning season will have to be altered. Reducing access to the river may alienate public access advocates.
Adaptive Management	*Active adaptive management.* This action can be set up as an experiment because spawning gravel is to be applied on a relative regular basis. The depth and spatial extent of gravel augmentation can be varied deliberately, as can the particle size distribution of the added gravel, to see whether these factors affect spawning behavior or success. Monitoring can facilitate additional learning on the movement of gravels through the channel.

Augmenting riffles with spawning-sized gravels should be approached as a pilot project, in conjunction with monitoring of spawning distribution and survival-to-emergence. It will be important to observe where adult salmon prefer to spawn so as to augment riffles that will provide habitat benefits. It will also be important to examine if current gravel quality in the river is sufficient to support survival-to-emergence rates that may reduce the need or scale of gravel augmentation. Salmon population modeling suggests that spawning habitat may be limiting in the San Joaquin River, so some scale of gravel augmentation in Reach 1 will likely be required. It is expected that adult salmon will spawn principally in the reach between Friant Dam and Highway 41.

Cost considerations. The table below shows the potential costs for this action for two different scenarios. One scenario assumes that spawning gravel is mined from local sites where the floodplain is lowered to promote floodplain inundation and riparian vegetation recruitment, and therefore the gravel would be free-of-charge. The other scenario assumes that spawning gravel will need to be purchased from local aggregate miners. These cost estimates are based on the material required to augment four riffles between Friant Dam and Lost Lake Park with an average depth of 2.0 ft of additional gravel, as a potential pilot study to examine fish use of augmented spawning sites. The estimated total amount of spawning-sized gravel required for these four areas is 1,036 cubic yards.

Cost for augmenting selected spawning riffle in Reach 1A

Cost Component	Spawning	Spawning gravel

	gravel mined adjacent to site	purchased from local miner
Haul rate (operator) ($/hr)	70.00	70.00
Haul distance (mi)	1.0	1.0
Haul rate (cy/hr)	23.6	23.6
Haul costs ($/cy)	2.97	2.97
Excavation ($/cy)	1.00	1.00
Grading ($/cy)	1.00	1.00
Sieve material ($/cy)	8.00	8.00
Materials ($/cy)	0.00	4.80
Total haul costs ($/cy)	13.97	18.77
Fill required for action (cy)	1,036	1,036
Cost with 20% for loss and shrinkage of material	$19,538	$26,252
Site preparation	$2,250	$2,250
Total estimated cost*	$30,000	$41,000

*Includes contingencies, contractor costs, engineering services, and construction costs

The total project cost for this action ranges from $30,000 to $41,000 depending on the cost of fill material.

Action 9. Mechanically disturb and remove fine sediment from spawning gravels.

This action would use mechanical means to flush sand and fine sediment from existing spawning riffles. As described in Section 3 of the Draft Strategies Report, we do not expect river flows to be sufficient to scour gravels except in isolated, high gradient areas, so that subsurface fine sediment will be exposed to transport. A variety of methods can be used to remove fine sediments from spawning gravels, including:

- Hydraulic gravel cleaning, which includes mechanical or hydraulic disturbance followed by suction removal of suspended fines for subsequent dewatering and removal;
- Excavation-sieving-replacement techniques, which involve mechanical or suction dredging to remove all sediment for subsequent cleaning and replacement of coarse materials; and,
- Flushing flows with mechanical disturbance, which would use mechanical disturbance using a bulldozer at moderate flows sufficient to pass the sediment downstream and out of the riffle.

Criteria	Characterization of Action
Ecosystem Restoration	*Substitution*. The action is expected to artificially provide benefits of a geomorphically active river that recruits, scours and transports coarse sediment, but does not restore geomorphic functions or processes to the San Joaquin River that provide these functions naturally. Before flow regulation, high flows would transport coarse sediment from upstream, rework the channel gravels, and scour spawning riffles of fine sediment.
Sustainability	*Interim measure*. The action may benefit spawning riffle conditions, but the duration of those benefits is unknown because local fine sediment sources for the San Joaquin River are poorly understood. *High maintenance.* If upstream fine sediment sources are not identified and reduced in other restoration actions, mechanical flushing of fine sediment in spawning riffles may need to be repeated often to maintain

Criteria	Characterization of Action
	suitable permeability for the survival of incubating salmon eggs and emergence of fry.
Synergies and Conflicts	*Synergy.* With regulatory approval for water quality impacts (i.e., CVRWQCB), appropriately selected (i.e., method) and timed (e.g., during a spring emigration pulse flow) cleaning activities could improve fish survival during outmigration by increasing turbidity and therefore decreasing the efficiency of visual predation by fish and bird species. Also, increases in turbidity, which would be associated with gravel cleaning and sediment mobilization, may serve as outmigration cues for juvenile salmonids. With sufficient flow magnitude and duration, mobilized fine sediment could be transported downstream and deposited on the floodplain, building the floodplain and providing substrates for riparian vegetation recruitment. Mechanical mobilization and removal of fine sediment from gravels also has the potential to improve conditions for benthic macroinvertebrate production, which is an important salmonid food source. *Conflicts*. Increases in turbidity from mechanical sediment mobilization could impair water quality and potentially impact designated beneficial uses in the SWRCB basin plan for other fish and aquatic species. For example, if mechanically-mobilized sediment is transported into downstream rearing pools, invertebrate production and rearing conditions for yearlings could be impacted.
Societal/ Infrastructural Impacts	*Ancillary costs*. Increased fine sediment transport and turbidity could impair recreational uses of the San Joaquin River. There is also the potential for diversion structures and screens to be affected by increased turbidity, but the degree of potential impairment is unknown.
Confidence	*Typical*. A number of gravel-cleaning methods have been shown to be effective in cleaning sand from spawning riffles on the Tuolumne River (TID/MID 1992). The effectiveness of different techniques can range quite broadly, from complete removal of all fine sediments (e.g., excavation-sieving-replacement techniques) to only surficial removal of fines in one location and relocation of those fines to downstream riffles (gravel ripping and bulldozing techniques). With sufficient flows, we can be fairly confident that mechanically-mobilized sediment will be transported downstream from the cleaned riffle. However, we are unsure of what impacts transported sediment will have downstream. In-situ gravel cleaning offers greater control over downstream impacts, but we are unsure how quickly fine sediment from upstream will re-infiltrate the cleaned riffle.
Cost-effectiveness	*Typical*. Due to uncertainties in upstream sediment supply rates and the downstream fate of mechanically-mobilized sediment, the mid- to long-term effectiveness of mechanical disturbance is not clear. These uncertainties create difficulties in determining the cost-effectiveness of the action. Further determining the cost-effectiveness of this action would require comparison with other methods of improving spawning gravel quality such as augmenting spawning gravels.
Flexibility	*Reversible*. Mechanical disturbance of spawning gravels could be stopped at any time, and conditions would revert to a pre-action state.

Criteria	Characterization of Action
Strategic Value	*Neutral*. Water quality permits would need to be acquired prior to gravel cleaning.
Adaptive Management	*Active*. The action could support several active adaptive management experiments: turbidity could be varied to test smolt survival as a function of turbidity; half of a riffle could be cleaned with the other half as a control condition to test invertebrate production, spawning preference, and alevin emergence as a function of permeability. *Passive*. Infiltration bag experiments could be used to monitor fine sediment delivery into spawning riffles from upstream sources.

It is unclear how current gravel quality will affect salmon survival-to-emergence, and initial invertebrate monitoring suggests that food production is quite high in Reach 1. Consequently, the need to improve spawning gravel quality is unknown. Early pilot-scale riffle cleaning experiments could be conducted in association with emergence trapping studies to assess the value of mechanical removal of fine sediment. It will also be important to identify fine sediment sources in Reach 1 to assess the potential duration of habitat benefits derived from mechanical riffle cleaning. Infiltration bag experiments can also elucidate the potential duration of benefits of cleaned riffles.

Cost considerations. Costs for cleaning spawning riffles in the Tuolumne River were recently estimated for the Turlock and Modesto Irrigation Districts by reviewing cost data available from published reports (Stillwater Sciences, unpublished technical memorandum). In these literature surveys, costs range very broadly, from less than $1.00 per square meter cleaned, to more than $47.00 per square meter cleaned. Although costs are sensitive to the method of cleaning that is selected, and the size of areas to be cleaned, in general costs increase with energy expenditure with the lowest costs associated with flushing flows, followed by in-situ gravel cleaning, followed by excavation and replacement techniques.

Action 10. Build a functioning, multi-stage channel through large gravel mining pits.

This action includes reconstructing a multi-stage river channel through large gravel pits in Reach 1. This re-constructed channel would be separated from remaining areas of gravel pits by dikes. The primary goal of the re-constructed channel would be to facilitate the upstream and downstream passage of fish and the routing of flow and sediment. The multi-stage channel would also provide opportunities for constructing surfaces designed to inundate annually to support floodplain rearing of juvenile salmonids, as well as low-elevation surfaces that could support natural recruitment of riparian vegetation.

Criteria	Characterization of Action
Ecosystem Restoration	*Rehabilitation*. Re-building a functioning channel through captured gravel pits would mimic historical channel conditions, though the scale and geometry of the constructed multi-stage channel would likely be different from historical conditions because of the regulated flow regime.
Sustainability	*One-time intervention*. Once a channel has been re-constructed, it will likely require little maintenance. The channel will be expected to evolve over time, but such changes are likely to preserve habitat values that are similar to the originally constructed channel.

Criteria	Characterization of Action
	Low maintenance. Unmanaged flood flow releases have the potential to breach some of the dikes that separate the re-constructed channel from the surrounding gravel pits, which would require repairing the breaches.
Synergies and Conflicts	*Synergy*. Isolating gravel pits would likely reduce lentic habitat that supports non-native fish which can prey upon juvenile salmon. Replacing gravel pits with a functioning channel would also facilitate timely upstream and downstream passage of fish. The multi-stage channel also provides opportunities for constructing surfaces that inundate annually, thereby providing rearing habitat for juvenile salmonids. Other surfaces of the multi-stage channel would likely support recruitment-based restoration of riparian vegetation. Re-constructing the channel will also restore sediment routing, principally of fine sediment. *Conflicts*. Isolating gravel pits may reduce the extent of some existing wetland habitat. However, it may be possible to design the dikes that isolate the re-constructed channel from gravel pits in a manner that expands wetland habitat.
Societal/ Infrastructural Impacts	*No significant impacts*. Captured gravel mining pits provide few social benefits, so re-constructing a functioning channel and isolating gravel pits will likely produce no significant impacts to infrastructure or human activities.
Confidence	*Typical*. There have been several efforts to re-construct functioning channels and floodplains through gravel mining pits on other Central Valley rivers, including the Tuolumne River, the Merced River, and Clear Creek. The re-constructed channel can be expected to provide the ecosystem benefits predicted; however, the channel will evolve over time.
Cost-effectiveness	*Efficient to typical*. Re-constructing a channel through large gravel pits would likely require a significant one-time investment initially; however there are numerous ecosystem and flood management benefits of a re-constructed channel that would help to balance the cost of the channel re-construction.
Flexibility	*Reversible*. If the re-constructed channel does not provide the expected benefits, it can be abandoned, and the river will eventually re-capture the gravel pits to re-create current conditions. However, abandoning the re-constructed channel would strand a significant cost investment.
Strategic Value	*Neutral*. Re-constructing a channel through captured gravel pits will require significant effort and resources for design, permitting, and implementation; therefore, it will require time to complete, which will delay the actualization of ecosystem and flood management benefits.
Adaptive Management	*Active adaptive management.* Because several floodplain areas would be regraded in the three-stage design, areas could be designed differently to test the microhabitat preferences of salmonids in the San Joaquin River. Substrate, slope, and area of inundation could be manipulated to determine which criteria are most important for rearing fish. *Passive adaptive management*. Ongoing management and monitoring will be required to ensure that floodplain habitats do indeed create conditions that enhance habitat value and promote rapid growth in juvenile

Criteria	Characterization of Action
	salmonids. Habitats could be monitored for production of macroinvertebrates, growth of juvenile fish, use and access of areas, possible stranding, and duration of inundation.

Isolating gravel pits in Reach 1 will be necessary to restore self-sustaining populations of salmonid species. Re-constructing a channel through these large pits will require a significant investment of time and resources, but the multiple potential ecosystem and flood management benefits balance the effort associated with the action. There are several similar efforts on other Central Valley rivers to reconstruct a functioning channel and floodplain through captured gravel pits. However, the scale of effort required to re-construct a channel through gravel pits in the San Joaquin River is considerably larger than similar efforts on these other Central Valley rivers.

Cost Considerations. Like Action 7, cost estimates for this action were estimated by breaking Reach 1 into three haul distance zones to estimate the cost of filling the pits. The three zones are as follows:

- Zone 1: Friant Dam (RM 267.5) to the downstream extent of Cobbs Island (RM 258.0)
- Zone 2: downstream extent of Cobbs Island (RM 258.0) to Highway 99 (RM 243.2)
- Zone 3: Reach 1B Highway 99 (RM 243.2) to Gravelly Ford (RM 229.0)

Potential fill material sites were identified close to dike construction and channel reconstruction reaches to reduce the haul distance from the fill material source areas. A per-unit cost was estimated for each of the three zones under two scenarios: (1) free fill material; and (2) purchased fill material. Purchasing fill material added $4.80 to the per-unit cost. The tables below shows the cost components for the different zones in Reach 1; the first table assumes that fill material can be secured free of charge; the second table assumes that fill material must be purchased.

Estimated costs for building a functioning, multi-staged channel through isolated mining pits without charge for source material

Cost Component	Zone 1	Zone 2	Zone 3
Haul rate (operator) ($/hr)	70.00	70.00	70.00
Haul distance (mi)	1.0	2.75	2.75
Haul rate (cy/hr)	31.9	23.6	23.6
Haul costs ($/cy)	2.19	2.97	2.97
Excavation ($/cy)	1.00	1.00	1.00
Grading ($/cy)	1.00	1.00	1.00
Materials ($/cy)	0.00	0.00	0.00
Total haul costs ($/cy)	4.2	5.0	5.0
Fill required for action (cy)	88,000	5,910,196	1,210,000
Cost with 20% for loss and shrinkage of material	$443,520	$35,461,176	$7,260,000
Site preparation	$58,500	$1,093,500	$121,500
Total estimated cost*	$698,000	$50,885,000	$10,275,000

*Includes contingencies, contractor costs, engineering services, and construction costs

Estimated costs for building a functioning, multi-staged channel through isolated mining pits with charge for source material

Cost Component	Zone 1	Zone 2	Zone 3
Haul rate (operator) ($/hr)	$70.00	$70.00	$70.00
Haul distance (mi)	1.0	2.75	2.75
Haul rate (cy/hr)	31.9	23.6	23.6

Haul costs ($/cy)	2.19	2.97	2.97
Excavation ($/cy)	1.00	1.00	1.00
Grading ($/cy)	1.00	1.00	1.00
Materials ($/cy)	4.80	4.80	4.80
Total haul costs ($/cy)	9.0	9.8	9.8
Fill required for action (cy)	88,000	5,910,196	1,210,000
Cost with 20% for loss and shrinkage of material	$950,400	$69,503,905	$14,229,600
Site preparation	$58,500	$1,093,500	$121,500
Total estimated cost*	$1,405,000	$98,271,000	$19,976,000

*Includes contingencies, contractor costs, engineering services, and construction costs

The total potential cost for this action ranges from $61,858,000 to $119,652,000, depending on the cost of fill material (sum of Zones 1, 2, and 3 under two scenarios as presented in Tables above). This cost estimate does not include the potential cost of land purchase, which is included in cost estimates for the creation of a floodway in Reach 1 (Action 6).

Action 11. Create alternative channel alignment around gravel pits.

We evaluated an alternative channel alignment that bypassed many of the Stuart Ness gravel pits in Reach 1 that have been captured by the channel. This alternative channel alignment would be aligned to the north of the gravel pits and run along the base of the northern bluff. The goal of this alternative alignment was to try and avoid the significant volume of fill material that would be required to re-construct a functioning river channel through the gravel pits. The re-aligned channel would reconnect with the historical secondary channel adjacent to the Fig Garden Golf Course, thereby bypassing the large captured gravel pits.

Criteria	Characterization of Action
Ecosystem Restoration	*Substitution.* The goal of this action is to provide an alternative alignment to create a functioning river channel that mimics the historical channel.
Sustainability	*One-time intervention.* This action would require a significant initial effort to excavate a new river channel in un-mined areas around the existing gravel pits. Following this initial effort, it is expected that the constructed channel would require little maintenance.
Synergies and Conflicts	*Synergy.* This action is expected to improve passage for migrating salmonids by replacing the lentic habitat associated with the gravel pits. Isolating the gravel pits could also reduce juvenile salmonid mortality by reducing predator habitat. As with Action 10, the constructed channel presents the same opportunity to design a multi-stage channel with low-lying floodplain benches that could to provide floodplain rearing for juvenile salmon. Similarly, riparian vegetation could be recruited on some of the new surfaces of the constructed channel.
Societal/ Infrastructural Impacts	*Ancillary costs.* This alternative channel alignment traverses a current staging area and processing facility associated with an active gravel mining operation.
Confidence	*Low confidence.* The depth to bedrock along this alternative channel path is unknown, which increases the uncertainty that a functioning channel can be created.
Cost-effectiveness	*Efficient.* In addition to the ecosystem benefits of a multi-stage channel and the isolation of lentic habitat described above, the excavation of this new channel could provide material for filling other gravel pits and for

Criteria	Characterization of Action
	supplementing the gravel supply to nearby channel reaches. *Inefficient.* As compared to re-building a channel through the captured gravel pits, this alternative alignment would likely involve higher land acquisition costs because of the difference in value between already mined areas and un-mined areas.
Flexibility	*Remediable.* The constructed channel could be isolated if it failed to provide the expected function and benefits; however, isolating the channel would likely require an additional commitment of significant resources.
Strategic Value	*Provocative.* Although the action will be beneficial to restoration of the ecosystem, the action is expected to alienate gravel miners and local property owners and may create a backlash towards other actions requiring land acquisition and purchasing of aggregate for spawning gravel augmentation.
Adaptive Management	*Passive adaptive management.* Monitoring the constructed channel would be required to ensure it provides the expected functions and benefits.

This action was not selected for inclusion in the restoration strategies because of uncertainties regarding the depth to bedrock along the alternative channel alignment, which raises questions about the feasibility of this action. This alternative channel alignment would likely be controversial, because it involves constructing an entirely new channel and it would require a significant disruption to an existing gravel mining operation. The goal of evaluating this alternative channel alignment was to avoid the cost of significant volumes of fill material required to re-claim a channel through the gravel pits. However, the additional cost associated with purchasing higher value lands and re-locating or buying out an active gravel processing facility undermines this goal of reducing costs.

Action 12. Create additional spawning habitat.

This action requires local alterations in the channel bed slope to create hydraulic and channel substrate conditions that are conducive to spawning. There are several sub-reaches within Reach 1A that, according to current topographic information, have channel gradients that are too steep to support salmon spawning. Filling these areas with material can potentially reduce local channel gradients and expand spawning habitat. The best candidate sites for this action would have both upstream and downstream grade control, such as bedrock outcrops, to improve the potential stability of these constructed sites. This action is conceptual, because more detailed topographic information is required to evaluate its feasibility. It is also unclear if attempts to change local channel gradients will be stable in the long-term.

Criteria	Characterization of Action
Ecosystem Restoration	*Intervention.* This action will artificially provide spawning habitat in areas that are currently unsuitable for spawning. This action will not restore the process or function of gravel recruitment or coarse sediment delivery to the channel from upstream sources.
Sustainability	*Low to high maintenance.* The stability of constructed sites is a key uncertainty. With the release of high flows, the constructed sites may evolve to approximate pre-treatment channel gradients, which would likely eliminate their value as spawning habitat. The stability of the sites will determine the maintenance required to sustain their habitat value.

Criteria	Characterization of Action
Synergies and Conflicts	*Synergy*. This action is expected to enhance the effectiveness of reintroducing salmon to the river by expanding spawning habitat and improving the potential for macroinvertebrate production. This action may also restore bedload routing on a local scale.
Societal/ Infrastructural Impacts	*No significant impacts*. There are no clear social benefits to locally high-gradient areas in Reach 1A, so this action is not expected to have any significant impact on human activities.
Confidence	*Low confidence*. This action is conceptual, and more detailed topographic information is required to assess its feasibility. There is considerable uncertainty about whether the constructed channel gradient will be maintained as the channel evolves with the release of high flows. Also, there is no way to predict if adult salmon will choose to spawn in the created sites, even if the treatment sites do provide suitable hydraulic conditions.
Cost-effectiveness	*Typical*. Because of the uncertainty about the duration of spawning habitat benefits, it is difficult to assess the cost-effectiveness of this action. However, if the treatment sites perform as expected, they have the potential for significantly expanding available spawning habitat in Reach 1.
Flexibility	*Remediable*. If the treatment sites do not function as planned, additional effort can mine the material introduced to the channel to restore pre-treatment conditions. *Fungible*. If the expected benefits of the treatment sites fail to materialize, then the material added to the channel may be mined for application in other locations, such as the augmentation of existing spawning riffles.
Strategic Value	*Provocative*. The current uncertainty underlying this concept will likely reduce its potential for garnering public support.
Adaptive Management	*Passive adaptive management*. This action would be accompanied by monitoring and could be phased so that the lessons learned from the first phase could be applied to subsequent treatment sites.

This restoration action is necessarily conceptual at this stage. More detailed topographic information is required to assess the feasibility of locally altering channel gradients to expand potential spawning habitat. If further analysis suggests that this action is worth pursuing, then a small pilot project should be implemented, accompanied by monitoring of channel response to high flows and salmon use of the created sites.

Cost considerations. A reconnaissance-level survey of Reach 1A identified 18 potential candidate sites where it may be possible to alter the local channel gradient to expand spawning habitat. A rough analysis of these candidate sites suggests a total volume of approximately 550,000 cubic yards of fill material would be required to build these candidate sites. (It is important to note that these calculations are highly provisional because they are not based on ground-surveyed topographic data.) The table below shows the potential costs for this action for two scenarios. One scenario assumes that fill material is mined from potential borrow sites where the floodplain could be re-graded to support floodplain rearing and/or riparian vegetation recruitment. The second scenario assumes that fill material will have to be purchased from local aggregate miners.

Estimated costs for augmenting selected spawning riffle in Reach 1A

Cost Component	Spawning gravel mined adjacent to site	Spawning gravel purchased from local miner
Haul rate (operator) ($/hr)	$70.00	$70.00
Haul distance (mi)	1.0	1.0
Haul rate (cy/hr)	23.6	23.6
Haul costs ($/cy)	2.97	2.97
Excavation ($/cy)	1.00	1.00
Grading ($/cy)	1.00	1.00
Sieve material ($/cy)	8.00	8.00
Materials ($/cy)	0.00	4.80
Total haul costs ($/cy)	13.97	18.77
Fill required for action (cy)	547,515	547,515
Cost with 20% for loss and shrinkage of material	$10,325,859	$13,873,756
Site preparation	$171,000	$171,000
Total estimated cost*	$14,611,000	$19,551,000

*Includes contingencies, contractor costs, engineering services, and construction costs

The total project cost for this action ranges from $14,611,000 to $19,551,000, depending on the cost of fill material.

Action 13. Reconnect side channels with the mainstem.

This action includes reconnecting side channels with the mainstem channel in Reach 1. In many cases, side channels have become disconnected from the mainstem by reduced flows or deliberate filling or isolation by berms. This action includes excavating side channels to elevations that are inundated more frequently under regulated flow conditions and removing barriers to side channel flow. For example, the side channel at Ledger Island has been isolated from the active channel by a berm which could be removed to reconnect it to the mainstem channel. The objective of this action is to restore spawning and rearing habitats for salmonids in side channels.

Criteria	Characterization of Action
Ecosystem Restoration	*Rehabilitation*. Side channels would be excavated to elevations that are more frequently inundated by regulated flows. The scale of this excavation would create conditions that mimic historical conditions.
Sustainability	*One-time intervention*. The side channels would need to be excavated and scaled just once. *Low maintenance*. Depending on sediment transport dynamics in the side channels, periodic excavation may be required if side channels aggrade.
Synergies and Conflicts	*Synergy*. This action supports several other restoration actions, including: improving the quality and quantity of juvenile salmonid rearing habitat; reducing fish passage barriers (supported by removal of berms); improving conditions for riparian revegetation; and potentially creating habitat for amphibians and aquatic reptiles. *Conflicts*. At certain flows, this action could result in side channels becoming backwater habitats with elevated temperatures and an increased abundance of predatory fish species.

Criteria	Characterization of Action
Societal/ Infrastructural Impacts	*Ancillary benefits*. The actions could provide increased recreational opportunities on the river. *Ancillary costs*. The action could impact adjacent low-elevation land uses that border side channels, such as gravel mining, agricultural activities, and some recreational areas. Some riparian water diversions are located on side channels, but it is unknown how the restoration of higher flows and fine sediment routing in side channels may affect these diversions.
Confidence	*High.* The side channels that would be reconnected by this action are remnant side channels that have been cut off from the mainstem largely as a result of reduced flows. The habitat value and uses of the remnant side channels should largely be restored by the action. *Low*. Bedrock underlying the side channels may limit the extent of excavation possible. Also, it is not clear how water will behave at the split channels or what the stage-discharge relationship will be in the reconnected side channels.
Cost-effectiveness	*Efficient*. The action would be a one-time excavation coupled with manipulations of flow to determine preferred inundation levels and duration in the side channels. The action supports multiple benefits and would be substantially less expensive than floodplain re-grading to create the same kinds of conditions and habitats.
Flexibility	*Remediable*. If re-connected side channels fail to provide the expected benefits, they could be filled and/or isolated and returned to pre-treatment conditions. *Proactive*. The action would reclaim side channel areas to support ecosystem benefits before those areas are further impacted by anthropogenic activities.
Strategic Value	*Leveraged.* The initial investment of excavating the side channel areas could yield important rearing benefits for salmon and could potentially create conditions that support a sport fishery. *Ripe*. Potential conflicts with existing land uses is relatively small, because side channels are often located in areas that are still inundated by high flow releases from Friant Dam.
Adaptive Management	*Passive*. The action can be monitored to track sediment transport through the side channels, fish and wildlife use, and riparian recruitment.

Re-connecting side channels offers a relatively low-cost way of expanding potential habitat to support juvenile salmonid rearing and wildlife use.

Potential Large-Scale Restoration Actions for Reach 2

Action 14. Create a floodway.

In all of the restoration strategies, the flood conveyance capacity of Reach 2B is projected to be expanded, which will require setting back at least one levee (Action 15). In Strategies 2 and 3, the flood conveyance capacity of Reach 2A is projected to be expanded, which can be achieved by either setting back levees or strengthening and raising existing levees. As with Reach 1, defining a broader floodway in Reach 2 will allow the river to re-connect with a portion of its former floodplain. Reach 2 presents the best potential for restoring channel migration and floodplain building, so defining a broader floodplain will provide the space necessary to restore these processes. The distance of potential levee setbacks is flexible, and it will depend in large measure on balancing ecosystem and flood management improvements with retiring land from production via purchase or easement.

Criteria	Characterization of Action
Ecosystem Restoration	*Rehabilitation*. This action would restore a floodway in Reach 2 where the channel would be allowed to re-connect with a portion of its former floodplain, but the floodway would likely be reduced in scale from pre-disturbance conditions.
Sustainability	*One-time intervention*. The action would primarily involve the one-time purchase of privately owned parcels or easements from willing sellers within the selected floodway alignment. This action could build off of the current efforts of the San Joaquin River Parkway Trust to purchase parcels adjacent to the river channel for conservation and restoration in Reach 1. This action would also require building new setback levees. *Low-maintenance*. A wider levee setback will likely require less levee maintenance over time than a more narrow floodway between levees, which runs a higher risk of breaching, overtopping, or other damage from the release of high flows.
Synergies and Conflicts	*Synergy*. By providing space for the channel to meander and re-connect with a portion of its former floodplain, this action supports many other restoration actions. In addition to channel migration and floodplain formation, overbank flows could also provide rearing habitat for juvenile salmon, and spawning habitat for resident fish. This action also supports both recruitment-based and horticultural restoration of riparian vegetation.
Societal/ Infrastructural Impacts	*Ancillary benefits*. The primary societal benefit of a floodway is the improvement to flood routing and storage, and the reduction of potential flood damage. Setback levees could be constructed with a clay core, which can provide greater flood protection, reduce levee maintenance, and reduce seepage. A publicly-owned floodway also improves recreational opportunities along the river. *Ancillary costs*. Creation of a floodway in Reach 2 requires taking land out of production, and purchasing easements or land from willing sellers.
Confidence	*High confidence*. Setting back levees to form a floodway has a high likelihood of achieving the expected ecosystem and flood management benefits.
Cost-effectiveness	*Typical*. Constructing setback levees with a clay core represents an initial commitment of significant resources (especially if material needs to be

Criteria	Characterization of Action
	transported from a distant source). However, the multiple ecosystem and flood management benefits associated with levee setbacks, coupled with reduced levee maintenance, help to balance the initial effort required to re-build and acquire land and easements for the floodway.
Flexibility	*Fungible*. If the floodway fails to provide the expected benefits, then land and easements purchased to define the floodway could support or be managed for other land uses. *Proactive.* The action is a precursor to other restoration actions and would provide the environment and conditions necessary to successfully implement a variety of restoration actions implicit in restoring a river. The action would also result in the potential preservation of the largest patch of existing elderberry savanna in the project area. *Remediable*. The floodway and associated setback levees could be abandoned or narrower levees could be constructed, but this would represent a stranding of a significant initial investment required for setting back levees.
Strategic Value	*Leveraged*. The action helps fulfill many other restoration objectives, such as expanding riparian vegetation, rearing habitat, and flood flow routing and storage. The support of local landowners, and the potential ecosystem and flood management benefits of a levee setback and floodway dedication, could also provide an important case study for similar actions downstream. *Provocative*. Creation of a floodway and setting back levees would require the purchase of private lands from willing sellers and would result in agricultural areas being taken out of production.
Adaptive Management	*Static*. While levee configurations would not be experimented with (due to costs), the action could support adaptive management experiments by providing the precursory conditions necessary to implement other restoration actions.

Anecdotal reports suggest that the actual conveyance capacity in Reach 2 is less than the advertised capacity of 8,000 cfs in Reach 2A, because the levees begin to pipe when flows reach the levee toes. For example, the 2003 San Joaquin River Flow Study contemplates a maximum discharge of 5,000 cfs because of concerns about levee stability in Reach 2. Consequently, expanding flood conveyance capacity by raising the current levees is unlikely to provide adequate flood protection. Making substantial improvements flood management conditions in Reach 2 will likely require building new levees, which provides an opportunity for building clay-core levees and setting them back from the channel to provide better protection for surrounding land uses. Because of the potential for restoring channel migration and floodplain building in Reach 2, any levee setback should consider floodway widths that are able to incorporate potential meander bends associated with a migrating river.

Cost Considerations. The cost to create a floodway in Reach 2 depends in large measure on the width of a levee setback, which affects both the amount of land or easements that will need to be purchased from willing sellers and the required height of a re-built levee. To estimate potential land and easement costs associated with different floodway widths, we examined levee setback widths of 1,000 feet and 1,500 feet. We selected these floodway widths based upon historical widths of riparian forest in Reach 2 and habitat needs of certain analysis species. The Background Report (McBain and Trush 2002) indicates historical widths of riparian vegetation ranging between 850 feet and 2,000 feet (as illustrated by 1914 maps). Section 3.5.5.1 reports that riparian buffer widths less than 350 feet will not support yellow-billed cuckoo, while optimal widths greater than 2,000 feet. Similarly, western pond turtles require riparian buffer widths greater than 1,650 feet.

A reconnaissance-level GIS analysis indicates that a 1,000 foot levee setback in Reach 2 would encompass approximately 13,400 acres of privately owned land. The average cost per acre in Reach 2 is approximately $6,500 (Correia 2002), which would represent an approximate cost of $87 million. Constructing setback levees in Reach 2A is estimated to cost approximately $60.5 million, and approximately $2.2 million in Reach 2B. Estimated land and construction costs to create a 1,000 ft floodway total approximately $150 million. If levees are setback in Reaches 2A and 2B to create a 1,500-ft floodway, approximately 15,100 acres would need to be purchased from willing sellers, at an approximate cost of $98 million. Estimated land and construction costs to create a 1,500 ft floodway total approximately $160.8 million.

Action 15. Setback left bank levee in Reach 2B.

In all of the restoration strategies, flood conveyance capacity in Reach 2B will be expanded from its current capacity of 2,500 cfs. Increasing the conveyance capacity of Reach 2B will require setting back at least one of the levees that borders the channel in the reach. For the restoration strategies, we examined setting back the left bank levee in Reach 2B to expand flow capacity and create a floodway. Only the left bank levee is identified for setback because: (1) the right bank levee is located at a higher elevation, so it may be less susceptible to breaching; (2) land protected by the right bank levee is almost entirely in agricultural production, while significant tracts of land behind the left bank levee are not currently in production; (3) lands currently behind the left bank levee protect one of the largest patches of elderberry savanna, which could be re-connected to the river; and, (4) the right bank levee protects an adjacent canal.

Criteria	Characterization of Action
Ecosystem Restoration	*Rehabilitation*. The action would contribute to the restoration of a broader floodway in Reach 2B, though it would likely be reduced in scale from the pre-disturbance floodway.
Sustainability	*One-time intervention*. The action would require an initial effort to re-build a clay-core levee that is set back from the channel. In order to set back the levee, this action will also involve the purchase of land or easements from willing sellers. *Low-maintenance*. The setback levee would be constructed with a clay core, enhancing levee stability and reducing maintenance requirements because of less frequent damage to the levee.
Synergies and Conflicts	*Synergy*. The action will help define the floodway in Reach 2 (Action 14) and support the multiple benefits associated with a defined floodway, including channel migration, floodplain building, and both recruitment-based and horticultural restoration of riparian vegetation. Reach 2 likely has the greatest potential to support channel migration, so setting back the left bank levee can provide space for the channel to migrate.
Societal/ Infrastructural	*Ancillary benefits*. The primary societal benefit of setting back levees is the improvement to flood routing and storage. By improving flood

Criteria	Characterization of Action
Impacts	management in Reach 2B, the extent and cost of flood damage could be greatly reduced. Setting back the levee can also reduce levee maintenance requirements and levee seepage. Increasing the flood conveyance capacity of Reach 2B by setting back a levee will permit routing higher flows, with their sediment load, into the mainstem channel, which will help restore sediment supply to downstream reaches. Routing higher flows through Reach 2B will also reduce the flow and sediment directed into the Chowchilla Bypass, which may reduce channel aggradation in the bypass and the ensuing need to dredge the head of the bypass. *Ancillary costs*. Implementation of the action will depend on the willingness of local landowners to sell land or easements and will result in some lands being taken out of agricultural production.
Confidence	*Typical*. Setting back levees is a fairly standard engineering practice to increase channel capacity, and re-connecting the channel with a portion of its former floodplain has a high likelihood of achieving the expected ecosystem and flood management benefits.
Cost-effectiveness	*Efficient*. The action supports multiple processes, including fish rearing, riparian vegetation recruitment, and flood routing and storage. In addition, land costs in Reach 2B are likely some of the lowest in the river corridor. *Typical*. Purchasing property from willing sellers and constructing new levees will require a significant initial investment of resources.
Flexibility	*Fungible*. If the levee setback and expansion of the floodway fail to produce the expected benefits, then floodplain lands can be sold and put to other uses, with the funds from the sale made available to support other restoration actions. *Proactive.* The action is a precursor to other restoration actions and would provide the space and conditions necessary to implement a variety of restoration actions. Purchasing lands from willing sellers between the channel and the new levees would also preserve the largest patch of elderberry savanna in the river corridor. *Remediable*. Setback levees could be abandoned and narrower levees constructed, but such an action would not only strand the initial investment to set back the levees, but also require a significant new investment to re-build levees closer to the channel.
Strategic Value	*Leveraged*. The action is a precursor to other restoration actions and would provide the environment and conditions necessary to meet multiple restoration objectives. *Ripe*. Considerably less agricultural land would be taken out of production to setback levees in Reach 2B as compared with other reaches. *Provocative*. The action would require buying land or easements from willing sellers and taking some agricultural areas out of production.
Adaptive Management	*Static*. This action generally would not require monitoring, but it could support adaptive management experiments by providing the precursory

Criteria	Characterization of Action
	conditions necessary to implement other restoration actions.

Reach 2B currently represents a hydraulic chokepoint in terms of flood conveyance, and seepage issues in the reach prevent the release of flows up to the current capacity of 2,500 cfs, which can reduce sediment routing in the reach. Setting back the left bank levee, and purchasing land and easements from willing sellers, can provide multiple flood management and ecosystem benefits. A left bank levee setback also provides a great opportunity for re-connecting the river channel with a large patch of elderberry savanna.

Cost considerations. The cost associated with a left bank levee setback depends upon the setback distance and the resultant amount of land and easements that would be required. A left bank levee setback that incorporates the current meander bends in Reach 2B encompasses approximately 4,600 acres of privately owned land. The average cost per acre in Reach 2B is $7,500 (Correia 2002), so the potential land and easement costs associated with a left bank levee setback that incorporates existing meander bends would be approximately $34.5 million. The cost of constructing a new, clay core levee that is set back from the channel is estimated to cost approximately $2.2 million. Therefore, the estimated land and construction cost to setback the left bank levee is $36.7 million.

Action 16. Create floodplain ponds to restore native fish.

Moyle et al. (2002) have received funding to explore opportunities for restoring Sacramento Perch in Central Valley rivers. One method for restoring this native resident fish involves creating floodplain ponds where Sacramento Perch would be actively managed. These ponds would be designed to be breached by flood flows every few years, so that flows would distribute Sacramento Perch downstream to re-colonize the mainstem channel (Moyle 2002). The goal of this approach is to periodically flood the mainstem river channel with native resident fish as a way of periodically re-establishing their distribution and abundance. Habitat for native resident fish may be limited in the San Joaquin River under current conditions, and the deep-bodied fish assemblage may benefit from spatial separation from non-native species in the main channel. Consequently, we have incorporated Moyle's approach in the three restoration strategies as a possible means for restoring several native resident fish species. Several of the species in this assemblage can thrive (and some may reproduce) in small ponds less than a half-acre in size or smaller, including Sacramento perch, hitch, and Sacramento blackfish. The ponds would be constructed so that they are easily maintained (e.g., removing excess vegetation, maintaining depth), and to that they can be drained and refilled periodically (as a means of controlling for non-native species in the ponds). This action also includes the possibility of operating Mendota Pool much like the floodplain ponds, emphasizing the restoration of native resident fish so that the Pool serves as a population source.

Criteria	Characterization of Action
Ecosystem Restoration	*Substitution*. Side channel habitats, deepwater sloughs, and large off-channel water bodies were likely a part of the natural landscape before anthropogenic development in the San Joaquin Valley. These areas were likely important for spawning and rearing of native resident fishes. Because recreating these types of habitats is not always possible, this action would encourage restoration of native resident fishes by artificially creating a function to benefit the ecosystem.
Sustainability	*One-time intervention*. A one-time measure to construct the floodplain

Criteria	Characterization of Action
	ponds would be required to initiate the action. Floodplain ponds would be built in areas that would be flooded and breached every few years, so as to allow fish to gain appropriate size before being introduced into the natural system, as well as to achieve high numbers to potentially outnumber and outcompete non-native species when introduced to the mainstem channel. *Low maintenance.* Because fresh water would have to be pumped into the ponds to provide sufficient dissolved oxygen, etc. some low maintenance may be required to maintain the ponds. In essence, these floodplain ponds would function like aquacultural operations, and would require associated management. In addition, minimizing encroachment of vegetation may also be required. Completely draining the ponds would also be required on occasion, to ensure that non-target species (such as largemouth bass) do not establish in the ponds.
Synergies and Conflicts	*Synergies*. Floodplain ponds will encourage the establishment of a native fish community within the San Joaquin River. The floodplain ponds can be designed and located so that they breach at flow magnitudes required for stimulating riparian recruitment. Thus, two restoration objectives could be achieved with the same flow. Floodplain ponds may also provide suitable habitat for wetland wildlife species, including waterfowl, giant garter snake, and red-legged frog. *Conflicts*. Also, because these ponds will be relatively separated from the river system, and will likely raise fish in confined conditions, connecting the ponds to the main river channel could result in introducing pathogens to the river ecosystem.
Societal/ Infrastructural Impacts	*Ancillary costs*. Floodplain ponds would be constructed on public-owned lands and are not expected to interfere with existing infrastructure. However, as described above, pathogens entering the mainstem San Joaquin from these floodplain ponds could reduce water quality. Because floodplain ponds will be stagnant water for much of the time, mosquitoes and other nuisance pests may also increase in the vicinity and may have societal impacts. Construction and design of the ponds should take these effects into consideration and attempt to mitigate impacts.
Confidence	*Low confidence*. Because this type of restoration activity has not been conducted on such a scale before, it is unclear if it will be a successful approach for re-establishing native resident fish populations.
Cost-effectiveness	*Typical*. Our ability to assess the cost-effectiveness is reduced because of the low/unknown confidence of the activity actually achieving restoration objectives. In addition to the one-time cost of constructing the ponds, the operation will require a water supply and maintenance.
Flexibility	*Fungible*. Although significant time and money may be lost by reversing the action, the constructed ponds would quickly revert to more natural conditions if abandoned. The remaining land could be re-sold and expenses could be recaptured. These assets could then be used for other restoration actions. *Remediable*. If the desired outcome is not achieved, the action is remediable, by filling in ponds and removing associated infrastructure to

Criteria	Characterization of Action
	re-establish the original state of the floodplain.
Strategic Value	*Neutral*. The action has no extraordinary strategic value. Floodplain ponds would essentially be managed as aquaculture, which has been practiced in Reach 1. *Leveraged*. If the action is proven feasible, and this method for establishing native resident fish populations is successful, then the action may provide the necessary pilot information that would allow application of the methodology to other Central Valley streams.
Adaptive Management	*Active adaptive management*. Because of the many uncertainties associated with this action, there are many opportunities to actively manage and to structure the construction and seeding of floodplain ponds to accelerate our understanding of the approach. This includes varying the: (a) design of the pools, to target different habitat needs of native resident fish species (depth, vegetation type and extent, etc.), (b) species of fish (including which species can be raised more effectively together, etc.), and (c) elevation on floodplain, to vary the time intervals of capture of fish from the floodplain ponds. These ponds will provide an excellent opportunity to experimentally-manipulate conditions with various treatment groups to further our understanding of how this may be applied elsewhere.

Although significant uncertainties are associated with implementation of this action, the potential benefits are high, and the proposed restoration of floodplain habitats in the San Joaquin River provide an opportunity for pilot tests of this concept. Most of the resident native fish species that historically existed in the mainstem San Joaquin River are still present, although the abundance and distribution of many species has substantially declined, especially on the valley floor. In order to enhance populations, and to ensure adequate numbers in creating a self-sustaining population which can compete with non-native species, seeding the ecosystem with large numbers of native fish species may provide a competitive edge and allow populations to persist. This action, as described above, also provides an opportunity to conduct this type of restoration on a pilot and experimental scale in order to assess the viability of the approach. Many of the other restoration actions proposed for this reach could be coupled with this action. For example, floodplain re-grading, which is proposed for multiple areas of this reach, could be tailored to create floodplain ponds in specific, strategic locations.

Action 17. Develop a bypass channel around Mendota Pool and Dam.

Constructing a bypass channel around Mendota Dam and Pool would likely facilitate easier upstream and downstream migration of fish, especially salmon species, than providing passage through Mendota Dam and Pool. A bypass channel would also obviate the need to screen water diversions on Mendota Pool to reduce juvenile salmonid entrainment, and it would likely reduce juvenile salmonid mortality associated with predation by non-native fish species that are in Mendota Pool. A bypass channel also provides an opportunity to develop a broad riparian corridor to improve habitat for native fish and wildlife species. The bypass channel would be flanked by levees to protect the Columbia Canal and adjacent land uses.

Criteria	Characterization of Action
Ecosystem	*Substitution*. This action is expected to recreate process, function, and

Criteria	Characterization of Action
Restoration	condition of the original channel, but is short of complete restoration due to the confining levees and drop control structures at the downstream extent of the bypass channel. This action will likely restore sediment connectivity and fish migration passage. Additionally, re-grading the channel will allow for the establishment of riparian vegetation. The bypass channel is a substitution for a restored mainstem channel so that Mendota Pool and Dam can continue to fulfill its water supply function.
Sustainability	*One-time intervention*. Excavation of a multi-stage channel and floodway would require a significant investment of time and resources initially, but the channel would be expected to e self-maintaining after construction. The constructed channel will evolve over time, but it would be expected to continue providing the same types of habitat benefits. *Low maintenance*. The grade control structures at the lower end of the bypass channel may require periodic maintenance, though it is expected that the drop structures would be anchored by large boulders or rip-rap. Levees that border the bypass channel would likely require periodic maintenance.
Synergies and Conflicts	*Synergy.* This action is expected to meet restoration objectives of providing fish passage while also increasing wildlife habitat and floodplain rearing habitat. A bypass channel will also facilitate routing sediment to downstream reaches. *Conflict*. Fish that prey upon juvenile salmonids may congregate near the control structure that directs water into the bypass channel, and/or near the drop structures at the lower end of the bypass channel, thereby increasing potential predation risk.
Societal/ Infrastructural Impacts	*Ancillary costs.* A portion of the Columbia Canal would likely need to be converted from an open ditch to an inverted siphon that crosses under the lower end of the bypass channel. Constructing the bypass channel and floodway would also require taking land out of production. If a bypass channel is constructed, then Mendota Pool would likely be isolated from the mainstem channel in Reach 2B by constructing a permanent weir to prevent juvenile salmon from entering Mendota Pool. Such a structure could interfere with the ability of some water diverters to access flood flows. This impact could potentially be mitigated by placing screened pumps where the weir isolates Mendota Pool from Reach 2B, so that water could be pumped into Mendota Pool during certain conditions. *Ancillary benefits*. A bypass channel would likely provide greater flexibility in operating Mendota Dam during periods of high flow.
Confidence	*Typical.* Though there are some uncertainties about how the bypass channel may evolve as high flows are released, it is likely that a constructed bypass channel will provide the expected benefits.
Cost-effectiveness	*Typical.* A bypass channel would provide multiple ecosystem and flood management benefits—likely more benefits that routing fish, flow, and sediment through Mendota Pool and Dam. However, the cost-effectiveness of a bypass channel would be determined, in large measure, by comparing the costs of the bypass channel with the costs of screening diversions on

Criteria	Characterization of Action
	Mendota Pool and upgrading fish passage facilities on Mendota Dam. Because we do not have a sufficient cost estimate for screening Mendota Pool diversions, it is not possible to evaluate the cost-effectiveness of a bypass channel.
Flexibility	*Remediable to Irreversible*. It would be possible to fill in the excavated channel and return the bypass channel floodway to production; however, this would strand the significant cost of building the channel, and add the cost of filling in the constructed channel and floodplain.
Strategic Value	*Neutral.* This action is expected to provide many ecosystem and flood management benefits. *Provocative*. Developing a functioning bypass channel that provides ecosystem and flood management benefits would require taking land out of agricultural production and buying land or easements from willing sellers. Because of the extent of agricultural production in this reach of the river, a bypass channel could galvanize opposition to restoration in the San Joaquin River.
Adaptive Management	*Passive adaptive management.* The action would include monitoring of fish passage, juvenile salmonid rearing, channel evolution, riparian establishment and succession, and sediment routing.

Alternative designs for a bypass channel have examined more narrow channels that do not meander as a way of reducing the footprint of the bypass channel, and the resultant impact upon land. However, this channel design provides very little flood management benefit, and it generally presents potential problems to fish passage because of the need for steep grade control structures. A bypass channel that meanders (thereby creating channel complexity and reducing the scale of potential grade control structures) and has a functional floodplain generally provides more ecosystem and flood management benefits than a straight bypass channel. It also provides more ecosystem and flood management benefits than routing fish, flow, and sediment through Mendota Pool and Dam. However, constructing a functioning bypass channel that provides these ecosystem and flood management benefits requires a significant commitment of land, which would require purchasing land from willing sellers and taking agricultural land out of production. Because of the significant flood management and ecosystem benefits that could be produced by a re-constructed multi-stage channel with floodway and levees, this action should warrant further examination in conjunction with local landowners.

Cost considerations. Costs were estimated for a bypass channel and associated floodway capable of conveying a discharge of 8,000 cf, flanked by clay-core levees to protect adjacent land uses. The estimated construction cost includes modifying the path of the Columbia Canal, excavating the new channel, and building two levees. Excavation of a bypass channel and floodplain would likely produce excess material that may require disposal. The table below shows the estimated cost components for constructing a bypass channel around Mendota Pool and Dam.

Cost component (unit)	$/unit	Quantity	Cost
Clear and grub/channel improvements (acre)	2,500	53	$131,375
Levee material conditioning (cy)	2.0	658,116	$1,316,232
Levee construction (cy)	11.4	658,116	$7,515,818
Channel excavation/haul off-site	6.8	508,800	$3,479,370

Cost component (unit)	$/unit	Quantity	Cost
(cy)			
Excavate new irrigation canal (cy)	6.8	197,120	$1,347,985
RSP Drop structure (cy)	84.5	1,030	$87,035
Rounded subtotal			$13,878,000
Contingencies (20%)			$2,776,000
Contractor costs (6%)			$999,240
Engineering services (5%)			$832,700
Construction services (5%)			$832,700
Total estimated project cost			$19,318,240

These costs do not include potential land and easement costs required to secure an alignment for the bypass channel. The actual alignment of bypass channel, and the width of its floodway, are flexible, so the total commitment of land for a bypass channel, and the associated cost, is hard to estimate.

Action 18. Reconnect Lone Willow Slough with the mainstem.

The head of Lone Willow Slough is at the Chowchilla Bifurcation structure (the juncture between Reaches 2A and 2B), and it reconnects with the mainstem San Joaquin River in Reach 3 near Sack Dam. Consequently, Lone Willow Slough was considered as a potential approach to providing fish passage past Mendota Dam and Pool. Currently, Lone Willow Slough is discontinuous, as land use practices have filled in sections of the channel (DeFlitch 2002), so portions of the channel would need to be excavated and cleared to support perennial re-watering of the slough and to support fish passage.

Criteria	Characterization of Action
Ecosystem Restoration	*Rehabilitation*. The historical dimensions of Lone Willow Slough are unclear, but a restored slough would likely be smaller than its historical condition because of flow regulation by Friant Dam. Restoring the slough to be continuous, with perennial flow, would likely approximate its historical condition. The preservation and restoration of vegetation bordering the slough would potentially provide a movement corridor for wildlife species. *Intervention*. The principle aim of restoring Lone Willow Slough would be to provide fish passage past Mendota Dam. Though the historical role of the slough in providing a migration pathway for fish is unknown, its value as a fish migration pathway was likely small as compared to the mainstem channel. Re-constructing Lone Willow Slough to provide fish passage around Mendota Dam and Pool would thus be designed to substitute for the fish passage provided historically in the mainstem channel.
Sustainability	*One-time intervention*. Re-constructing Lone Willow Slough would likely require excavating and clearing part of the channel initially to provide unobstructed fish passage and flow continuity.

Criteria	Characterization of Action
	Low Maintenance. Depending upon sedimentation rates associated with neighboring land uses, the re-constructed channel would possibly need to be dredged periodically to maintain flow capacity and unobstructed fish passage.
Synergies and Conflicts	*Compatibility*. The restoration of Lone Willow Slough, coupled with the restoration of riparian vegetation along its alignment, would likely provide habitat for numerous amphibian and bird species, including Giant garner snake and Western pond turtle. *Conflict*. Restoring Lone Willow Slough as the key migration pathway for restored salmonid populations would likely need to be complemented by fish passage barriers that route adult upstream migrants into the Slough, as opposed to the mainstem channel in Reach 3. Similarly, a barrier would need to be placed at the head of Lone Willow Slough to direct juvenile salmon outmigrants into Lone Willow Slough rather than the mainstem channel in Reach 2B. Such barriers would also inhibit the movement of other fish species, which is not desirable. *Hazard*. Lone Willow Slough is bordered by extensive agricultural production, and irrigation runoff could be introduced to the channel, thereby degrading water quality in the primary pathway for restored fish.
Societal/ Infrastructural Impacts	*Ancillary Costs*. Re-constructing and re-watering Lone Willow Slough would likely produce more widespread disruptions to current land use activities, as compared to a Mendota Pool Bypass channel (Action 17), because it would affect a greater number of individual land owners. Also, the restoration of Lone Willow Slough would likely produce comparatively little flood management benefit, as compared with similar actions designed to expand flood conveyance capacity and enhance fish passage in Reach 2B.
Confidence	*Low Confidence*. It is difficult to assess the effectiveness of a re-constructed Lone Willow Slough in facilitating fish passage, considering historical fish populations probably used the mainstem channel more extensively for upstream and downstream migration.
Cost-effectiveness	*Typical*. Because the full length of Lone Willow Slough is not captured by recent aerial photographs, it is difficult to assess the effort that would be required to re-construct and re-water the slough. Nevertheless, the effort required to restore Lone Willow Slough would likely be smaller than the resources and effort required to facilitate fish passage and expand flood conveyance capacity in similar actions in Reach 2B (e.g., screening diversions on Mendota Pool, constructing a bypass channel around Mendota Pool and Dam).
Flexibility	*Fungible*. Any land purchased to support the re-construction of Lone Willow Slough could be sold if it proves to be ineffective as a fish migration pathway. Such funds could then be applied to restore other fish migration pathways. *Reversible*. If Lone Willow Slough proves ineffective as a fish migration pathway, it can be abandoned by blocking fish access at the upstream and downstream ends, and the slough could revert to its current function.

Criteria	Characterization of Action
Strategic Value	*Provocative*. Re-constructing Lone Willow Slough would likely disrupt land use activities and affect a greater number of landowners than similar actions designed to provide fish passage through Mendota Pool (Action 19), accompanied by screening of diversions, or through a Mendota Pool Bypass channel (Action 17).
Adaptive Management	*Passive adaptive management*. Re-connecting Lone Willow Slough can be accompanied by standard monitoring of fish migrating upstream and downstream to assess its value as a fish migration pathway.

The concept of restoring Lone Willow Slough to function as the primary fish migration corridor around Mendota Dam was abandoned early in the development of the restoration strategies because of its potential to impact numerous individual landowners for comparatively little gain in flood damage reduction. Though other actions included in the restoration strategies involve equally significant disruptions to land use activities and affect as many private landowners (e.g., re-constructing the mainstem channel in Reach 4B1 and developing a bypass channel around Mendota Dam), these impacts are generally balanced by a wider array of ecosystem and flood management benefits. The uncertainty of the effectiveness of Lone Willow Slough as a fish migration pathway also undermines its potential value relative to the social impacts associated with the action.

Action 19. Screen diversions on Mendota Pool.

There are numerous water diversions on Mendota Pool with varying capacities. Unscreened diversions can entrain outmigrating salmonid smolts and, for some types of diversions, may also provide a false pathway for adult upstream migration. Screening water diversions on Mendota Pool could help reduce entrainment losses of outmigrating salmonid smolts.

Criteria	Characterization of Action
Ecosystem Restoration	*Intervention.* The purpose of this action is to reduce the effect of a human activity upon fish migration. Screening diversions does not restore historic migration conditions, but it could help prevent stranding of migrating smolts in irrigation channels or flood bypass channels.
Sustainability	*One-time intervention.* Retrofitting water diversions with fish screens generally requires a single initial investment of resources and time. Screens can be expected to function, with periodic maintenance for decades. *Low maintenance*. Although installation of the screens will only have to occur once, regular maintenance and inspection will be required on the screens in order to maintain effective function.
Synergies and Conflicts	*Synergy*. Screening diversions can complement the release of outmigration pulse flows designed to facilitate the migration of juvenile salmonids. *Conflict*. Screened water diversions can become congregation points for fish species that prey on juvenile salmonids. Mendota Pool likely harbors non-native species that will present a predation risk to juvenile salmonids, so there may be no shortage of potential predators in the vicinity of the fish screens, which may substitute one source of mortality for another.

Criteria	Characterization of Action
Societal/ Infrastructural Impacts	*Ancillary costs*. Water diversions will need to be retrofitted with fish screens. The screens will also require periodic maintenance. Fish screens can become clogged with debris, which can impair water supply operations of the diversion until the screen is cleaned.
Confidence	*Typical*. If screens are designed, installed, and maintained properly, then they have the potential to reduce entrainment of outmigrating smolts. However, it is possible that fish screens will attract potential predators, which may reduce the general benefits of the fish screens.
Cost-effectiveness	*Typical*. Fish screening of water diversions generally require a significant initial investment of resources. Though fish screens can be expected to reduce entrainment, it is not always clear if a particular diversion is a particular entrainment hazard, which can raise questions about the benefits of fish screening relative to its cost.
Flexibility	*Reversible*. Screening diversions has no ecosystem-level impact except to provide “safer” conditions for juvenile fish passage. The action is reversible, although removing fish screen requires additional cost and effort.
Strategic Value	*Neutral*. Because of the costs associated with screening and the public support that would be required, there is no inherent strategic value to this action.
Adaptive Management	*Passive*. Monitoring will be required to ensure that juvenile fish are not entrained in the diversions. Monitoring of the distribution of potential predators in the vicinity of a screened diversion would also facilitate an assessment of the potential predation mortality that ma be associated with fish screens

The value of equipping water diversions with fish screens is a contested issue among resource managers and scientists. Though there is general agreement that fish screens can successfully reduce entrainment of fish, there is disagreement about the benefits of fish screens relative to their cost. Different water diversions can present different entrainment risks, because of differences in the scale, type, and location of diversions. Water diversions on Mendota Pool should be assessed for their entrainment potential prior to screening. This can involve both small- and large- scale smolt studies in which entrainment is monitored at each diversion under a range of operating conditions.

Cost considerations. It is difficult to estimate the potential screening costs for Mendota Pool diversions, because water diversions of similar scale and type can have radically different costs based on local conditions and the unique characteristics of a diversion. For example, a review of fish screening projects for diversions between 200 and 300 cfs produced costs ranging between $4 million and $15 million. In general, the larger or more complex the required screening system, the higher the cost. Increased cost may result from additional construction requirements to meet National Marine Fisheries Service and California Department of Fish and Game screening criteria. There are approximately five main diversions, ranging from 10 to 1,500 cfs, at Mendota Pool that could potentially require screening. Diversions of similar scale have been screened.

Potential Large-Scale Restoration Actions for Reach 3

Action 20. Create a floodway.

Reach 3 is bounded by steep banks and irrigation canals that parallel the channel. Within the bank, low-lying agricultural berms separate the channel from adjacent floodplain lands to protect them from inundation. Periodic high flow releases can inundate much of the area between the banks in Reach 3, which generally prevents the cultivation of high-value crops. The steep banks that border the mainstem channel in Reach 3 define a clear floodway. Removal of the berms, or strategic breaching of them, and the purchase of land or easements for the area between the steep banks would re-connect the channel with a portion of its former floodplain. With the restoration of a wide riparian vegetation corridor, Reach 3 could become an important corridor to support the movement of wildlife species.

Criteria	Characterization of Action
Ecosystem Restoration	*Rehabilitation*. The action would restore a functional floodway in Reach 3, but would be reduced in scale from the pre-disturbance floodway.
Sustainability	*One-time intervention*. The action would primarily involve the one-time purchase of privately owned parcels or easements from willing sellers within the floodway width and the removal, or strategic breaching, of the low-lying berms. Once berms are removed or breached, no maintenance would likely be required.
Synergies and Conflicts	*Synergy*. Defining a floodway where the river is free to access its floodplain would complement several other restoration actions, including floodplain inundation to support juvenile salmonid rearing and resident fish spawning. The restoration of a lush riparian corridor in Reach 3 could also provide an important movement corridor for wildlife species by helping to link existing refuge and preserve lands in Reaches 2 and 5.
Societal/ Infrastructural Impacts	*Ancillary benefits*. The primary social benefit of a floodway is the improvement to flood routing and storage. By improving flood management in Reach 3, flood damage could be reduced. In addition, a publicly-owned dedicated floodway improves recreational opportunities along the river. *Ancillary costs*. Creation of a floodway is dependent on the willingness of landowners to sell and would result in most of the agricultural areas between the banks being taken out of production.
Confidence	*Typical*. Providing space for the channel to re-connect with its floodplain is likely to provide the expected benefits to riparian vegetation recruitment and floodplain rearing and spawning.
Cost-effectiveness	*Typical*. Removing the agricultural berms in Reach 3 should be a typically cost-effective way to create a floodway since it supports multiple benefits, including fish rearing, riparian vegetation recruitment, and flood routing and storage.
Flexibility	*Fungible*. The action would primarily involve the purchase of privately owned parcels or easements from willing sellers within the floodway. If the floodway fails to provide the expected benefits, then floodplain lands could be sold, and the proceeds from the sale could be used to support other restoration activities. *Proactive*. The action is a precursor to other restoration actions and would

Criteria	Characterization of Action
	provide the environment and conditions necessary to successfully implement a variety of actions. *Remediable*. It would be possible to replace the berms or repair breaches in berms left in place.
Strategic Value	*Leveraged*. The action helps fulfill many other restoration objectives, such as improving riparian revegetation conditions, rearing habitat, and flood flow routing and storage. *Provocative*. Creation of a floodway and setting back levees would require the purchase of private lands or easements from willing sellers and would result in agricultural areas being taken out of production.
Adaptive Management	*Static*. The action could support adaptive management experiments by providing the precursory conditions necessary to implement other restoration actions.

Restoring thick bands of riparian forest and scrub in Reach 3 could provide an important corridor to support the movement of wildlife species between existing refuge lands in Reach 2 and Reach 5.

Cost considerations. The cost to create a floodway in Reach 3 is largely dependent on the number of acres that would need to be purchased from willing sellers to define the floodway. A planning-level analysis of recent aerial photos indicates that an estimated 4,000 acres of land exist between the steep banks in Reach 3. Assuming an average price per acre of $3,500 for lands in Reach 3 (Correia 2002), potential acquisition costs would be approximately $14 million.

Potential Large-Scale Restoration Actions for Reach 4

Action 21. Reconstruct a multi-stage channel in Reach 4B1.

Despite an advertised conveyance capacity of 1,500 cfs in Reach 4B, actual conveyance capacity is estimated to be 300 cfs. Restoring flow to the mainstem channel in Reach 4B will require constructing a channel that can transport the flow. Constructing a multi-stage channel with a floodway would produce numerous ecosystem benefits, including: improving salmonid migration, expanding floodplain rearing and spawning, and supporting riparian and wetland vegetation recruitment. Reconstructing the channel in Reach 4B1 also provides an opportunity to restore some of the seasonal or perennial wetlands that characterized this stretch of the river historically. Increasing and enhancing floodplain habitats in the project area may benefit native resident fish species that spawn on floodplains, such as Sacramento splittail, and Sacramento blackfish. Shallow, vegetated habitats also provide high-quality rearing habitat for other native resident fish, including Sacramento blackfish, hitch, Sacramento pikeminnow, hardhead, and Sacramento sucker. Re-building a channel to route flows through Reach 4B1 would also need to be accompanied by the construction of new levees to contain flows, because there are no natural features to prevent flows from inundating adjacent land. So constructing a new channel with a floodway that is flanked by clay-core levees would greatly improve flood management and reduce flood damage.

Criteria	**Characterization of Action**
Ecosystem Restoration	*Rehabilitation.* This action is expected to create conditions that are believed to be more typical of natural conditions, though likely at a reduced scale as compared to historical conditions. For example, the re-constructed channel and floodway provides an opportunity to restore seasonal and perennial wetlands, but with a much smaller spatial extent than the vast tule marshes that dominated the river corridor and its flood basins historically.
Sustainability	*One-time intervention.* Building a multi-stage channel that is flanked by levees will require an initial investment of significant time and resources. Following excavation of the constructed channel, little maintenance should be required. The channel will evolve over time in response to the release of high flows; however, the evolving channel would likely provide similar habitat benefits as the original constructed channel. *Low maintenance*. The new levees that would border a re-constructed channel would likely require periodic maintenance.
Synergies and Conflicts	*Synergy*. Re-constructing a multi-stage channel will complement several other actions to facilitate fish passage, juvenile salmonid rearing, and native resident fish spawning. The reconstructed channel and floodway also provides one of the best opportunities for restoring wetland habitat on a significant scale.
Societal/ Infrastructural Impacts	*Ancillary benefits*. This action will significantly enhance flood conveyance and storage in Reach 4B1. *Ancillary costs*. Re-constructing a channel and associated floodway in Reach 4B1 will require the purchase of land and/or easements, and taking agricultural land out of production.
Confidence	*High confidence*. Re-constructing the mainstem channel in Reach 4B1 is likely to provide most of the expected benefits, though there is uncertainty

Criteria	**Characterization of Action**
	about the extent of perennial wetlands that can be restored in the Reach owing to altered flow regime and groundwater conditions.
Cost-effectiveness	*Efficient*. A re-constructed channel is expected to provide multiple, and significant, ecosystem and flood management benefits for the resources committed to the action.
Flexibility	*Remediable*. It would be possible to fill in the excavated channel and floodplains and put the land back into production; however, such a reversal would strand a significant initial cost to build the channel and floodway.
Strategic Value	*Provocative*. Defining a channel and floodway that provides multiple ecosystem and flood management benefits will require the purchase of land and easements from willing sellers. It will also take agricultural land out of production. *Ripe.* Much of the area in Reach 4B flooded in 1997, and Reach 4B is vulnerable to floods in the future, which may stimulate interest in dedicating land to enhance flood protection for adjacent land.
Adaptive Management	*Passive adaptive management*. A re-constructed channel and floodway could be accompanied by monitoring of fish passage, spawning, and rearing in the multi-stage channel. The restoration of riparian berms and wetlands could include monitoring the distribution, abundance, and movement of wildlife species. *Active adaptive management*. It may be possible to examine alternative floodplain configurations to evaluate different designs for restoring wetland habitats in the re-constructed reach.

Constructing a multi-stage channel with a floodway and clay-core levees could significantly improve flood management in Reach 4B1. Much of the material that would be excavated for the multi-stage channel will likely be usable as source material for the construction of levees, which will help reduce the overall effort and cost for this action. Building a new channel and floodway with levees may be viewed with apprehension by local landowners because it will require taking land out of production. However, dedicating land to an expanded channel, coupled with clay-core levees, would greatly enhance flood protection for remaining adjacent lands.

Reach 4B also provides one of the best opportunities for restoring a variety of wetland habitat types because of the soil characteristics in the reach. In conjunction with a wide band of riparian vegetation restored in the Reach 3 floodway, a re-constructed channel in Reach 4B1 would help complete a contiguous corridor that would support the movement of wildlife between the Mendota Wildlife Refuge in Reach 2 and the San Luis National Wildlife Refuge in Reach 5. Because of the significant flood management and ecosystem benefits that could be produced by a re-constructed multi-stage channel with floodway and levees, this action should warrant further examination in conjunction with local landowners.

Cost considerations. Re-constructing a channel with a floodway would require the purchase of land or easements from willing sellers. Because the actual alignment and width of a floodway and levees is flexible, it is difficult to estimate purchase costs associated with the new channel, so we examined the amount of land associated with floodway widths of 1500 feet and 2500 feet. An average cost per acre is assumed to be an average of $5,000 in Reach 4B1 (non-agricultural lands range from $2,000 to $5,000 per acre and agricultural lands range from $5,000 to $10,000 per acre) (Correia 2002). Consequently, a floodway width of 1500 feet encompasses approximately 2970 acres of land, which translates into a potential acquisition cost of $14.9 million. A floodway width of 2500 feet encompasses approximately 4605 acres of land, which produces a potential acquisition cost of $23 million.

In addition to the cost of land or easements, a channel would need to be excavated and two levees would need to be built on each side of the re-constructed channel. The actual height and volume of a levee will be variable, depending upon the distance it is set back from the channel. We also assumed a levee top width of 25 feet; however, it may be possible to build levees with a more narrow levee top width, as have been approved for implementation elsewhere in the region, which would reduce the volume and cost of the levees.

There are two potential flood conveyance options for a re-constructed channel in Reach 4B1, depending on the overall flood routing approach for each restoration strategy. The tables below lay out estimated costs for flow capacities of 4,500 cfs and 8,000 cfs.

4,500 cfs capacity

Expanding the capacity of Reach 4B1 requires excavating a multi-stage channel and building levees from approximately RM 151 to RM 168.4. Levees are required to contain floods in this reach because the land lateral to the channel is generally flat for miles, and there are no natural features to contain high flows. The table below contains the estimated cost components for this action.

Cost component (unit)	$/unit	Quantity	Cost
Clear and grub/channel improvements (acre)	2,500	530	$1,192,500
Levee material conditioning (cy)	1.5	1,846,800	$2,770,200
Levee construction (cy)	11.4	1,846,800	$21,090,829
Channel excavation (cy)	6.1	1,588,800	$9,709,333
Rounded subtotal			$34,763,000
Contingencies (20%)			$6,953,000
Contractor costs (6%)			$2,502,960
Engineering services (5%)			$2,085,800
Construction services (5%)			$2,085,800
Total estimated project cost			$48,390,960

8,000 cfs capacity

The table below contains the estimated cost components for a re-constructed channel and floodway with a greater flood conveyance capacity.

Cost component (unit)	$/unit	Quantity	Cost
Clear and grub/channel improvements (acre)	2,500	530	$1,192,500
Levee material conditioning (cy)	1.5	2,730,000	$4,095,000
Levee construction (cy)	11.4	2,730,000	$31,177,152
Channel excavation (cy)	6.1	1,826,400	$11,161,333
Rounded subtotal			$47,626,000
Contingencies (20%)			$9,526,000

Cost component (unit)	$/unit	Quantity	Cost
Contractor costs (6%)			$3,429,120
Engineering services (5%)			$2,857,600
Construction services (5%)			$2,857,600
Total estimated project cost			$66,296,120

Action 22. Investigate alternative fish migration pathways in Reach 4B1

Because of the scale of effort required to re-construct a channel with floodway and levees through Reach 4B1, and the potential political sensitivity of such a proposal, we examined alternative pathways for routing fish and flows around Reach 4B1. We focused on two potential alternative routes: Pick-Anderson Slough and the Eastside Bypass Channel.

Criteria	**Characterization of Action**
Ecosystem Restoration	*Substitution*. The purpose of examining an alternative pathway for routing fish and flow is to compensate for channel conditions in the mainstem channel in Reach 4B1, which cannot currently provide fish passage or flow routing.
Sustainability	*One-time intervention*. Routing fish and flow through either Pick-Anderson Slough or the Eastside Bypass channel would require altering each channel. The Eastside Bypass channel would likely require less effort because of it larger conveyance capacity, as compared with Pick-Anderson slough. Routing fish through the Eastside bypass channel would likely require excavating a well-defined low flow channel to facilitate passage, while Pick-Anderson Slough would probably require more extensive modification of the channel to accommodate any significant flows.
Synergies and Conflicts	*Synergy*. Either alignment can provide fish passage.
Societal/ Infrastructural Impacts	*Ancillary costs*. Routing flow and fish through Pick-Anderson Slough would likely pose greater conflicts with current agricultural land uses than routing through the Eastside Bypass channel. *Ancillary benefit*. A social benefit of routing fish through the Eastside Bypass channel is that it would generally require fewer resources to implement as compared to restoring the mainstem channel in Reach 4B1 or Pick-Anderson Slough.
Confidence	*High*. The Eastside Bypass channel has sufficient capacity to convey flows routed from Reach 4A. Excavating a low-flow channel in the Bypass channel can also be expected to provide sufficient fish passage conditions, through the low-flow channel will need to be monitored to ensure it maintains adequate flows depths as the channel evolves.
Cost-effectiveness	*Efficient*. As compared to re-constructing a channel in the mainstem channel in Reach 4B and restoring Pick-Anderson Slough, routing fish and flow through the Eastside Bypass channel should be comparatively less expensive, while still satisfying the objectives of providing fish passage.
Flexibility	*Reversible*. If the excavated low-flow channel in the Eastside Bypass channel fails to provide adequate passage conditions, it can be abandoned as a fish migration route without harming the flood conveyance operation

Criteria	**Characterization of Action**
	of the bypass.
Strategic Value	*Provocative*. The purpose of providing fish passage through the Eastside Bypass channel is simply to move fish upstream and downstream; no habitat creation is contemplated for the bypass channel in order to preserve its flood conveyance capacity. The concept of providing a barren migration corridor for fish may be controversial with some stakeholders. Also, some stakeholder may be concerned that providing fish passage through the Eastside bypass would somehow decrease its flood routing capacity.
Adaptive Management	*Passive adaptive management*. Monitoring passage conditions in the excavated low-flow channel in the Eastside Bypass will help ensure sufficient passage conditions for fish.

Routing flow and fish through the Eastside Bypass channel can be achieved more quickly and with less expense as compared to re-constructing a mainstem channel in Reach 4B or restoring Pick-Anderson Slough. Using the Eastside Bypass channel also causes fewer potential conflicts with surrounding land uses, because it can generally be achieved without the disruptions to private land that are required for restoring a channel in the mainstem Reach 4B or Pick-Anderson Slough. Routing fish and flow can also be an interim measure to support fish passage and restored flows while a multi-stage channel with a floodway and levees is constructed in the mainstem Reach 4B1, because such excavations and levee construction will take time to design, permit, and implement. Routing fish through the Eastside Bypass channel will require providing fish passage facilities at the Mariposa Bifurcation structure.

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