CALFED SCIENCE FELLOWS PROGRAM

In cooperation with the

California Sea Grant College Program

FELLOWSHIP APPLICATION COVER PAGE

APPLICANT TYPE ☐ Postdoctoral Researcher ☐ Ph.D. Graduate Student

PROJECT NUMBER ______________

PROJECT TITLE A Mechanistic Model to Evaluate and Improve Riparian Restoration Success

FINANCIAL SUMMARY

First Year CALFED Funds Requested:	$ 50,396
Total CALFED Funds Requested:	$ 100,263
Duration:	2 years
Proposed Start/Completion Dates:	9/1/02 - 8/31/04

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Will animal subjects be used? ☐ Yes ☐ No

APPROVAL DATE: ______________ PROTOCOL #: ______________ PENDING: ______________

Does this application involve any recombinant DNA technology or research? ☐ Yes ☐ No

A MECHANISTIC MODEL TO EVALUATE AND IMPROVE RIPARIAN RESTORATION SUCCESS

I. Introduction and Problem Statement

As a result of human development, riparian forests in California's Central Valley have been reduced by more than ninety percent of their historical extent (Katibah 1984). Many of CALFED's priority at-risk species rely on riparian ecosystems to maintain fundamental habitats and processes. Thus restoration of riparian forests is a priority objective for CALFED (CALFED 1999, AFRP 1997, SJRMP 1995, CALFED 2001). If large-scale restoration efforts are to be successful, the mechanisms driving these natural processes need to be understood more precisely and evaluated under realistic field conditions. The goal of this research proposal is to develop a predictive understanding of recruitment and survival of the pioneer riparian tree species—cottonwoods and willows—that dominate the crucial initial phase of riparian community recovery.

Since European widespread settlement began 150 years ago, riparian ecosystems in the San Joaquin and Sacramento basins have been severely altered by the cumulative effects of instream mining, dam and levee construction, farming, grazing, and urban encroachment (Vick 1995; Cain 1997; JSA and MEI 1998; McBain and Trush 2000, Stillwater Sciences 2001, 2002). The vast majority of riparian forest, marsh, and seasonal wetland habitat throughout the entire Central Valley has been lost over the past century. Riparian forest age and canopy structure of remaining stands have become less complex as older hardwood trees mature and die, and regeneration of young ones is inhibited by human-induced processes (Katibah 1984, JSA 1998, McBain and Trush 2000, Stillwater Sciences 2001). Because in the southwestern United States most fish and wildlife species are directly dependent on riparian areas for some or all of their life cycle (Rinne 1993; Naiman et al. 1993; Naiman and Decamps 1997; Tellman et al. 1997; Patten 1998), impacts of habitat loss on terrestrial and aquatic communities have the potential to be much greater than the riparian areal proportion within the landscape.

Many of CALFED's priority at-risk species rely on riparian forests for water temperature regulation, nutrient and sediment deposition, and allochthonous food web inputs. In its Draft Stage 1 Implementation Plan, CALFED (2001) outlines the need to increase the extent of self-sustaining riparian habitat (especially in the San Joaquin Basin), for ecologically functioning flow schedules, and for ecologically-based mechanistic studies, implementation designs and monitoring plans to guide floodplain restoration projects (see Appendix A). A great deal of effort and resources have been allocated in the last five years for floodplain restoration projects in the Central Valley, yet current program assessments cite the lack of process-based studies to guide their design and monitor their success (*e.g.*, Adaptive Management Scientific and Technical Panel 2001; CALFED 2001). Hypothesis-based monitoring of ecosystem processes needs to be at the core of adaptive management programs but is not fully implemented in most projects.

I am seeking funding for two years under the CALFED Science Fellows Program to develop a field-calibrated model of factors affecting recruitment and survival of pioneer riparian tree species and use the model to evaluate the success of habitat recovery at two recently completed floodplain restoration projects. My research goal addresses the need for a quantitative, field-based understanding of physical and biological processes that can guide process-based restoration actions.

I began work on the recruitment model in fall 2001 as my dissertation research project. The first year of field study (2002) is funded by CALFED in a pilot grant to Stillwater Sciences to develop a mechanistic framework of riparian recruitment processes for the San Joaquin Basin. This pilot project, which includes one year of model calibration at sandbar sites on the Tuolumne River, will be completed in fall 2002. This current proposal extends the calibration research for a second field season and tests the model at two new sites (Special Run Pool 9 Channel Restoration on the Tuolumne River and the Robinson Reach Habitat Enhancement Project on the Merced River) in 2003-04. Extending the study temporally is critical to understanding the interannual variability of flow patterns and seed release periods, which are key processes affecting recruitment success. Applying the model to evaluate recently constructed, high-priority CALFED restoration projects will improve both the general applicability of the model and the scientific level of post-project monitoring. Anticipated project (and Ph.D.) completion is fall 2004; the project schedule is outlined in Table 1.

The mechanisms of cottonwood recruitment and survival are well understood in other ecosystems (Stromberg et al. 1993; Stromberg 1997; Auble and Scott 1998; Scott et al. 1999, 2000; Shafroth et al. 1998, 2000), but relatively little work has been done to date on Central Valley species and ecosystems, despite intense interest and investment in ecosystem restoration. It is crucial that we develop data specific to the Central Valley to construct locally-applicable models. This proposal seeks to identify and address scientific information gaps and develop a series of management tools using a rigorous research program on Central Valley rivers.

As part of this effort, I plan to synthesize existing data on recruitment mechanisms and parameters from existing Central Valley literature and data sets into a publicly-available database. This will require integration of my project data with other existing sources of hydrologic, topographic and vegetation data. Anticipated products from this project include:

- a database of Central Valley riparian source data, as well as reference (non-local) and regional values for parameters influencing riparian recruitment;
- completion of field-based, regionally- and species-specific numerical model calibrating a general conceptual framework to field sites on the Tuolumne River
- a field-tested evaluation of the model's ability to predict recruitment success on on-going restoration projects on the Tuolumne and Merced rivers;
- detailed criteria for designing flow schedules that will benefit natural recruitment of native riparian trees; and
- detailed criteria for the design of floodplain reconstruction projects in the San Joaquin Basin.

II. Conceptual Model and Hypotheses

Conceptual Model

Previous work that I and others have conducted on the Tuolumne, Merced, and mainstem San Joaquin rivers document that seedlings germinate readily on low bars in these rivers, but apparently do not survive to reproductive maturity (Stella et al. in press; McBain and Trush 2000; Stillwater Sciences 2001; FWUA/NRDC Coalition 2001). There are very few sapling cohorts in evidence along these rivers, suggesting that recruitment and successional processes for these species are impaired.

Central Valley riparian tree species have evolved reproduction strategies that depend on the timing and magnitude of river flow conditions during the historical spring snowmelt period. Early successional species such as cottonwood and willow release many seeds in spring that are viable for a short time, typically 2–3 weeks and require bare, moist substrates to germinate (Braatne et al. 1996). On sloping point bars and river banks, recruitment events often occur in narrow bands that are constrained at the higher elevations by the seedlings' ability to maintain contact with the receding water table following spring floods, and at lower elevations by prolonged inundation and frequent scour during subsequent high-flow periods. River regulation changes flow timing, magnitude, and rate of recession and has the potential to reduce the viability of riparian seedlings.

I will combine field observations with controlled greenhouse experiments to calibrate the recruitment box model for the Tuolumne River (Mahoney and Rood 1998). The "box" describes the window of optimal conditions for seedling recruitment (Figure 1) and is defined spatially by bank elevation relative to river hydrology and temporally by the spring seed release period. The sloping line within the recruitment box represents the maximum survivable rate of water table decline, which varies by species and by local water demand (vapor pressure deficit). Water table declines steeper than this rate will not support successful seedling establishment. Experimental studies in other ecosystems estimate this rate to be approximately 2-4 cm/day for various cottonwood species and somewhat less for willows (McBride et al. 1989; Mahoney and Rood 1992 and 1998; Segelquist et al. 1993).

The recruitment box calibration studies are designed to provide quantitative information necessary for several restoration approaches in the Central Valley, including reconfiguring individual floodplain sites to maximize recruitment success and prescribing flow releases to increase recruitment throughout a river corridor. Using these approaches, land and water managers can model the most cost-effective scenarios to restore natural recruitment processes in Central Valley riparian woodlands (Figure 2).

I will focus on three key species with different life histories and management concerns to parameterize the model: Fremont cottonwood (*Populus fremontii*), black willow (*Salix gooddingii*) and sandbar willow (*S. exigua*). The first two are dominant canopy trees in pioneer successional communities that are important sources of instream woody debris and bird and wildlife habitat; these trees are in decline throughout most of the Central Valley (Thomson 1980; Roberts et al. 1980). Sandbar willow, in contrast, is a ubiquitous, vigorously-cloning shrub that colonizes formerly dynamic river channels following flow regulation and contributes to channel narrowing and simplification of instream fish habitat (Pelzman 1973). There is a patchy body of research on all species; my proposed studies are designed to compare recruitment ecologies between species, fill in data gaps, and suggest ecologically-based management strategies.

Limiting Factor Hypotheses

The field and greenhouse studies will investigate specific hypotheses about relationships between recruitment success and environmental conditions and more general hypotheses regarding the spatial and temporal patterns of microclimate, flow, and groundwater (below). Results of the proposed seedling germination and survival studies will be evaluated in light of potential mechanisms governing seedling recruitment and survival, stated below as alternative limiting factors:

1. Poor germination due to inadequate seed supply from reproducing adults.

2. Poor germination due to poor seed bed conditions. There are two possible mechanisms that reduce seed bed quality: (2a) competition from existing vegetation; and (2b) out-of-phase timing between seed release and seed bed moisture.

3. Mortality due to fluvial forces. Seedlings of riparian trees may be killed during the winter following germination because of physical disturbance, including (3a) sediment scour; (3b) burial by deposition; or (3c) prolonged inundation.

4. Mortality due to water stress. Seedlings of riparian trees may fail to survive the first several growing seasons because of inadequate soil moisture conditions. This mechanism can be divided into two parts, distinguished by seasonal timing of moisture stress: (4a) seedling desiccation in the spring near the high stage line due to water table declines outstripping seedlings' root growth; and (4b) desiccation later in the season due to an inadequate perennial water table.

Data analyses will be designed to test these hypotheses. Results of this study will also shed light on more general questions regarding patterns of environmental factors that influence seedling recruitment, such as:

5. Species-specific and climatologically-influenced variation in peak seed release timing.

6. Effects of vapor pressure deficit on seedling water demand and physiological response.

7. Seasonal and river-scale linkages between groundwater and surface water levels.

III. Research Approach

The proposed research will be done in three tasks, detailed below. Task 1 includes analysis of existing data from existing sources and recent field studies. In Task 2 I will calibrate the recruitment box model (Figure 1) for three sites on the Tuolumne River using existing (2002) and new (2003-04) data. In Task 3 I will apply the model to recently completed restoration sites on the Tuolumne and Merced rivers to predict germination and survival patterns of naturally recruiting seedlings and provide management recommendations to improve flow and floodplain restoration approaches (Figure 2). The projected schedule is outlined in Table 1.

Task 1: Analysis of existing data

Recruitment mechanisms and parameters

Though the mechanisms governing recruitment of pioneer riparian trees are well understood , the conceptual models have been developed for ecosystems outside of California (Auble et al. 1994; Scott et al. 1997; Mahoney and Rood 1998; Johnson 1998; Shafroth et al. 2000) and process-based research has not focused on Central Valley native species and environments. However, a large body of work does exist from conference proceedings on Calfornia riparian systems (Sands 1977, Warner and Hendrix 1984, Abell 1989, The Wilderness Society, in press) and other published and unpublished sources (Table 2 and Appendix A). The purpose of this task is to analyze and synthesize existing knowledge about recruitment processes and environmental conditions in the Central Valley and compare them to reference values from work done on other ecosystems. The outcome of this task will be a database of reference and regional values culled from available data and standardized wherever possible. The database will include an annotated bibliography describing the main findings and identified data gaps. I will work with the CALFED Science Consortium, the Department of Fish and Game and other CALFED agencies to make this database publicly available.

Central Valley recruitment model data sources
Constructing and calibrating a regional model of riparian recruitment requires integrating physical and biological data from many sources, identifying data gaps, and augmenting existing knowledge with new data. The pilot study I am currently conducting with Stillwater Sciences has required compiling and analyzing existing sources of hydrologic, geomorphic, riparian vegetation, and photographic in the Central Valley (see Appendix B). Under the proposed project I will expand my use of these data sources. For example, I will integrate historical flow data with site stage-discharge relationships to estimate pre-dam spring hydrograph recession rates; these parameters will guide design of treatment ranges in the root-growth studies. Existing floodplain topography at the restoration sites will be used for model verification to construct probability surfaces for predicting areas of potential riparian recruitment. Existing aerial photographs will be used for site selection and assessment. Regional groundwater records will be used to estimate ranges of groundwater depths and dynamics that can support natural vegetation recruitment processes.

Additional data analyses
Some of the data being generated under the current Stillwater Sciences project will not be able to be analyzed under the existing contract scope. These include innovated digital photographic methods of recording whole tree seed release, sticky trap results of seed capture experiments, seedling ecophysiological responses to experimental recession rates, and species composition and cover data from the sandbar germination plots. In all cases, the data collection was done to augment the pilot project scope and done systematically to allow later analysis. It is important and timely to analyze these data under the current proposal and summarize results in peer-reviewed journal articles and the recruitment process database.

Task 2: Develop and calibrate a general recruitment model for San Joaquin Basin rivers
The purpose of this task is to construct a general predictive model that is field-parameterized for the Central Valley, most specifically for the San Joaquin Basin. I will develop the model using existing data sources (Task 1), the Stillwater Sciences pilot study results, and field studies conducted under this research proposal to calibrate and test the model. These calibration field studies are designed to fill known data gaps and are outlined in more detail in the subtasks below. Field studies to test the model at existing and on-going floodplain restoration sites are described in Task 3. Field study protocols developed for the Stillwater Sciences pilot project are described in Appendix C

The general research approach is to quantify seedling recruitment and survival against the context of seed release phenology , site-specific topography, flow regime, and seedling water demand (vapor pressure deficit). Results will be integrated with historical flow data and published plant physiological thresholds (McBride et al. 1989; Mahoney and Rood 1998) to construct a predictive model of recruitment success and survival at sites where topographic information and flow data are known.

The field tasks structured as a series of site-based observational studies and greenhouse experiments to parameterize the general recruitment box model and to test the effects of various environmental factors on the germination success and survival of seedlings of Fremont cottonwood, Goodding's willow, and sandbar willow. This research addresses several critical unknowns about these species' life histories in their Central Valley context, including:

A. length of seed release and viability period
B. maximum seedling root growth and the maximum survivable rate of water table decline
C. field conditions of water table dynamics and soil moisture availability and bank elevation corresponding to seedling desiccation and scour thresholds

D. actual seedling recruitment density, timing, and survival under field conditions

Data analyses will be designed to: (1) quantify regional values and uncertainty for recruitment box model parameters; (2) validate model parameters in predicting seedling recruitment and survival at test sites on the Tuolumne River sites; (3) evaluate relationships between environmental factors (*e.g.* flow, temperature, vapor pressure deficit) and dependent biological processes (*e.g.,* seed release timing, seedling survival and/or desiccation); and (3) evaluate whether environmental conditions and existing management actions are conducive to seedling recruitment and survival. The subtasks comprising the model calibration efforts are described below.

Task 2.1: Seed release timing and viability

In this task I will document seed release timing for the three riparian tree species by observing reproductive output of female trees in the field at six different sites within the San Joaquin Basin over the growing season (see Appendix C for site characteristics and field methods). This information will define the temporal dimension (horizontal axis) of the recruitment box model. Scant phenological data are available for Central Valley riparian species, and most of those are for the Sacramento River system (*e.g*., CALFED 2000; Peterson 2001). From studies on other rivers (*e.g.,* Mahoney and Rood 1998), the target period for cottonwood and willow seed dispersal is April through June. Because the timing is expected to vary with environmental variables such as temperature and humidity, the study will be conducted in two years and at a variety of sites within the San Joaquin Basin.

Seed viability is another important component of the temporal recruitment window. It is generally believed that willow and cottonwood seeds are viable only 2-3 weeks following dispersal (Braatne 1996), but Pelzman (1973) found that laboratory viability for some Central Valley species was several months. To resolve this information for San Joaquin Basin populations in my study (and especially for black willow, which has not been studied to date), I am conducting viability assays for the three tree species. In order to rule out the presence of a seed bank, I am assessing germination composition from soil samples taken before the 2002 seed release period. Limited additional seed bank and viability studies will be necessary in 1993 at the proposed model validation sites.

Task 2.2: Root growth experiments

The objective of this task is to determine seedling growth and mortality rates for the three species in response to different water table decline scenarios. This research component corresponds to the sloping line within the recruitment box model, which represents the maximum survivable rate of water table decline. An additional objective is to assess differences in physiological stress response and life history strategies between the three target species.

Because river and groundwater hydrology in any one year may not provide a suitably large range of conditions (especially on regulated rivers where flows may be very stable), I will conduct controlled experiments in steel tanks at the UC Russell Reservation in Lafayette, CA to manipulate seedling water tables at a variety of recession rates. Recession rates are designed to bracket the hypothesized rate of maximum root growth (which determines survival) for each species as well as field-verified water table recession rates occurring at the Tuolumne River study sites under existing conditions and calculated for pre-regulation flow regimes. Methods developed for hydropower studies (McBride et al. 1989) and other ecosystems (Kranjec et al. 1998; Mahoney and Rood 1991 and 1992; Segelquist et al. 1993) will be refined for Central Valley species and regulated water decline rates.

Task 2.3: Field-based hydrologic measurements

I will measure water availability to plants at field sites on the lower Tuolumne River by monitoring channel water stage, water table elevation, and soil moisture level during the growing season and to document the water table recession rate following controlled spring flow releases for salmon smolt outmigration. By documenting the field conditions at potential recruitment sites (sandbars), I will calibrate the vertical axis of the recruitment box model, which corresponds to bank elevation where successful recruitment occurs. The field data is also necessary to ensure that controlled decline rates in the tank experiment are comparable to field conditions.

Under the Vernalis Adaptive Management Plan, a program to increase the populations of Central Valley salmonids, San Joaquin Basin dam operators release controlled pulse flows during April and May of each year. This planned pulse provides an excellent opportunity for monitoring the effects of flooding on riparian recruitment, and this year (2002) I am monitoring surface water dynamics, water table elevations and surface moisture changes over time following recession of the pulse flows.

During the 2002 growing season, hydrologic data are being collected to document site inundation (using continuous stage-recorders), water table recession rates (using ground wells), and soil moisture patterns (volumetric water content using time-series standing-wave impedance measurements) at three sandbar sites on the lower Tuolumne River. Because the river's hydrology and the VAMP releases vary from year to year, and seedling survival is partly dependent on inter-annual hydrologic patterns the collection of a second year of data under this proposal is important for model calibration. Sampling would continue at these sites during 2003 to expand the model calibration range, and sampling will be initiated at two floodplain restoration/model testing sites (see Task 3 below). Site locations and characteristics are listed in Table 3. Differences in substrate texture at the restoration site will provide an excellent opportunity to parameterize that factor, which is not included in the Stillwater Sciences study, for the regional recruitment model.

Task 2.4: Model calibration using field recruitment surveys

The objective of this task is to calibrate the recruitment box model at the model sandbar site by documenting actual seedling survival relative to site hydrologic conditions. I will document germination and survival of naturally-recruiting cohorts over the growing season and winter in 2002 and 2003. In spring 2002, 180 paired plots were established on the three sandbar sites (see Appendix C for methods). Plots are stratified between two dominant sandbar elevations and between upstream and downstream sectors of the bar to enable gross comparisons of seedling survival at different water table depths and with potentially different deposition and scour patterns. Each pair includes one treatment plot in which competition from existing vegetation is removed and one control plot.

Natural recruitment will be surveyed throughout the seed release and growing seasons. Seedlings will be mapped, aged and monitored for survival. Sampling events will begin immediately after the VAMP flow pulse and at intervals through the spring and summer.

In order to calibrate the general recruitment model, I will compare recruitment success (density and survival) to differences in plot hydrology (*e.g.*, inundation duration, water table depth, soil desiccation) and competition from existing vegetation. Seedling survival will also be assessed in relation to site vapor pressure deficits. Time-series differences in species composition of seedling recruits will be compared to seed release timing and seed capture patterns at the bar sites. I will evaluate results within the limiting factor hypothesis framework (Table 4) and quantify ranges (central tendency and variance) for three main parameters of the recruitment box model (Figure 1).

Task 3. Model verification: predicting and testing restoration success

The true value of the regional model calibration efforts will be determined by its success in predicting success of actual restoration efforts. CALFED, its constituent agencies, and the CVPIA Anadromous Fisheries Restoration Program (AFRP), have allocated significant resources in the last five years to floodplain reconstruction projects and flow studies that prioritize benefits to fish and riparian habitat.

However, project assessments to date note a general lack of hypothesis-driven planning and monitoring that integrates our understanding of physical and biological mechanisms (Adaptive Management Scientific and Technical Panel. 2001; CALFED Science Panel comments at the February 2002 Lower Merced River Adaptive Management Forum).

In this task I will test the regional recruitment model at two large-scale, CALFED-funded floodplain restoration sites: the Robinson Reach of the Merced River Salmon Enhancement Project (CDWR 2001) and the SRP 9 Channel Restoration (McBain and Trush 2000; AFRP 1997). I will use existing CDWR and CDFG data, including pre-project vegetation surveys, groundwater monitoring, and post-project floodplain topography and stage-discharge relationships, as well as supplemental data collection using methods developed for the model calibration project (Task 2 and Appendix C) to predict areas of successful recruitment within the floodplain restoration sites based on hypothesized limiting factors (Table 4). Model predictions will be rigorously tested using a plot-based sampling design outlined in Task 2.4 above. Results will be analyzed using the limiting factor framework and included in the recruitment processes database developed under Task 1.

I will work closely with biologists, engineers and project managers from California Department of Fish and Game, California Department of Water Resources and the Tuolumne Irrigation District to ensure that the model-testing task provides needed post-project assessment, complements on-going agency efforts, and addresses past vegetation monitoring weaknesses identified in the Tuolumne and Merced River Adaptive Management Forums. This component will provide a scientifically-rigorous adaptive management framework for evaluating the restoration projects' success, will maximize efficiency and standardize monitoring efforts between projects, and will inform future restoration efforts. I will work with the Tuolumne River Technical Advisory Committee and the Merced River Stakeholder Group to garner input to the model testing studies and present results.

A field-parameterized regional recruitment model will also be applicable on a corridor-wide scale to design and evaluate flow releases to increase riparian recruitment. Though Central Valley restoration projects to date have not taken this approach, designing ecologically-sensitive flow schedules is a high-priority CALFED action (CALFED 2001; see Appendix A), and pilot projects on the San Joaquin River have taken this approach (FWUA/NRDC Coalition 2001; Scott et al. 2000). As part of this task I will evaluate the VAMP pulse flows on recruitment success on the Tuolumne (in 2002 and 2003) and Merced (in 2003) rivers as potential recruitment flows. Though they are intended primarily to aid salmon smolt outmigration, the controlled timing, magnitude and recession rates of the flows are within the range of feasible future riparian restoration actions and warrant analysis. Comparing the effects of the pulse flows between rivers in 2003 will provide an excellent opportunity to field-test potentially different flow timing and recession treatments, as indicated by the 2002 VAMP operational plan (MBK Associates 2002).

IV. Anticipated Benefits

This project will directly benefit CALFED and its public constituents by the development of field-tested, regionally applicable tools for designing and evaluating restoration projects. In addition to directly benefiting two existing, high-priority restoration projects, the proposed recruitment model will become a guide for future riparian restoration projects in the Central Valley. The riparian restoration database will provide CALFED planners, stakeholders and other researchers a much-needed source of existing information organized to aid the development of hypothesis-driven restoration designs and adaptive management plans. The anticipated products specific to each proposal task are listed in Table 5.

In addition to these products, this project will allow members of the mentorship team and me to fulfill important professional and research goals. In collaboration with my academic and community mentors, I intend to write and publish at lease three peer-reviewed journal articles, complete my dissertation, and present the results of the project at several technical meetings, including the 2004 CALFED Science Conference. I have already registered to present the technical methods and preliminary results from the on-going Stillwater Sciences pilot study as a poster at the Ecological Society of America's 2002 annual meeting and in a presentation at the 2003 CALFED Science Conference.

My research mentors will realize project benefits in co-authoring peer-reviewed articles and applying their existing research expertise to new ecosystems and resource management challenges. For Dr. McBride, this project updates a riparian research direction begun almost twenty years ago. For Dr. Battles, this project reflects an opportunity to extend his theoretical and field-based research in forest community ecology to riparian woodlands.

This project will benefit the CALFED community mentors through the application of rigorous basic science to restoration management strategies on regulated rivers and through co-authorship of restoration-oriented journal articles. As a member of the CALFED Independent Science Board, Dr. Patten has been an outspoken advocate for hypothesis-driven research on mechanisms that sustain riparian communities and for ecologically-focused and quantifiable restoration goals. Ms. Reed and the Departments of Fish and Game and Water Resources stand to benefit from the process-based scientific approach used to evaluate the SRP 9 and Robinson Reach floodplain revegetation success. Coordinating this proposed research effort with the agencies' monitoring needs for those projects offers a unique opportunity to simultaneously test a new, process-based model for restoration, augment resources for post-project monitoring, standardize and compare restoration success between projects, establish an adaptive management framework for follow-up project maintenance and design of new habitat enhancement projects, and evaluate current managed flow regimes for riparian restoration.

Table 1. Proposed project schedule

		2002 Pilot Study				Proposed CALFED Science Fellow Project								
Task number	**Task Description**	**Fall 2001**	**Winter 2002**	**Spring 2002**	**Summer 2002**	**Fall 2002**	**Winter 2003**	**Spring 2003**	**Summer 2003**	**Fall 2003**	**Winter 2004**	**Spring 2004**	**Summer 2004**	**Fall 2004**
1	**Analysis of existing data**													
	Riparian database development					■	■	■	■	■				
	Analysis of pilot study data					■	■							
2	**Model calibration (Tuolumne sites)**													
2.1	Seed release timing and viability			■	■			■	■					
2.2	Root growth experiments				■									
2.3	Site hydrology	■	■	■	■	■	■	■	■	■				
2.4	Seedling recruitment surveys			■	■			■	■	■				
3	**Model verification (restoration sites)**													
	Field studies					■	■	■	■	■				
	Model predictions									■	■			
	Data analysis and model testing										■	■	■	
	Management recommendations													■

Table 2. Examples of reference (non-California) and regional data sources on experimental and observational results of riparian recruitment studies.

Process	Reference parameters	Regional parameters/ application	River system	Data gaps for the Central Valley
Seed release phenology	Mahoney and Rood 1998	Peltman 1973	Clear Creek	Methods unreplicable
		Bair 2001	Trinity	Qualitative
		Peterson 2002	Sacramento	One year only
		Friant WUA/NRDC 1999	San Joaquin	No cottonwood data
Seed viability	Braatne 1996	Peltman 1973	Clear Creek	No black willow data
Root growth rates	Segelquist et al. 1993 Rood and Mahoney?	McBride et al. 1989	Laboratory study	No black willow; treatment range inadequate
Site hydrology	Mahoney and Rood 1998	Stillwater Sciences 2001 Stella et al. in press	Merced	Pilot study at one site
		Friant WUA/NRDC 1999	San Joaquin	No integration with vegetation data
		TNC (get ref)	Sacramento	Pilot study at one site
Seedling recruitment and survival	Stromberg 1997	Bair 2001	Trinity	No Central Valley data
		Stillwater Sciences 2001 Stella et al. in press	Merced	Pilot study at one site
		Friant WUA/NRDC 1999	San Joaquin	No integration with hydrology data
Model application	Shafroth et al. 1998 Auble et al. 1994	none		

Table 3. Model calibration and testing sites.

River	Site	River Kilometer	Substrate	Sampling Purpose	Sampling initiated
Tuolumne	Ott	8.2	sand	model calibration	Fall 2001
Tuolumne	Grayson	9.2	sand	model calibration	Fall 2001
Tuolumne	Venn	11.1	sand	model calibration	Fall 2001

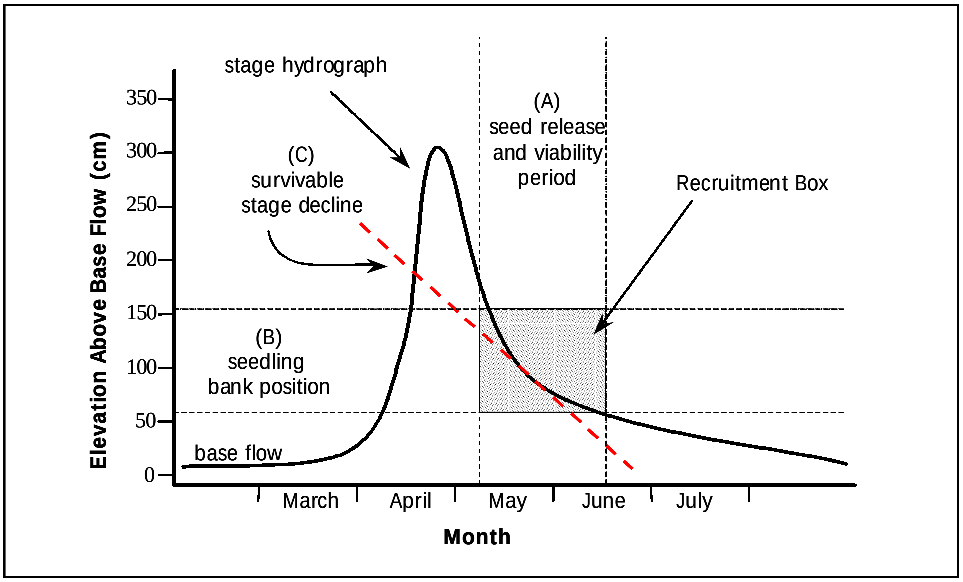
River	Site	River Kilometer	Substrate	Sampling Purpose	Sampling initiated
Tuolumne	SRP 9	41.0	sand & gravel	model testing and restoration monitoring	proposed Fall 2003
Merced	Robinson	70.4	gravel	model testing and restoration monitoring	proposed Fall 2003

Table 4. Limiting factor hypotheses and methods of testing.

Limiting Factor	Factor Isolation Method	Predicted Results if Factor is Limiting
1. seed availability	Sticky traps at sandbar sites	No germination accompanied by lack of seed catch
2. seed bed availability		
2a. competition from existing vegetation	Cleared vs. control plots	Higher germination on cleared plots.
2b. timing of seed bed availability	Varied plot elevations	Low germination in moist plots Peak seed abundance out of phase with availability of moist seed beds.
3. physical disturbance		
3a. scour	Varied plot elevations	Evidence of seedling removal.
3b. deposition	Varied plot elevations	Evidence of new scour or deposition.
3b. prolonged inundation	Varied plot elevations	Increased mortality following prolonged inundation.
4. water stress		
4a. flow recession steeper than seedling root growth	Varied plot elevations Root growth observations	High germination followed by high mortality in early summer. Root growth less than water table recession.
4b. perennial water table inadequate	Varied plot elevations Soil moisture patterns	High mortality in later summer/fall in plots with deeper water tables

Table 5. Anticipated project products.

Task	Products	Description
1. Analyze and synthesize existing data	Central Valley riparian database	Annotated bibliography; flow records; seedling survival surveys; vegetation maps
	Recruitment model matrix	Compares model parameters (phenology, hydrology, seedling survival, physiological response) from reference (non-California) and Central Valley-based sources
	Data analysis of 2002 pilot recruitment study	New analyses of adult phenology, seedling physiology, and plot competition using 2002 pilot study data.
2. Calibrate recruitment model	Predictive numerical model relating recruitment success to seasonal and site-specific environmental conditions	The model integrates field-based values (central tendency and variation) for each model parameter. Model inputs are site topography, hydrology and existing vegetation. Output is predicted recruitment success.
3. Model verification	Baseline vegetation surveys of restoration sites and recruitment predictions	As-built condition of floodplain sites (plot cover, species composition, elevation, substrate)
	Post-winter recruitment assessment	Quantitative recruitment assessment (species composition, density, survival) and evaluation of model predictions
	Pulse flow assessment	Evaluation of VAMP pulse hydrograph (magnitude, timing, duration, rate of change) in promoting natural recruitment processes and management recommendations.



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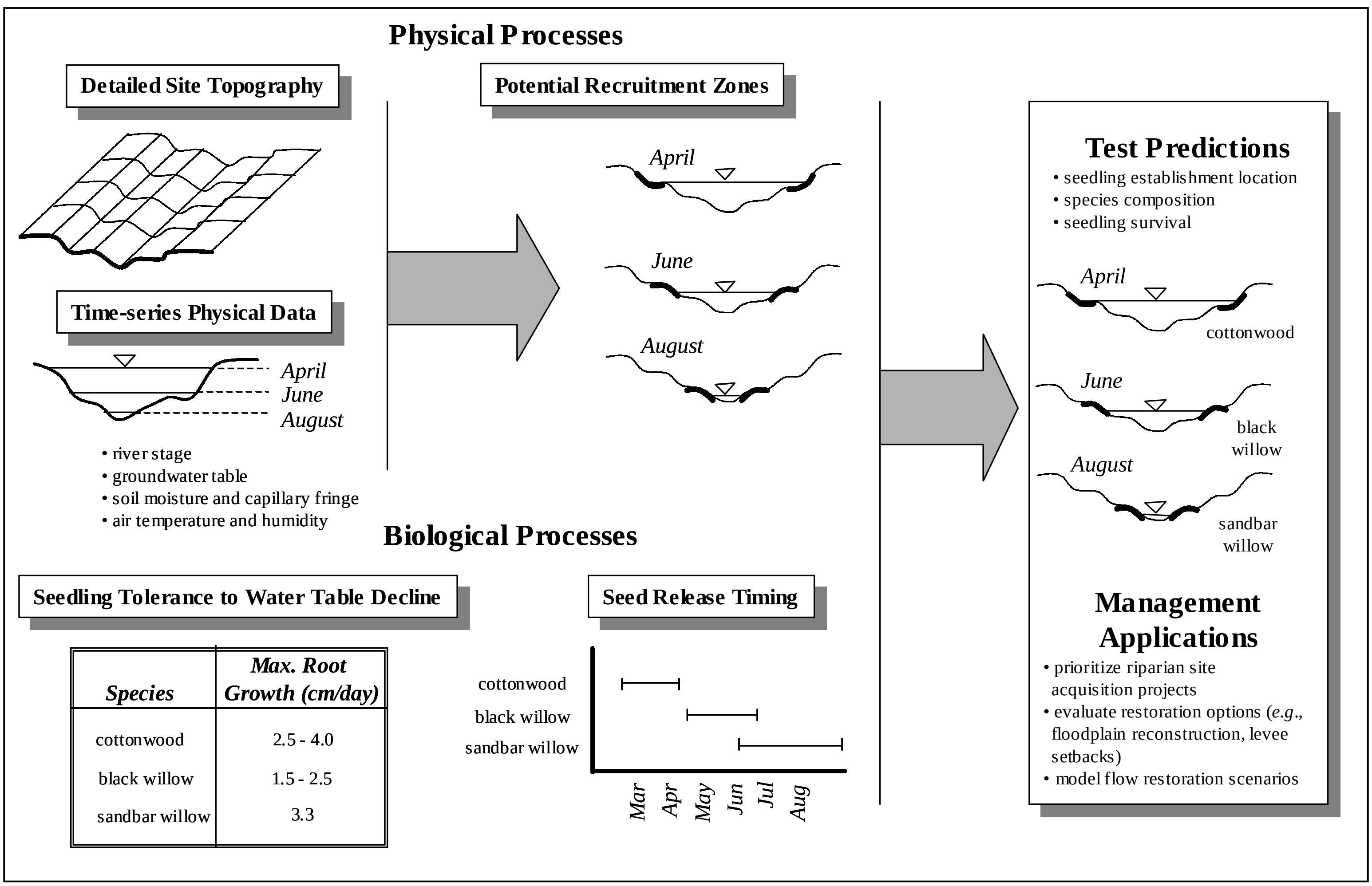

Figure 2. General conceptual framework for application of the recruitment box model.

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TABLES AND FIGURES

Table 1. Proposed project schedule

		2002 Pilot Study				Proposed CALFED Science Fellow Project								
Task number	**Task Description**	**Fall 2001**	**Winter 2002**	**Spring 2002**	**Summer 2002**	**Fall 2002**	**Winter 2003**	**Spring 2003**	**Summer 2003**	**Fall 2003**	**Winter 2004**	**Spring 2004**	**Summer 2004**	**Fall 2004**
1	**Analysis of existing data**													
	Riparian database development					■	■	■	■	■				
	Analysis of pilot study data					■	■							
2	**Model calibration (Tuolumne sites)**													
2.1	Seed release timing and viability			■	■			■	■					
2.2	Root growth experiments				■									
2.3	Site hydrology	■	■	■	■	■	■	■	■	■				
2.4	Seedling recruitment surveys			■	■			■	■	■				
3	**Model verification (restoration sites)**													
	Field studies					■	■	■	■	■				
	Model predictions									■	■			
	Data analysis and model testing										■	■	■	
	Management recommendations													■

Table 2. Examples of reference (non-California) and regional data sources on experimental and observational results of riparian recruitment studies.

Process	Reference parameters	Regional parameters/ application	River system	Data gaps for the Central Valley
Seed release phenology	Mahoney and Rood 1998	Peltman 1973	Clear Creek	Methods unreplicable
		Bair 2001	Trinity	Qualitative
		Peterson 2002	Sacramento	One year only
		Friant WUA/NRDC 1999	San Joaquin	No cottonwood data
Seed viability	Braatne 1996	Peltman 1973	Clear Creek	No black willow data
Root growth rates	Segelquist et al. 1993 Rood and Mahoney?	McBride et al. 1989	Laboratory study	No black willow; treatment range inadequate
Site hydrology	Mahoney and Rood 1998	Stillwater Sciences 2001 Stella et al. in press	Merced	Pilot study at one site
		Friant WUA/NRDC 1999	San Joaquin	No integration with vegetation data
		TNC (get ref)	Sacramento	Pilot study at one site
Seedling recruitment and survival	Stromberg 1997	Bair 2001	Trinity	No Central Valley data
		Stillwater Sciences 2001 Stella et al. in press	Merced	Pilot study at one site
		Friant WUA/NRDC 1999	San Joaquin	No integration with hydrology data
Model application	Shafroth et al. 1998 Auble et al. 1994	none		

Table 3. Model calibration and testing sites.

River	Site	River Kilometer	Substrate	Sampling Purpose	Sampling initiated
Tuolumne	Ott	8.2	sand	model calibration	Fall 2001
Tuolumne	Grayson	9.2	sand	model calibration	Fall 2001
Tuolumne	Venn	11.1	sand	model calibration	Fall 2001
Tuolumne	SRP 9	41.0	sand & gravel	model testing and restoration monitoring	proposed Fall 2003
Merced	Robinson	70.4	gravel	model testing and restoration monitoring	proposed Fall 2003

Table 4. Limiting factor hypotheses and methods of testing.

Limiting Factor	Factor Isolation Method	Predicted Results if Factor is Limiting
1. seed availability	Sticky traps at sandbar sites	No germination accompanied by lack of seed catch
2. seed bed availability		
2a. competition from existing vegetation	Cleared vs. control plots	Higher germination on cleared plots.
2b. timing of seed bed availability	Varied plot elevations	Low germination in moist plots Peak seed abundance out of phase with availability of moist seed beds.
3. physical disturbance		
3a. scour	Varied plot elevations	Evidence of seedling removal.
3b. deposition	Varied plot elevations	Evidence of new scour or deposition.
3b. prolonged inundation	Varied plot elevations	Increased mortality following prolonged inundation.
4. water stress		
4a. flow recession steeper than seedling root growth	Varied plot elevations Root growth observations	High germination followed by high mortality in early summer. Root growth less than water table recession.
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Table 5. Anticipated project products.

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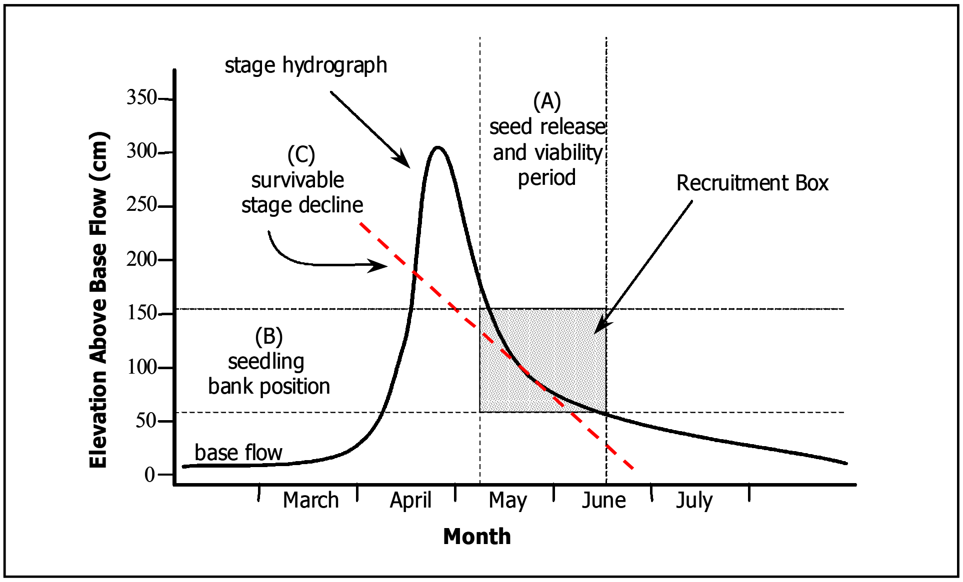
3. Model verification	Baseline vegetation surveys of restoration sites and recruitment predictions	As-built condition of floodplain sites (plot cover, species composition, elevation, substrate)
	Post-winter recruitment assessment	Quantitative recruitment assessment (species composition, density, survival) and evaluation of model predictions
	Pulse flow assessment	Evaluation of VAMP pulse hydrograph (magnitude, timing, duration, rate of change) in promoting natural recruitment processes and management recommendations.



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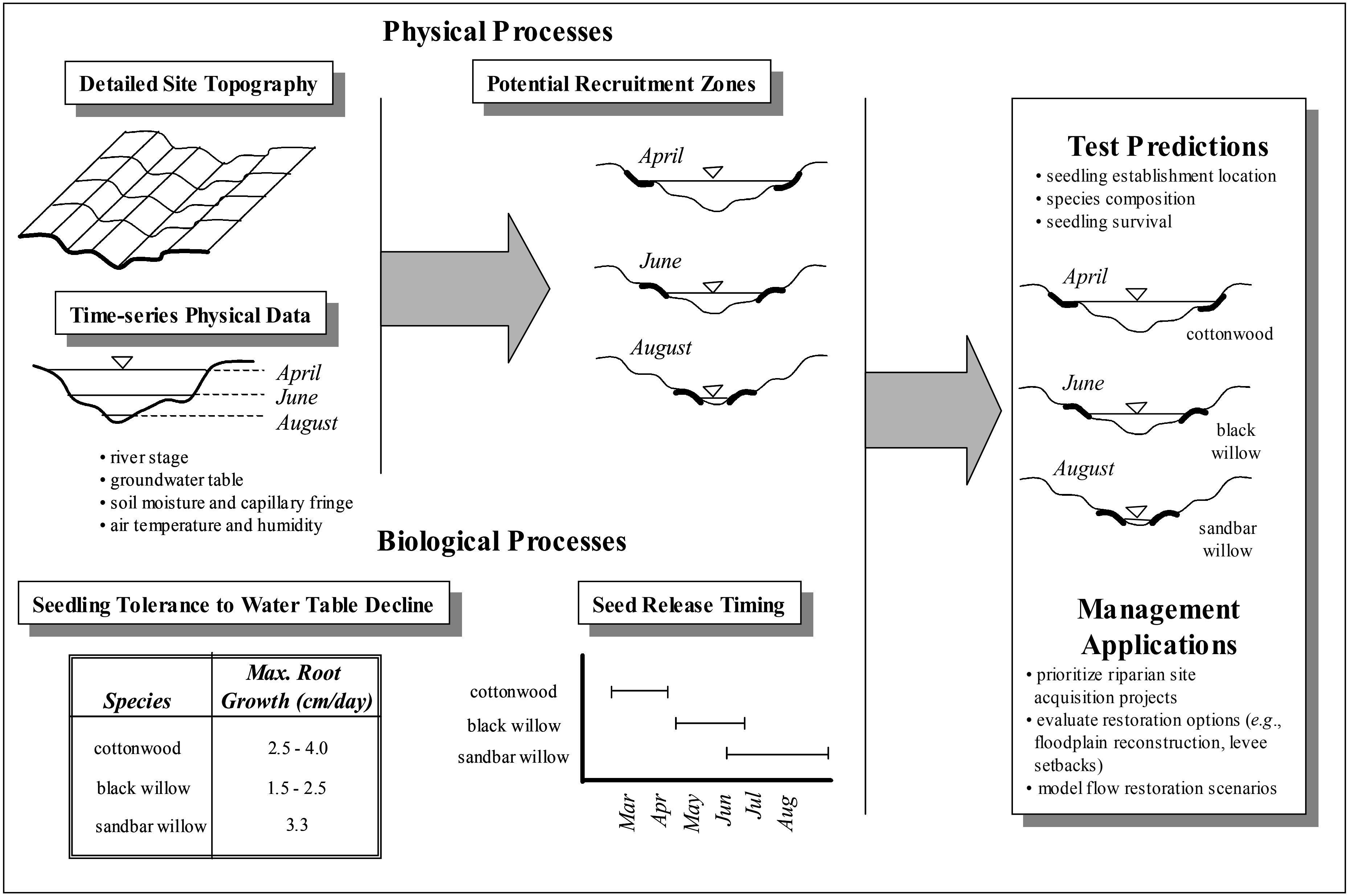

Figure 2. General conceptual framework for application of the recruitment box model.

APPENDICES

Appendix A

CALFED Riparian Restoration Priorities
(source: Draft Stage 1 Implementation Plan)

The table below lists the CALFED priorities that my research addresses, including strategic and regional goals, and multi-species conservation strategy methods as outlined in the Draft Stage 1 Implementation Plan. The Plan outlines the implementation strategy for the first seven years of the CALFED Ecosystem Restoration Program and is the basis of the most recent competitive grant program (the 2002 Proposal Solicitation Package).

DRAFT STAGE 1 IMPLEMENTATION PLAN STRATEGIC GOALS		
Strategic Goal	**Description**	**Page #**
1. At-risk species	"(Non-fish related) projects should include at-risk species surveys and studying the efficacy of reintroductions programs for these species. This information is important to guide ecosystem restoration projects so that they can provide for the protection and conservation of these species, and to ensure that projects do not inadvertently contribute to the further local decline of these species."	22-23
2. Ecosystem processes and biotic communities	"Defining ecologically functional flow schedules will require analyzing current downstream channel and habitat conditions, and **developing and testing hypotheses regarding flow requirements for various geomorphic and ecological functions… including recruitment of riparian vegetation**…Research, monitoring, and implementation projects designed to develop a better understanding of geomorphic flow thresholds and hydrologic-biologic relationships will facilitate estimating environmental flow needs, so that environmental dedications of water are effective and efficient in achieving restoration objectives, thereby minimizing potential effects on water supply and hydropower generation."	25-26
4. Habitat protection and restoration	"Priority actions should focus on **restoring and protecting natural riparian habitats** to support recovery of at-risk species, enhancing and/or maintaining native biotic communities, and rehabilitating stream corridor ecological processes. In general the success of riparian restoration projects is often variable, usually because the mechanisms that help dictate success are not understood." Cites need for studies that vary study ecological conditions to isolate ecological processes and to capture the range of natural variability. Cites **monitoring needs, including "water table elevations, root growth patterns and rates, and riparian establishment success**." "In addition to direct experiments, **explicit quantitative mechanistic and process studies are needed to understand how these actions affect environmental processes, ecosystem processes, and life histories of critical species**. Studies that compare such effects among restoration strategies are critical for future prioritization of CALFED Program activities."	30
DRAFT STAGE 1 IMPLEMENTATION PLAN RESTORATION PRIORITIES FOR THE SAN JOAQUIN REGION		
Priority Actions	**Description**	**Page**
1. Continue habitat restoration actions including channel-floodplain reconstruction projects and	***Riparian and riverine aquatic habitat restoration and research***. Scientific studies to determine appropriate conditions for the germination and establishment of riparian woody plants along the San Joaquin River are … needed.	69-71

habitat restoration studies in collaboration with local groups.		
2. **Restore geomorphic processes in stream and riparian corridors**	*San Joaquin floodplain evaluation.* Develop floodplain management plans, including feasibility studies to construct setback levees, to restore and improve opportunities for rivers to inundate their floodplain on a seasonal basis on tributaries within the San Joaquin River. ***Biological value of floodplain habitats***. Additional information is needed to better understand the role of natural and managed floodplains to the food web and in the survival and growth of young fish.	71
4. Implement actions to improve understanding of at-risk species in the region.	*Other at-risk species life history studies.* Preserve existing habitat and restore additional habitat to benefit riparian brush rabbit, riparian woodrat, valley elderberry longhorn beetle, giant garter snake and vernal pool species.	72
6. Conduct adaptive management experiments in regard to natural and modified flow regimes to promote ecosystem functions or otherwise support restoration actions.	*Mechanistic models as restoration tools.* Develop methods, including a combination of simulation models and physical measurements, to evaluate flow, sediment transport and other fluvial processes. **Develop ecologically based plans and process understanding to aid restoration of conditions in the rivers, sloughs and floodplains**… *Instream flow programs.* Conduct instream flow studies to improve our understanding of the effects of flows and flow regimes on ecological and physical processes…. *Effects of managed flow fluctuations.* Projects are needed to evaluate the effects of managed flow fluctuations on ecosystem processes and habitat conditions, especially effects of flow fluctuations on anadromous fish habitat below dams……..	73-74
CALFED ECOSYSTEM RESTORATION PROGRAM—MULTI-SPECIES CONSERVATION STRATEGY MILESTONES		
Milestone Description	**Species that would benefit from achieving milestones**	**Page**
Restore and maintain a defined stream-meander zone and **increase floodplain habitat on the San Joaquin River** between Vernalis and the mouth of the Merced River	cuckoo, California yellow warbler, bank swallow	132
Develop and implement a program **to establish, restore, and maintain riparian habitat to improve floodplain habitat**, salmonid shaded riverine aquatic habitat and instream cover along at least one tributary within the East San Joaquin and San Joaquin River Ecological Management Zones.	Central Valley steelhead, fall/late fall-run Chinook salmon, western yellow-billed cuckoo, Valley elderberry long-horn beetle, riparian brush rabbit, California yellow warbler, Least Bell's vireo, little willow flycatcher, delta coyote thistle	132-133
Implement 25 percent of the ERP target for diverse**, self-sustaining riparian community** for all EMZ's in the San Joaquin River Basin.	San Joaquin Valley woodrat, delta coyote thistle, western yellow-billed cuckoo, Valley elderberry long-horn beetle, riparian brush rabbit	133
Develop and begin implementation of a study to **determine the appropriate conditions for the germination and establishment of riparian woody plants along the Sacramento River and San Joaquin River.** Complete development of a cooperative program to plan vegetation on unvegetated riprapped banks consistent with flood control requirements.		138

Appendix B

Central Valley Riparian Data Sources

Primary data sources to be used in constructing a predictive recruitment model

River	Information	Format	Source
All rivers	flow data (see Appendix B for list of Central Valley gauges)	Electronic stage and discharge records	USGS; CDWR; TID
Tuolumne	corridor vegetation maps	GIS files	McBain and Trush
	plant species lists	data tables	McBain and Trush
	floodplain inundation maps	GIS files	Stillwater Sciences
	bathymetry and floodplain topography	DTMs	COE (partial)
	aerial photographs	prints and digital images	Stillwater Sciences; CDWR; COE
Merced	corridor vegetation maps	GIS files	Stillwater Sciences
	plant species lists	data tables	Stillwater Sciences; CDWR
	bathymetry and floodplain topography	DTMs	COE (partial); CDWR
	corridor geomorphic surfaces maps	GIS files	Stillwater Sciences
	riparian vegetation functional analysis	data tables, text, figures	Stillwater Sciences
	hydrologic analysis	data tables, text, figures	Stillwater Sciences
	aerial photographs	prints and digital images	Stillwater; CDWR; COE
San Joaquin	groundwater data	electronic data tables, figures	Jones & Stokes, Inc. MEI, Inc.
	vegetation maps (example reaches only)	hard copies	Jones & Stokes, Inc.
	current hydraulic model -- in progress		COE
	bathymetry and floodplain topography	DTMs	COE
	aerial photographs and photo atlas	prints and digital images	Stillwater; CDWR; COE
Sacramento	historic channel planform		CDWR - Cepello
	Riparian monitoring sites (evaluate riparian, hydrogeomorphic relationships)		TNC
	bathymetry and floodplain topography	DTMs	COE
	riparian vegetation composition (several sites)	Ph.D. thesis	Greco 1999
	current hydraulic model	digital files	COE
	channel migration model		Larsen
	recent orthophotos and photo atlases		CDWR/CSU

Central Valley Hydrologic Data

Agency	Gauge Number	Gauge Name	Drainage Area (square miles)	Gage Datum (NGVD 1929 for USGS gauges)	Data Type
Cosumnes					
CDWR	MCC	Cosumnes R Nr **McConnell**		5	river stage 3/19/97-present
USGS	11335000	COSUMNES R A **MICHIGAN BAR** CA	536	168	annual peak 1907-present daily avg Q 1907-present water quality samples 10/23/52 to 9/5/80
USGS	11333000	Camp C Nr Somerset CA	63	1,820	annual peak 1955-present daily avg Q 1955-present
Merced					
USGS	11273000	**MERCED R SLOUGH** NR NEWMAN CA			annual peak 1950-72 daily avg Q 1941-72
USGS	11273500	Merced R at **River Road** Bridge, near Newman	1,276	72	water quality samples 1985-1999
USGS	11272500	MERCED R NR **STEVINSON** CA	1,273	73	annual peak 1924-95 daily avg Q 1940-95 water quality samples 1951-1997
CDWR	MST	MERCED R NR **STEVINSON** CA		82	daily avg & hrly Q 1997-present
USGS	11271290	MERCED R A **SHAFFER BRIDGE** NR CRESSEY CA	1,117		water quality samples 1976-1977
CDWR	CRS (B05155)	Merced River at **Cressey**		165	daily avg & hrly Q 1999-present
CDWR	MSN (B05170)	Merced River near **Snelling**		260	daily avg & hrly Q 1999-present
Merced ID		Merced ID Gauge **Crocker Huffman**			flow , 1920-present (by request--web data not available)
USGS	11270900	MERCED R BL **MERCED FALLS** DAM NR SNELL CA	1,061		annual peak 1911-present daily avg Q 1901-present water quality samples 1966-1994
CDWR	MMF	Merced River below **Merced Falls**		310	hourly discharge 6/18/1998 to present
USGS	11269500	**Lk McClure** A Exchequer CA	1,037		water quality samples 1976-1977
CDWR	EXC	New Exchequer Dam-Lake McClure		879	reservoir data
Merced ID	MBB	Merced River near **Briceburg**		1,150	hourly discharge (cfs) 6/9/99 to present
San Joaquin					
USGS	11303500	SAN JOAQUIN R NR **VERNALIS** CA	13,536	25	annual peak 1923-present daily avg Q 1923-present water quality samples 1950-1999
USGS/DWR	VNS	San Joaquin River at **VERNALIS**		35	daily avg & hrly Q 1984-present
USGS	11274550	SAN JOAQUIN R NR **CROWS LANDING** CA	9,694	45	annual peak 1996-present daily avg Q 1995-present water quality samples 1962-1966
USGS	11274000	SAN JOAQUIN R NR **NEWMAN** CA	9,520		annual peak 1868-present daily avg Q 1912-2000 water quality samples 1951-1993

USGS	11261100	**Salt Slough** A Hwy 165 Nr Stevinson CA		30	annual peak 1986-present daily avg Q 1985-present water quality samples 1984-1994
USGS	11260815	San Joaquin R Nr **STEVINSON** CA		30	water quality samples 1985-1994
USGS	11254000	SAN JOAQUIN R NR **MENDOTA** CA	3,940	141	annual peak 1940-present daily avg Q 1939-present water quality samples 1951-1984
USGS	11251000	SAN JOAQUIN R BL **FRIANT** CA	1,676	294	annual peak 1908-present daily avg Q 1907-present water quality samples 1951-1984
Stanislaus					
USGS	11303000	STANISLAUS R A **RIPON** CA	1,075	73	annual peak 1938-present daily avg Q 1940-present water quality samples 1985-1994.
USGS	11302500	STANISLAUS R A **OAKDALE** CA	1,302		annual peak 1896-present daily avg Q 1895-present
CDWR	OBB	Stanislaus River at **Orange Blossom Bridge**		117	daily avg & hrly Q 1984-present
USGS	11302000	STANISLAUS R BL GOODWIN DAM NR **KNIGHTS FERRY** CA	986		annual peak 1955-present daily avg Q 1957-present WQ
USGS	11302000	Stanislaus River at **Knights Ferry**	982		annual peak 1903-present daily avg Q 1903-present
USGS	11299997	STANISLAUS R BL TULLOCH PP NR **KNIGHTS FERRY** CA	980		
USGS	11300000	Stanislaus River near **Knights Ferry**	972		daily avg 1915-32
USGS	11299500	STANISLAUS R BL MELONES PH NR **SONORA** CA	905		annual peak 1932-present daily avg Q 1931-present WQ
USGS	11299200	NEW MELONES PP BL NEW MELONES DAM NR **SONORA** CA			daily avg 1974-present
USGS	11299995	Tulloch Res Nr Knights Ferry CA	905		daily avg 1905-present
USGS	11299000	**NEW MELONES RES** NR SONORA CA	904		
Tuolumne					
USGS	11290000	TUOLUMNE R A **MODESTO** CA	1,884	50	annual peak 1895-present daily avg Q 1895-present WQ
USGS	11289000	**Modesto CN** Nr La Grange CA			daily avg 1909-present
USGS	11289500	**Turlock CN** Nr La Grange CA			daily avg 1899-present
Turlock Irrigation District	TLG	**Tuolumne R-La Grange Dam**			full natural flow
USGS	11289650	TUOLUMNE R BL LAGRANGE DAM **NR LAGRANGE** CA	1,538		annual peak 1971-present daily avg Q 1970-present
USGS	11287500	Don Pedro Res Nr **La Grange** CA	1,555		

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Appendix C

Field Methods and Analyses

The following field methods and analyses were developed and are being implemented in the 2002 Stillwater Sciences pilot riparian model project. Under this current proposal these methods will be used to collect a second year of phenology, hydrology, and seedling survival data at the pilot sites and would be replicated at the restoration sites to test the predictive model and accomplish post-project monitoring.

Task 2.1: Seed release timing
The objective of this task is to determine the duration and timing of the seed release period, and peak release timing for the three species of interest. This information will define the temporal dimension (horizontal axis) of the recruitment box model (Figure C-1). Scant phenological data are available for Central Valley riparian species, and most of those are for the Sacramento River system (*e.g.*, CALFED 2000; Peterson 2001). From studies on other rivers (summarized in Mahoney and Rood 1998), the target period for cottonwood and willow seed dispersal is April through June. Because the timing is expected to vary with environmental variables such as temperature and humidity, the study will be conducted in two years and at a variety of sites within the San Joaquin Basin.

Seed release of adult trees
In 2002, six sites are being monitored for seed release timing, three each on the Tuolumne and San Joaquin Rivers. Sites are distributed between three major latitudes and longitudinally from the confluence of both rivers upstream to the first major dam on each river (Table C-1).

Table C-1. Phenology sites established in spring 2002 with existing data. Sites in bold are locations of major floodplain restoration projects that are proposed for phenology sampling in 2003 for testing the predictive model.

River	Site Name	River Kilometer	Approximate Latitude	Elevation (m)	Date Established
Tuolumne	Ott	8.2	37° 39’	12	Spring 2002
Tuolumne	Lakewood	35.1	37° 35’	23	Spring 2002
Tuolumne	Basso	77.2	37° 37’	60	Spring 2002
Tuolumne	**SRP 9**				**Proposed for 2003**
San Joaquin	Hwy 140	428.0	37° 20’	20	Spring 2002
San Joaquin	Firebaugh	313.8	36° 50’	44	Spring 2002
San Joaquin	Lost Lake	201.1	36° 58’	98	Spring 2002
Merced	**Robinson**				**Proposed for 2003**

At each site, ten dominant female trees of each of the three species are tagged and mapped. From a fixed observation point, an observer counts dehisced catkins in three canopy sectors for a fixed period of time (20 seconds) at the same binocular magnification (Figure C-2). After sampling each canopy sector, an overall percentage of canopy area covered by cotton will be estimated. In addition to the visual counts, a digital photograph of the target point will be taken at each visit. The proportion of canopy covered by cotton (dehisced capsules) will be measured using digital post-processing techniques (Adobe Photoshop, ArcView and/or similar programs).

At each site, a data logger is continuously recording temperature and relative humidity. Analyses will focus on identifying differences in seed release timing among species, timing of peak release, and correlation of local temperature patterns with seed release duration, initiation and timing of peak.

In addition to the detailed data on species of concern, we are documenting general observations of morphological development milestones (*e.g.*, bud break, flowering, fruit development and dehiscence) for most major Central Valley riparian tree species.

Seed capture

In addition to the synoptic survey of seed release timing, seed will be trapped and counted at one of the model sandbar sites to verify that seedfall on the river bank corresponds to observed catkin dehiscence. Sticky traps will be deployed for a fixed time (e.g. 8 hrs) on individual sampling days throughout the seed release period in order to document the density and species composition of trapped seed. Traps consist of gridded 20 x 20 cm sheets coated in Tanglefoot and mounted to plywood boards fixed parallel to the sandbar surface. Traps will be analyzed using a dissecting scope to count seeds and identify them to species. Analyses will focus on differences in seed density over time and at different distances from the channel.

Seed viability

The objectives of this task are to determine actual seed viability for the three target species, assess changes in viability throughout the seed release period, and determine whether these species form a seed bank. Seeds will be collected from 3-4 female trees at each of the phenology study sites at early, middle, and late stages of the seed release period. Seeds will be transported to the University of California, Berkeley and germinated in petrie dishes in an indoor laboratory. For each assay, 25 seeds from one seed batch will be planted on filter paper that will be kept continually moist. Germinants will be counted daily until no more seeds germinate. Approximately ten replicate assays will be conducted for each seed batch. Analyses will determine percent germination over time for each species and assess correlations between seed viability and timing of release.

The need for high flows to coincide with seed release periods is predicated on the assumption that pioneer riparian trees do not form a seed bed. To test that assumption, I will run a pilot study to determine if the Tuolumne River sandbar sites contain viable seeds. Before the seed release period, sand substrate will be collected from the top 10 cm of soil from each sandbar site and transported to a University of California Berkeley greenhouse. Samples will be transferred to planter boxes, watered continuously, and observed periodically over several weeks for germination. Germinants will be counted and identified to species (for both target and non-target species).

Task 2.2: Root growth experiments

The objective of this task is to determine seedling growth and mortality rates in response to different water table decline scenarios. This research component corresponds to the sloping line within the recruitment box model (Figure C-1), which represents the maximum survivable rate of water table decline. An additional objective is to assess differences in physiological stress response and life history strategies between the three target species.

The root growth study will be conducted at the University of California's Russell Reservation in Lafayette, CA. Several (3-5) patterns of water table recession will be simulated for seedlings grown in steel-walled tanks (125 cm deep, 61 cm diameter, sealed at the bottom). Treatment recession rates will be designed to bracket the hypothesized range of survival for each species (ranging between 2 and 10 cm recession/day) as well as actual recession rates occurring at the Tuolumne River study sites under existing and pre-regulation flow regimes.

The tanks will be located outdoors free from direct shading and the outside surface of each tank will be painted silver to increase sunlight reflection. The tanks will be filled initially and water table levels will be controlled hydrostatically by draining water through a flexible pipe plumbed in the bottom of the tank and clamped to a meter stick oriented vertically on the tank's exterior wall. The clamp position will be moved daily according to the water table decline prescription.

Seedlings of the three target species will be germinated in a lath house at the Russell Reservation and transferred to PVC tubes (60 cm long, 2.5 cm diameter) filled with river sand. The tubes will be suspended in the steel tanks and subject to the water table recession treatments. Seedlings will be monitored for survival and several physiological measures (*e.g.*, photosynthetic rate, xylem water potential) during the growing season. If destructive sampling will be required, individuals will be selected at random from each treatment level. At the end of the growing season, seedlings will be harvested and measured for root growth and biomass of roots and shoots. A data logger will record continuous air temperature and relative humidity at the tank site for calculation of vapor pressure defecit.

Seedling survival, physiological response, root length and biomass will be compared across species and treatments. Vapor pressure deficit will be calculated and analyzed relative to water supply available to each treatment. Species-specific tolerances to water table decline will be determined and compared to field conditions and seedling survival at the sandbar sites.

Task 2.3: Site hydrology (surface and groundwater elevation and soil moisture)

The objective of this task is to monitor rates of surface water and groundwater decline following pulse flows and determine the time-lag effect on soil moisture following the pulse. By documenting the field conditions at potential recruitment sites (sandbars), I will calibrate the vertical axis of the recruitment box model (Figure C-1), which corresponds to bank elevation where successful recruitment occurs. The field data is also necessary to ensure that controlled decline rates in the tank experiment are comparable to riverine hydrologic conditions.

Under the Vernalis Adaptive Management Plan, a program to increase the populations of Central Valley salmonids, San Joaquin Basin dam operators release controlled pulse flows during April and May of each year. This planned pulse provides an excellent opportunity for monitoring the effects of flooding on riparian recruitment, and this year (2002) I am monitoring water table elevations and surface moisture changes over time following recession of the pulse flows. Because the river's hydrology and the VAMP release vary from year to year, I propose to continue this research in 2003. Seedling survival is dependent on inter and intra-annual hydrologic patterns, suggesting that collecting multi-year data is an important part of this research plan.

Hydrologic data are being collected to document site inundation, water table recession rates, and soil moisture patterns at three sandbar sites on the lower Tuolumne River. Under this proposal, sampling would continue at these sites during 2003, and sampling will initiated at the floodplain restoration/model testing sites. Site locations and characteristics are listed in Table C- 2.

Table C-2. Model calibration and testing sites. New sites are listed in bold type.

River	Site	River Kilometer	Substrate	Sampling Purpose	Sampling initiated

Tuolumne	Ott	8.2	sand	model calibration	Fall 2001
Tuolumne	Grayson	9.2	sand	model calibration	Fall 2001
Tuolumne	Venn	11.1	sand	model calibration	Fall 2001
Tuolumne	**SRP 9**		**sand and gravel**	**model testing and restoration monitoring**	**proposed Fall 2003**
Merced	**Robinson**		**gravel**	**model testing and restoration monitoring**	**proposed Fall 2003**

Site instrumentation for the three Tuolumne calibration sites was completed in 2001 and 2002, and consists of water surface elevation logger, an array of ground wells, and period soil moisture measurements using a standing wave impedance instrument (Figure C-3). Each component is described in more detail below.

Monitor river water surface elevation

Water surface elevation has been monitored continuously since December 2001 using a pressure transducer (Global Water, Inc Model WL-15) installed in the channel and connected by cable to a remote data logger. The transducer head is installed at a locally deep section of channel within a PVC pipe extending perpendicular from the bank. At each transducer location, a staff gage is installed to allow calibration of tranducer readings. All relevant elevation points are surveyed to local benchmarks, including tranducer head elevation, river bed elevation, and staff gauge elevations. During periodic site visits, transducer conditions will be noted and elevations resurveyed to the benchmarks to ensure that instrument position has not changed.

Monitor water table level.

There are a minimum of 4 wells on each bar distributed longitudinally between upstream and downstream sectors. Wells are constructed of PVC pipe with a porous section at the bottom and are driven 0.5 m minimum below the winter baseflow water table. Well ground surface and lip elevations are surveyed to the site benchmarks. Well monitors will measure the distance from the well lip to the water table using either an electronic water level detector or chalked steel tape. Water table levels will be monitored throughout the pulse flow period, growing season, and following winter.

Measure soil moisture following controlled pulse flows (April-May 2002 and 2003)

Soil moisture studies will be conducted at fixed plots on the three sandbar sites before and after pulse flows to establish the pattern and rate of soil desiccation. Post-pulse monitoring will be done on a geometric frequency schedule (1, 2, 4, 8, 16 days following event).

Volumetric soil water content will be measured using a Theta Probe (Macaulay Land Use Research Institute), which uses a simplified standing wave measurement to determine the impedance of a sensing rod array (and apparent dielectric constant). The probe will be calibrated using soil samples from the sandbar sites.

Following calibration, measurements will be taken at the surface of each of the seedling sample plots (see Task 2.4 below) and at several depths in a limited number of locations. Measurement events will be scheduled to capture the soil dry-down period following the April-May pulse flow events. In addition to the instantaneous measurements, one Theta Probe will be deployed at one sandbar site to record soil moisture continuously to determine the temporal character of the dry-down event.

Hydrologic analyses
Site hydrologic data will be used to determine peak flow periods relative to seed release timing and rates of surface and groundwater recession relative to root growth rates. Soil moisture data will be analyzed for rate of soil desiccation relative to plant physiological thresholds.

Task 2.4: Model verification: field seedling recruitment patterns

The objective of this task is to calibrate the recruitment box model at the model sandbar site by documenting actual seedling survival relative to site hydrologic conditions. I will document germination and survival of naturally-recruiting cohorts over the growing season and winter in 2002 and 2003. In spring 2002, study plots were established on the three sandbar sites (Figure C-3). Because the dominant bar morphology at the study sites consists of two benches stepping up from the low-flow channel edge, the plots were stratified between two dominant elevations and between upstream and downstream sectors of the bar. These sectors were delineated to enable gross comparisons of seedling survival between different water table depths and bar areas with potentially different deposition and scour patterns.

On each bar, a total of 60 paired plots were established to observe natural seedling recruitment. Each pair includes one 0.25 m^2 treatment plot in which competition from existing vegetation is removed and one control plot. Treatment plots were cleared of existing vegetation by excavating the top 15 cm of soil, sieving for plant material using 1.25 cm hardware cloth, replacing the soil and compacting to a grade level to the control plot.

Natural recruitment will be surveyed throughout the seed release and growing seasons. Seedlings will be mapped, aged and monitored for survival. Sampling events will occur immediately after the high-flow pulse and at approximate monthly intervals through the spring and summer (Table C-3). Standing biomass on the control plots will be quantified from planform photographs.

Table C-3. Seedling sampling schedule.

Purpose	Sampling time	Field work/sampling tasks
Install and clear plots; collect baseline (pre-pulse) density and composition data.	early April	Survey plot location and elevation Monument plots with rebar Clear treatment plots to mineral soil For control plots: Census existing seedling age, species, density Herbaceous spp. comp, % percent cover, light envir
Survey new recruitment	late May-early June 2003	Seedling age, species, density Herbaceous spp. comp, % percent cover, mortality
Survey mortality/new recruitment	late June 2003	Seedling age, species, density Herbaceous spp. comp, % percent cover, mortality
Survey mortality/new recruitment	late July 2003	Seedling age, species, density Herbaceous spp. comp, % percent cover, mortality
Survey mortality/new recruitment	late August 2003	Seedling age, species, density Herbaceous spp. comp, % percent cover, mortality
Survey post-summer mortality	late September 2003	Seedling age, species, density Herbaceous spp. comp, % percent cover, mortality Harvest control plot biomass and weigh
Survey post-winter mortality	April-May 2004	Seedling age, species, density, substrate Herbaceous spp. composition and percent cover

Analyses

Data analyses will take the following general approach use a suite of statistical methods (Table C-4):

- from physical data, match each plot location to elevation above channel and water table and soil moisture regime
- calculate vapor pressure deficits for all three sandbar sites
- document elevation and density of seedling recruits for a given time period
- document seedling germination and survival in plot resurveys
- predict plots where successful recruitment should occur, based on hydrological data
- evaluate whether actual survival patterns are consistent with predictions

Table C-4. Proposed statistical analyses of seedling germination and survival data.

Ecological process	Treatments/Factors	Evaluation Measures	Statistical Tests
competition from existing vegetation	cleared vs. control	recruitment density seedling survival	paired T-tests
desiccation due to gross-scale differences in water table depth and/or soil moisture availability	high vs. low bench	recruitment density seedling survival	unpaired T-tests
desiccation due to finer-scale differences in water table depth and/or soil moisture availability	plot elevation depth to groundwater soil moisture content inundation duration vapor pressure deficit (for between-sandbar comparisons)	recruitment density seedling survival	linear regression logistic regression

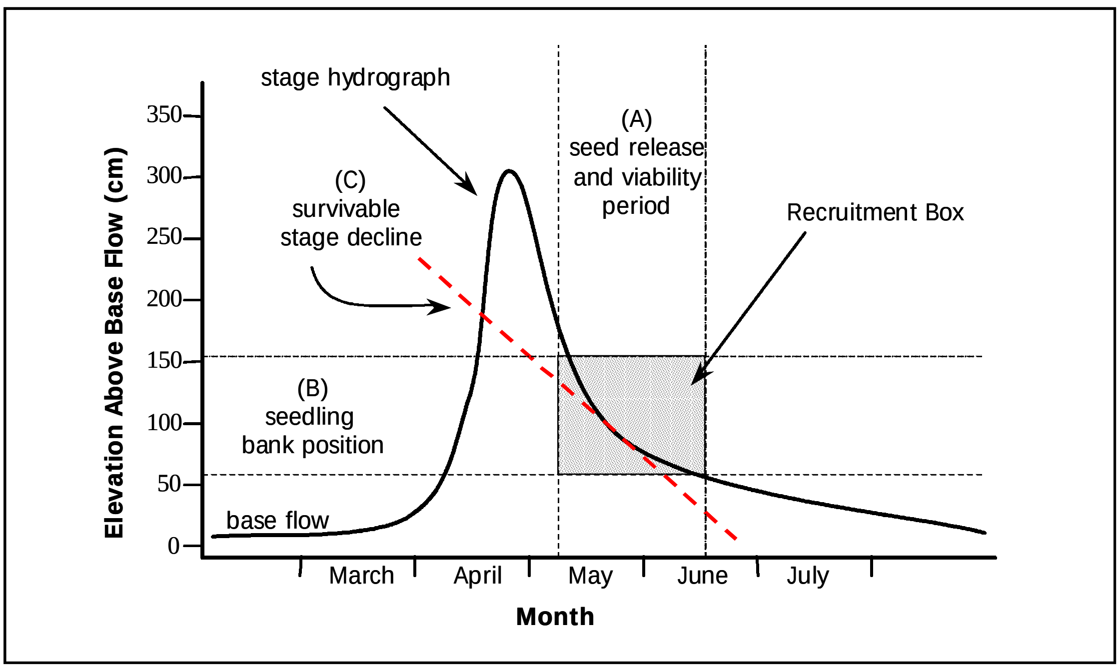

Figure C-1. The recruitment box model (redrawn from Mahoney and Rood 1998)

Seed Release Phenology Data Collection

- fixed observation points (10 for each spp.)
- distance to target tree canopy line measured
- timed counts of open catkins (1 per each of 3 canopy strata)
- local air temperature and relative humidity

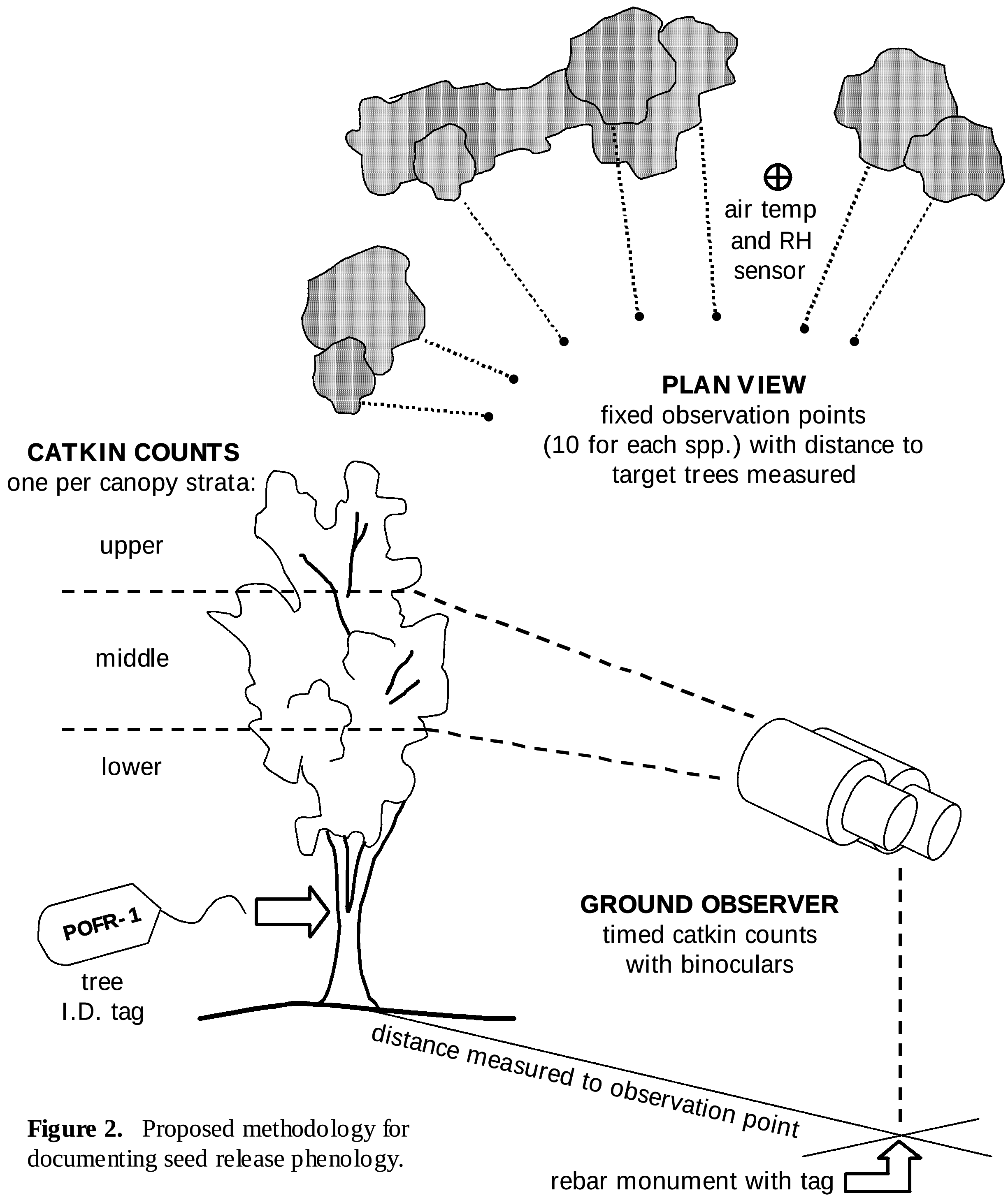

Figure 2. Proposed methodology for documenting seed release phenology.

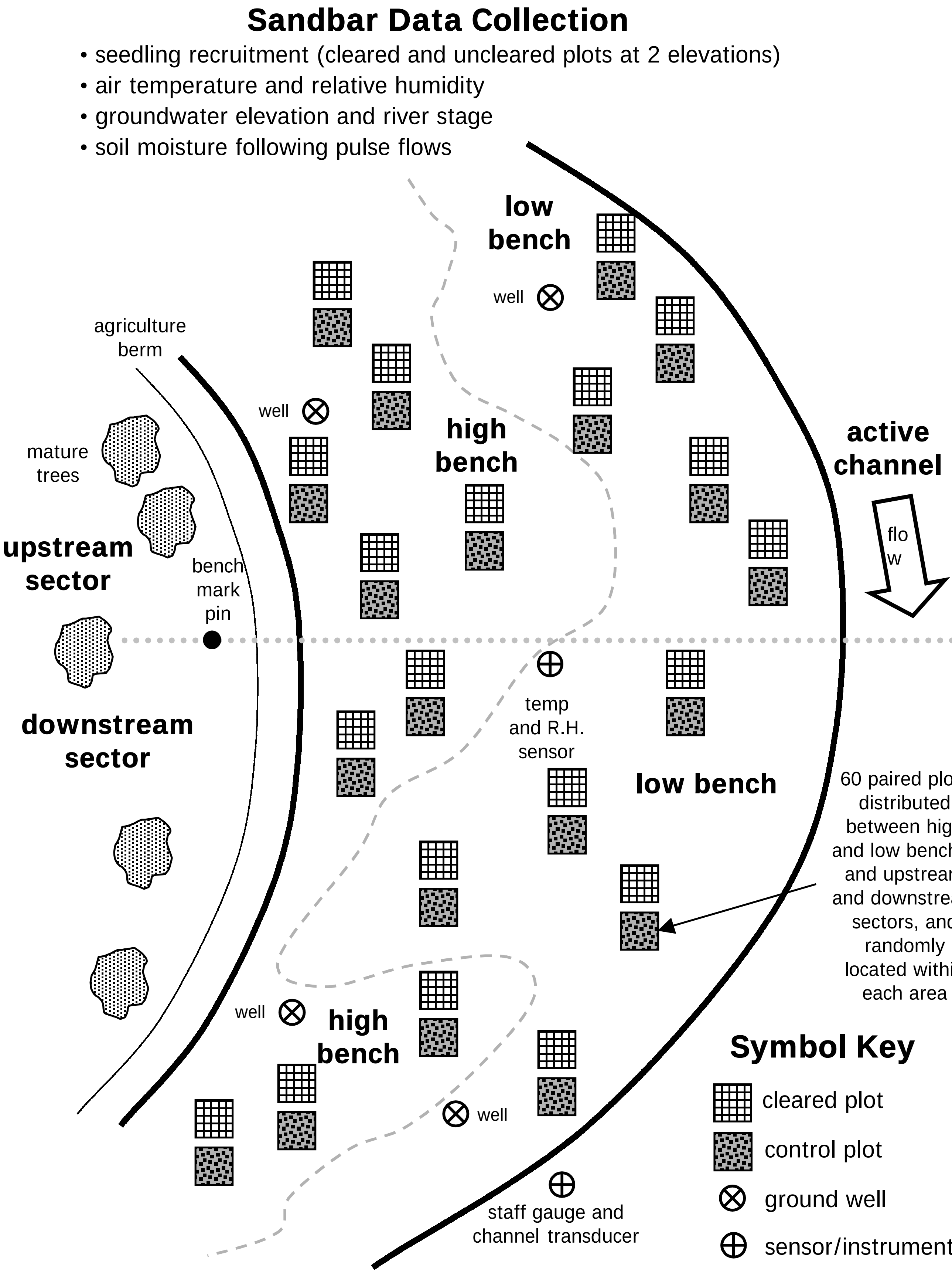

Figure C-3. Proposed methodology for documenting site hydrology and recruitment.