Ecosystem Restoration Program - 2002 Proposal Solicitation Package (PSP): Signature Page

Each applicant submitting a proposal to the CALFED Bay-Delta Program Ecosystem Restoration Program must submit a signed Signature Page.

Failure to sign and submit this form will result in the application not being considered for funding.

The individual signing below declares the following:

- the truthfulness of all representations in this proposal;
- the individual signing the form is authorized to submit the application on behalf of the applicant (if applicant is an entity or organization; and
- the applicant has read and understood the conflict of interest and confidentiality discussion in the PSP Section 2.4 and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent as provided in this PSP.

Proposal Title:

Cosumnes River Preserve Perennial Pepperweed Control Project

_____
Authorized Signature

_____
Printed Name

_____
Organization

Ecosystem Restoration Program - 2002 Proposal Solicitation Package (PSP): Form I - Project Information

All applicants must complete this form for their proposals. *Failure to answer these questions will result in the application not being considered for funding.*

1. Proposal Title:

Cosumnes River Preserve Perennial Pepperweed Control Project

2. Proposal Applicants:

Information Center for the Environment and John Muir Institute of the Environment, University of California, Davis

3. Corresponding Contact Person:

Professor James F. Quinn
Address: One Shields Avenue, Davis, CA 95616 University of California, Davis
Phone: (530) 752-8027
Fax: (530) 752-9515
E-mail of primary contact: jfquinn@ucdavis.edu

4. Project Keywords:

Nonnative Invasive Species
Riparian Ecology
Weed Science

5. Type of project:

Full Implementation

6. Does the project involve land acquisition, either in fee or through a conservation easement?

No.

7. If yes, is there an existing specific restoration plan for this site?

8. Topic Area
Non-Native Invasive Species

9. Type of applicant
University

10. Location – GIS coordinates

Latitude: 38.3002510
Longitude: -121.3756256
Datum: (leave blank)

Describe project location using information such as water bodies, river miles, road intersections, landmarks, and size in acres.

The Cosumnes River Preserve between Highway 99 and Interstate 5 encompassing approximately 20,000 acres.

11. Location – Ecozone

11.1 Cosumnes River

12. Location – County

Sacramento

13. Location – City. Does your project fall within a city jurisdiction?

No.

14. If yes, please list the city:

15. Location – Tribal Lands. Does your project fall on or adjacent to tribal lands?

No.

16. Location – Congressional District.

11

17. Location – California State Senate District & California Assembly District

California State Senate District Number: 4 and 5
California Assembly District Number: 8 and 10

18. How many years of funding are you requesting?

3 years

19. Requested Funds:

a. Are your overhead rates different depending on whether funds are state or federal?

Yes.

b. If yes, list the different overhead rates and total requested funds.

Total requested funds at the general University imposed 26% indirect rate is $418,995.64. The total requested funds at an indirect rate of 17.5%, as implemented through the Cooperative Ecosystem Study Unit (CESU), are $397,727.01.

c. If no, list single overhead rate and total requested funds.

d. Do you have cost share partners already identified?

Yes.

If yes, list partners and amount contributed by each.

The Bureau of Land Management will contribute one work month of Rick Cooper (Preserve Manager) for project support and oversight, ~$6,500.

e. Do you have potential cost share partners?

No.

If yes, list partners and amount contributed by each.

f. Are you specifically seeking non-federal cost share funds through this solicitation?

No.

If yes, list total non-federal funds requested.

g. If the total non-federal cost share funds requested above does not match the total state funds requested in 19a, please explain the difference.

20. Is this proposal for next-phase funding of an ongoing project funded by CALFED?

No.

If yes, identify project number(s), title(s) and CALFED program.

21. Have you previously received funding from CALFED for other projects not listed above?

Yes.

If yes, identify project number(s), title, and CALFED program.

Project Title: "Linked hydrogeomorphic-ecosystem models to support adaptive management: Cosumnes-Mokelumne Paired Basin Project."
Project Number CALFED Project 99-NO6

Project Title: "McCormack-Williamson Tract Restoration Planning, Design and Monitoring Program"
Project Number: CALFED Project # 2000-FO8

Project Title: "The influence of flood regimes, vegetative and geomorphic structures on the links between aquatic and terrestrial systems: Applications to CALFED restoration and watershed monitoring strategies"
Project Number: CALFED Project # 2001-NO1

Additionally and as a result of five previous rounds of proposals and directed action, CALFED has awarded the Preserve partners a total of $51,676,022 to acquire and restore Preserve lands. These grants have resulted in acquisition of properties totaling almost 14,300 acres. Additionally, almost $1,500,000 in CVPIA funds has been used on the acquisition of Valensin Ranch and Howard Ranch. Once acquired these lands have undergone extensive improvements including implementation of prescribed grazing and fire programs, management of exotic species, removal of unnecessary infrastructure, and construction of necessary infrastructure. Additionally, significant baseline biological information is obtained including rare and endangered species and invasive species surveys. Furthermore, the Preserve partners have also studied the effects of fire and grazing on the diversity of vernal pool species and have studied the management of sandhill crane habitat on Staten Island.

22. Is this proposal for next-phase funding of an ongoing project funded by CVPIA?

No.

If yes, identify project number(s), title, and CVPIA program.

23. Have you previously received funding from CVPIA for other projects not listed above?

No.

24. Is this proposal for next-phase of an ongoing project funded by an entity other than CALFED or CVPIA?

No.

If yes, identify project number(s), title, and funding source.

25. Please list suggested reviewers for your proposal. (optional)

Name	Organization	Phone	Email
John Randall	The Nature Conservancy	(530) 754-8890	jarandall@ucdavis.edu
Steve Schoenig	CA Dept. Food & Ag.	(916) 654-0768	sschoenig@cdfa.ca.gov
Joe DiTomaso	UC Davis Weed Science	(530) 754-8715	ditomaso@vegmail.ucdavis.edu
Carla Bossard	St. Mary's College	(916) 631-4032	cbossard@stmarys-ca.edu
Mark Schwartz	UC Davis Environmental Science & Policy	(530) 752-0671	mwschwartz@ucdavis.edu

26. Comments.

Ecosystem Restoration Program - 2002 Proposal Solicitation Package (PSP): Form II - Executive Summary

All applicants must complete this form for their proposals. *Failure to answer these questions will result in the application not being considered for funding.*

Proposal Title: Cosumnes River Preserve Perennial Pepperweed (*Lepidium latifolium*) Control Project

Please provide a brief but complete (about 300 words) summary description of the proposed project; its geographic location, project type, project objective, approach to implement the proposal, hypotheses and uncertainties, expected outcome and relationship to CALFED ERP and/or CVPIA goals.

This proposal, continuing the established partnership between the Cosumnes River Preserve (CRP) and the UC Davis Information Center for the Environment (ICE), complements ongoing Cosumnes research by performing an intensive study of the most rapidly expanding invasive plant in the Cosumnes study area, *Lepidium latifolium*. The Cosumnes River Preserve serves as a model of habitat conservation and floodplain restoration in the Central Valley. Scientists in the Cosumnes Research Group I and II (CRG) (CALFED grants #1999-NO6, #2000-FO8, #2001-NO1) and on CRP staff are studying changes in hydrology, vegetation, and aquatic and terrestrial biota that are occurring in response to natural and man-made breaches to levees along the Cosumnes river within preserve boundaries. The proposed research represents a pilot-species, pilot-region application of a general framework to experimentally develop control strategies for terrestrial invasives that can be used to inform future restoration activities in the CALFED region.

This proposal will address several scientific needs of the ERP via targeted research and pilot projects regarding adaptive management and monitoring of weed control efforts in general and *Lepidium* specifically. Inventory and continued monitoring of existing *Lepidium* populations at the Cosumnes River Preserve will provide the background data necessary to statistically analyze population change as adaptive management projects proceed (Objective 1). Targeted research on control of *Lepidium* will use a scientific hypothesis-testing approach to refine our conceptual model and guide adaptive management actions (Objective 2). This research is explicitly designed to add to existing knowledge about relationships between management techniques and ecosystem structure and function by testing current hypotheses concerning weed control and ecosystem restoration. Results will then be used in an adaptive management framework to guide full-scale implementation of *Lepidium* management at the Preserve, as well as being incorporated into a framework for meta-analysis of related projects in the CALFED region (Objective 3).

Ecosystem Restoration Program - 2002 Proposal Solicitation Package (PSP): Form III - Environmental Compliance Checklist

All applicants must complete this form for their proposals. *Failure to answer these questions will result in the application not being considered for funding.*

Successful applicants are responsible for complying with all applicable laws and regulations for their projects, including the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA).

Any necessary NEPA or CEQA documents for an approved project must tier from the CALFED Programmatic Record of Decision and Programmatic EIS/EIR to avoid or minimize the projects adverse environmental impacts. Applicants are encouraged to review the Programmatic EIS/EIR and incorporate the applicable mitigation strategies from Appendix A of the Programmatic Record of Decision in developing their projects and the NEPA/CEQA documents for their projects.

1. **CEQA or NEPA Compliance**
   a. Will this project require compliance with CEQA?

   No.

   b. Will this project require compliance with NEPA?

   Yes.

   If neither CEQA or NEPA compliance is required, please explain why compliance is not required for the actions in this proposal.

2. **If the project will require CEQA and/or NEPA compliance, identify the lead agency(ies). Please write out all words in the agency title other than United States (use the abbreviation US) or California (use the abbreviation CA). If not applicable, put None.**

   CEQA Lead Agency:
   NEPA Lead Agency (or co-lead:) US Bureau of Land Management
   NEPA Co-Lead Agency (if applicable):

3. **Please check which type of CEQA/NEPA documentation is anticipated.**

   CEQA

   ☐ Categorical Exemption
   ☐ Negative Declaration or Mitigated Negative Declaration
   ☐ EIR
   ☉ none

NEPA

- ☐ Categorical Exclusion
- ☉ Environmental Assessment/FONSI
- ☐ EIS
- ☐ none

If you anticipate relying on either the Categorical Exemption or Categorical Exclusion for this project, please specifically identify the exemption and/or exclusion that you believe covers this project.

CEQA/NEPA Process

a. Is the CEQA/NEPA process complete?

No.

b. If the CEQA/NEPA process is not complete, please describe the dates for completing draft and/or final CEQA/NEPA documents.

BLM will be the NEPA lead. CRP is currently in the process of putting together a Programmatic EA for herbicide use on the Preserve that will include the actions covered in the proposal. This will be an expansion of our existing EA for herbicide use. The Programmatic EA should be complete by February 2004. Additionally, each herbicide used on this project will be covered by a Pesticide Use Permit.

c. If the CEQA/NEPA document has been completed, please list document name(s):

4. **Environmental Permitting and Approvals**

Successful applicants must tier their project's permitting from the CALFED Record of Decision and attachments providing programmatic guidance on complying with the state and federal endangered species acts, the Coastal Zone Management Act, and sections 404 and 401 of the Clean Water Act. The CALFED Program will provide assistance with project permitting through its newly established permit clearing house.

Please indicate what permits or other approvals may be required for the activities contained in your proposal and also which have already been obtained. Please check all that apply. If a permit is *not* required, leave both Required? and Obtained? check boxes blank.

LOCAL PERMITS AND APPROVALS

Conditional use permit

Variance

Subdivision Map Act

Grading Permit

General Plan Amendment

Specific Plan Approval

Rezone

Williamson Act Contract Cancellation

Other

STATE PERMITS AND APPROVALS

Scientific Collecting Permit

CESA Compliance: 2081

CESA Compliance: NCCP

1601/03

CWA 401 certification

Coastal Development Permit

Reclamation Board Approval

Notification of DPC or BCDC

Other

FEDERAL PERMITS AND APPROVALS

ESA Compliance Section 7 Consultation

ESA Compliance Section 10 Permit

Rivers and Harbors Act

CWA 404

Other REQUIRED, OBTAINED

PERMISSION TO ACCESS PROPERTY

Permission to access city, county or other local agency land.
Agency Name:

Permission to access state land.
Agency Name:

Permission to access federal land.
Agency Name:

Permission to access private land.

Landowner Name:

Comments. If you have comments on any of the above questions, please enter the question number followed by a specific comment.

A Pesticide Use Proposal has been obtained for the herbicide that will be used. CRP is currently in the process of putting together a Programmatic EA for herbicide use on the Preserve that will include the actions covered in the proposal. This will be an expansion of the existing EA for herbicide use.

Ecosystem Restoration Program - 2002 Proposal Solicitation Package (PSP): Form IV - Land Use Checklist

All applicants must complete this form for their proposals. Failure to answer these questions will result in the application not being considered for funding.

1. Does the project involve land acquisition, either in fee or through a conservation easement?

No.

2. If you answered yes to #1, please answer the following questions:

a. How many acres will be acquired?

b. Will existing water rights be acquired?

c. Are any changes to water rights or delivery of water proposed?

d. If yes, please describe proposed changes.

e. Will the applicant require access across public or private property that the applicant does not own to accomplish the activities in the proposal?

3. Do the actions in the proposal involve physical changes in the land use?

No.

4. If you answered no to #3, explain what type of actions are involved in the proposal (i.e., research only, planning only).

Experimental eradication of exotics in a naturalized or semi naturalized area.

5. If you answered yes to #3, please answer the following questions:

a. How many acres of land will be subject to a land use change under the proposal?

b. Describe what changes will occur on the land involved in the proposal.

c. List current and proposed land use, zoning and general plan designations of the area subject to a land use change under the proposal.

d. **Is the land currently under a Williamson Act contract?** *(For multiple sites, answer Yes if true for any parcel, and provide an explanation in the Comments box below)*

e. **Is the land mapped as Prime Farmland, Farmland of Statewide Importance, Unique Farmland or Farmland of Local Importance under the California Department of Conservation's Farmland Mapping and Monitoring Program?** For more information, contact the California Department of Conservation, Division of Land Resource Protection, Farmland Mapping and Monitoring Program (http://www.consrv.ca.gov/dlrp/FMMP/index.htm). (For multiple sites, answer Yes if true for any parcel, and provide an explanation in the Comments box below)

f. If yes, please list classification:

g. Describe what entity or organization will manage the property and provide operations and maintenance services.

6. Comments.

Ecosystem Restoration Program - 2002 Proposal Solicitation Package (PSP): Form V - Conflict of Interest Checklist

All applicants must complete this form for their proposals. *Failure to answer these questions will result in the application not being considered for funding.*

You may update your information at any time. The [update proposal] button is located at the bottom of this form.

Please list below the full names and organizations of all individuals in the following categories:

- ∉ Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal or who will benefit financially if the proposal is funded.
- ∉ Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.
- ∉ Individuals not listed in the proposal who helped with proposal development, for example by reviewing drafts, or by providing critical suggestions or ideas contained within the proposal.

The information provided on this form will be used to select appropriate and unbiased reviewers for your proposal.

Applicant(s):

James F. Quinn, Professor, Department of Environmental Science and Policy, University of California, Davis

Subcontractor(s):

Are specific subcontractors identified in this proposal?

Yes.

If yes, please list the name(s) and organization(s):

Rebecca Waegell is a Project Manager with The Nature Conservancy at the Cosumnes River Preserve. She has been at the Preserve for the last 8 years and has worked closely with the Preserve Manager to carry out management activities on all lands within the Preserve. She is the lead person in charge of exotics control at the Preserve and has successfully implemented efforts to control such highly invasive weeds as fig, tree of heaven, locust and osage orange. In addition to her activities at the Preserve she is on the board of directors of the California Exotic Pest Plant Council and is a member of the Sacramento Weed Abatement Team. She has a B.S. in zoology from the University of California at Davis. Ms. Waegell has a Certified Applicator's Licence for supervision of pesticide use.

Helped with proposal development

Are there persons who helped with proposal development?

If yes, please list the name(s) and organization(s):

Becky Waegell	The Nature Conservancy
Ramona Swenson	The Nature Conservancy
Renee Spenst	UC Davis
Joshua H. Viers	UC Davis
James F. Quinn	UC Davis
Ingrid Hogle	UC Davis
Rob Wilson	UC Davis Cooperative Extension
Chris Conard	SMTP Bufferlands

Form VI: Budget Summary YEAR 1

Salaries				
Student Assistants	$	8.00	1920	$ 15,360.00
PGR I	$	14.87	360	$ 5,353.20
PGR II	$	17.82	860	$ 15,325.20
Programmer I	$	18.51	540	$ 9,996.21
Administrative Analyst	$	24.31	300	$ 7,293.00
Analyst III - Supervisor	$	30.00	360	$ 10,800.00
Academic Administrator	$	44.44	40	$ 1,777.60
Subtotal Staff			4,380	$ 65,905.21
Benefits				
Student Assistants		2.00%		$ 307.20
PGR I		31.55%		$ 1,688.93
PGR II		31.55%		$ 4,835.10
Programmer I		30.00%		$ 2,998.86
Administrative Analyst		33.54%		$ 2,446.39
Analyst III - Supervisor		31.00%		$ 3,348.00
Academic Administrator		22.00%		$ 391.07
Subtotal Staff Benefits				$ 16,015.56
Travel				
Travel Costs				$ 6,500.00
Subtotal Travel				$ 6,500.00
Supplies & Expendables				
Supplies				$ 9,000.00
Subtotal Supplies				$ 9,000.00
Services				
Soil Testing (UC Davis)	$	49.95	40.00	$ 1,998.00
LiDAR Data from Airborne1				$ 16,000.00
The Nature Conservancy				$ 35,000.00
Subtotal Services				$ 54,996.00
Equipment				
Equipment				$ 24,896.00
Subtotal Equipment				$ 24,896.00
Total Direct Costs				$ 175,314.76
Indirect Costs		0.260		$ 32,608.88
		Grand Totals:	**$**	**207,923.64**

Form VI: Budget Summary YEAR 2

Staff	Salary Rate	Year 2	
		Hours	$
Salaries			
Student Assistants	$ 8.00	1920	$ 15,360.00
PGR I	$ 14.87	180	$ 2,676.60
PGR II	$ 17.82	540	$ 9,622.80
Programmer I	$ 18.51	0	$ -
Administrative Analyst	$ 24.31	300	$ 7,293.00
Analyst III - Supervisor	$ 30.00	360	$ 10,800.00
Academic Administrator	$ 44.44	40	$ 1,777.60
Subtotal Staff		3340	$ 47,530.00
Benefits			
Student Assistants	2.00%		$ 307.20
PGR I	31.55%		$ 844.47
PGR II	31.55%		$ 3,035.99
Programmer I	30.00%		$ -
Administrative Analyst	33.54%		$ 2,446.39
Analyst III - Supervisor	31.00%		$ 3,348.00
Academic Administrator	22.00%		$ 391.07
Subtotal Staff Benefits			$ 10,373.12
Travel			
Travel Costs			$6,500.00
Subtotal Travel			$6,500.00
Supplies & Expendables			
Supplies			$ 3,000.00
Subtotal Supplies			$ 3,000.00
Services			
Soil Testing (UC Davis)	$ 49.95		$ -
LiDAR Data from Airborne1			$ -
The Nature Conservancy			$ 20,000.00
Subtotal Services			$ 20,000.00
Equipment			
Equipment			$ -
Subtotal Equipment			$ -
Total Direct Costs			$ 87,403.12
Indirect Costs	0.260		$ 17,524.81
	Grand Totals:	**$**	**104,927.93**

Form VI: Budget Summary YEAR 3

Staff	Salary Rate	Year 3	
		Hours	$
Salaries			
Student Assistants	$ 8.00	1920	$ 15,360.00
PGR I	$ 14.87	0	$ -
PGR II	$ 17.82	680	$ 12,117.60
Programmer I	$ 18.51	0	$ -
Administrative Analyst	$ 24.31	300	$ 7,293.00
Analyst III - Supervisor	$ 30.00	360	$ 10,800.00
Academic Administrator	$ 44.44	40	$ 1,777.60
Subtotal Staff		3300	$ 47,348.20
Benefits			
Student Assistants	2.00%		$ 307.20
PGR I	31.55%		$ -
PGR II	31.55%		$ 3,823.10
Programmer I	30.00%		$ -
Administrative Analyst	33.54%		$ 2,446.39
Analyst III - Supervisor	31.00%		$ 3,348.00
Academic Administrator	22.00%		$ 391.07
Subtotal Staff Benefits			$ 10,315.76
Travel			
Travel Costs			$6,500.00
Subtotal Travel			$6,500.00
Supplies & Expendables			
Supplies			$ 3,000.00
Subtotal Supplies			$ 3,000.00
Services			
Soil Testing (UC Davis)	$ 49.95	40.00	$ 1,998.00
LiDAR Data from Airborne1			$ -
The Nature Conservancy			$ 20,000.00
Subtotal Services			$ 20,000.00
Equipment			
Equipment			$ -
Subtotal Equipment			$ -
Total Direct Costs			$ 89,161.96
Indirect Costs	0.260		$ 17,982.11
	Grand Totals:	**$**	**107,144.07**

Ecosystem Restoration Program - 2002 Proposal Solicitation Package (PSP): Form VII - Budget Justification

All applicants must complete this form for their proposals. ***Failure to answer these questions will result in the application not being considered for funding.***

Direct Labor Hours. Provide estimated hours proposed for each individual.

Three Student Assistants (SAs) will be hired for 3.5 months each for each of the three years. Students will be trained by The Nature Conservancy and directed by a UC Davis Post Graduate Researcher (PGR) II on a daily basis. SAs will participate in experiment treatments, inventory and monitoring. A UC Davis PGR I will also be under the direction of a PGR II to facilitate GIS inventory mapping of the existing infestation for two months the first year and one month the second year. The PGR II, currently on staff with the Information Center for the Environment, will continue existing efforts and participate directly in experimentation and monitoring; the PGR II will also provide daily guidance to Student Assistants. The PGR II position is estimated at one FTE over the three-year period with slightly more time spent in Year 1 for project initiation.

A UC Davis Programmer I, currently on staff with ICE and responsible for Team Arundo database programming, will provide database design and implementation for three months of Year 1. An Administrative Analyst from the John Muir Institute will provide clerical, bookkeeping, and administrative capacity at 1.67 months per year over Years 1 – 3. Similarly, Analyst III-Supervisor currently on staff with ICE will provide continual project management, supervision over all directed staff, and scientific quality control at two months per year over Years 1-3. Lastly, Academic Administrator in Environmental will provide budgetary control and facilitate interagency coordination at one week per year over Years 1-3. Professor James F. Quinn will provide in-kind contribution as a full Professor at UC Davis with Principal Investigator status.

Salary. Provide estimated rate of compensation proposed for each individual.

Please see specific rates in attached Budgets.

Benefits. Provide the overall benefit rate applicable to each category of employee proposed in the project.

Benefit rates range from 2% for Student Assistants to 33.5% for administrative staffing. Please see the attached Budgets for specific benefit rates.

Travel. Provide purpose and estimate costs for all non-local travel.

Most of the travel is for local travel, through either vehicle reimbursement or rental of a university vehicle; daily travel will be required throughout five months of each year. One state or professional society conference meeting per year is included for three scientific staff each. Any remaining funds will be used to offset costs incurred to support

University staff directly employed in performing the terms of the specified scope of work. These costs include, but are not limited to travel to continuing education programs related to skills needed for this project, travel to professional conferences associated with the subject of this agreement and other travel appropriately related supporting the ability of staff to advance the subjects of this agreement

Supplies & Expendables. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies.

All supplies are directly associated with the project, including equipment in the first year that does not meet the definition of $5000 per item. Supplies comprise the costs incurred to support University staff and assets directly employed in performing the terms of the specified scope of work. These costs include, but are not limited to mailing services, postal charges, courier services, copying and reproduction services, data communication equipment, stationary and office supplies, equipment maintenance, freight, professional development, continuing education assistance, subscriptions, technical and academic publications and journals, miscellaneous repairs, space rental and campus meeting room rental. Other project specific funds include reinforcement bars for permanent plot markers, plastic piping, and a metal detector for plot detection.

Services or Consultants. Identify the specific tasks for which these services would be used. Estimate amount of time required and the hourly or daily rate.

Soil samples, processed by UC Davis Soil Science Laboratory, will be submitted for analysis for Lepidium-invaded patches (5) and non-invaded patches (5) at four sites in Year 1 and Year 3 for a total of 80 samples. Costs per sample are $49.95 and include grinding, particle size, bulk density, and saturation percent (pH, EC, Ca, Mg, Na, Cl, HCO_3, CO_3).

Light Detection and Ranging (LiDAR) data from Airborne1 (El Segundo, CA) will be acquired for $16,000. This one time cost in Year 1 covers project initiation, dearchiving of existing raw data from 2001, and georegistration for ~135 km2, encompassing the core parcels of Cosumnes River Preserve. These raster data include last-return bare earth digital elevations and first-return canopy elevations with 36cm vertical accuracy and 30cm horizontal accuracy.

The Nature Conservancy (TNC) will enter into a service contract with UC Davis to supply staffing, training, guidance and supervision, supplies and equipment to all phases of this proposal. Rebecca Waegell will provide supervision of weed contol activities, acquisition of necessary permits, property access and use of Preserve equipment and facilities. TNC has estimated the cost of this suite of services for a total of $75000, with $35000 available for Year 1 and $20000 for each subsequent year.

Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of

equipment is proposed, list parts and materials required for each, and show costs separately from the other items.

Equipment costs include the purchase of a server computer with RAID capacity ($13000) to handle all data storage needs (Dell PowerEdge ® 1750 Dual 2.8 GHz with Dell Power Vault ® 220S External SCSI Array). A GIS workstation ($5000) will be purchased to be used by staff to handle all spatial analysis needs (Dell Dimension ® 8300 Pentium 4 ® 3.2 GHz). Lastly, a Trimble Recon Global Positioning System two-pack ($6,896.00) will be purchased to handle all inventory and on-the-ground mapping needs (400 MHz Intel XScale ®). All prices reflect educational discount pricing. Any remaining funds will be used to offset costs incurred to support University staff and assets directly employed in performing the terms of the specified scope of work. These costs include, but are not limited to laptop computers, large format scanners and printers and other general equipment deemed necessary for the conduct of work in a GIS Environmental Informatics setting.

Project Management. Describe the specific costs associated with insuring accomplishment of a specific project, such as inspection of work in progress, validation of costs, report preparation, giving presentations, response to project specific questions and necessary costs directly associated with specific project oversight.

All project management costs are implicit within staffing costs. These include direct project oversight by Administrative Analyst, Analyst III – Supervisor, and Academic Administrator throughout the life of the project.

Other Direct Costs. Provide any other direct costs not already covered.

None.

Indirect Costs. Explain what is encompassed in the overhead rate (indirect costs). Overhead should include costs associated with general office requirements such as rent, phones, furniture, general office staff, etc., generally distributed by a predetermined percentage (or surcharge) of specific costs. *[CORRECTION: If overhead costs are different for State and Federal funds, note the different overhead rates and corresponding total requested funds on Form I - Project Information, Question 17a. On Form VI - Budget Summary, fill out one detailed budget for each year of requested funds, indicating on the form whether you are presenting the indirect costs based on the Federal overhead rate or State overhead rate. Our assumption is that line items other than indirect costs will remain the same whether funds come from State or Federal sources. If this assumption is not true for your budget, provide an explanation on the Budget Justification form.]* Agencies should include any internal costs associated with the management of project funds.

Indirect costs are not charged on Equipment, nor on the first $25000 of the external contract with The Nature Conservancy. The University of California employs negotiated facilities and administrative costs rates (formerly termed "indirect cost rates") of 26% for

budgeting and administering off-campus organized research, instruction, and other sponsored projects. These rates apply to all federal and non-federal projects (http://ovcr.ucdavis.edu/IndirectCosts/Directive03-083.pdf). Currently, the University of California, Davis is observing the 26% indirect rate for all projects initiating after January 1, 2004 through State funding programs. Agreements through the Cooperative Ecosystem Study Unit (CESU) with Federal entities are eligible for the 17.5% indirect rate and may be available.

Cosumnes River Preserve Perennial Pepperweed (Lepidium latifolium) Control Project

A. Project Description: Project Goals and Scope of Work

A-1. Problem Statement

Perennial pepperweed, *Lepidium latifolium*, is a highly invasive perennial herb that can thrive in a wide range of habitats including riparian areas, wetlands, marshes, and floodplains (Bossard et al. 2000; Young et al. 1995). *Lepidium latifolium* (hereafter referred to as *Lepidium*) has already invaded many habitats throughout the San Francisco Bay-Delta area, and is of particular concern in areas where active restoration is underway. Once established this plant creates large monospecific stands that displace native plants and animals and can alter soil composition by concentrating salts at the surface (Blank & Young 1997; Renz & DiTomaso 1998; Young et al. 1995). It interferes with regeneration of cottonwood and willow species, as well as key herbaceous species, in riparian and wetland areas (Young et al. 1995). It is on the A-list of the California Invasive Plant Council's (CALIPC, formerly CalEPPC) list of Exotic Pest plants of Greatest Ecological Concern in California, and on the California Department of Food and Agriculture's B list of noxious weeds due to its highly invasive nature. This species is considered a high-ranking threat to critical habitats within the Cosumnes River Preserve (CRP 2002). It is a priority for control efforts because of its highly invasive nature, the threat it poses to native habitats including valley oak riparian forest, mixed riparian forest, seasonal and permanent wetlands and associated uplands, and because potential for its control is considered high.

Lepidium has emerged as the invasive plant of most concern in the restoration projects in the Cosumnes River Preserve. The Nature Conservancy, on behalf of all of the partner land managers in the Preserve (including BLM, Fish and Game, U.S. Fish and Wildlife Service, Ducks Unlimited, Sacramento County, and a number of local farmers and ranchers) is planning an aggressive program of *Lepidium* control. However, the available science for choosing the best control strategy is limited, despite the importance of the plant throughout the Delta region and on many other restoration sites. As a result, TNC and BLM, on behalf of the entire project, propose a research and adaptive management program for Lepidium to build on two CALFED and Packard Foundation-funded Cosumnes Research Group (CRG) projects.

Under these, the Cosumnes River Preserve serves as a model of habitat conservation and floodplain restoration in the Central Valley. Scientists in the Cosumnes Research Group I and II (CRG) (CALFED grants #1999-NO6, #2000-FO8, #2001-NO1) and on CRP staff are studying changes in hydrology, vegetation, and aquatic and terrestrial biota that are occurring in response to natural and man-made breaches to levees along the Cosumnes River within preserve boundaries. Research and monitoring at these passive and active restoration areas is providing valuable data that can be used to inform future restoration activities in the CALFED region. CRG is led by the Center for Integrated Watershed Science and Management (UCD Watershed Center) and the Information Center for the Environment (ICE) at UC Davis, but involves all of the agencies active in the Cosumnes Floodplain, and is one of the major field sites for the Bay-Delta Science Consortium.

More generally, since CRG wrote the original CALFED proposals, it has become increasingly clear that the biological element most likely to disrupt the desired future conditions in the Cosumnes floodplain (and generally throughout the Delta region) is invasive species. This

proposal complements ongoing Cosumnes research by performing an intensive study of the most rapidly expanding invasive plant in the Cosumnes study area. The approach closely follows recommendations of the recent CALFED workshop on Adaptive Management of Invasive Species (Davis, July 2003), and represents a pilot-species, pilot-region application of a general framework to experimentally develop control strategies for terrestrial invasives in the CALFED region. Workshop results (Qualset *in prep.;* Webb 2003) included recommendations that:

- Experimental designs should incorporate literature review, a conceptual model, hypothesis testing, sufficient replicates for statistical significance, control plots, predictive modeling, and partnerships betweens academics/scientists and practitioners.
- Performance measures should be linked to project goals and objectives, include peer review and collaboration, measure the ability to assess success or failure, include measurement of NIS and native species abundance, and measure variables such as distribution, rate of spread, structure, environmental conditions and change in vigor of NIS.
- Monitoring should establish baseline data at an appropriate spatial and temporal scale, use standard methods, measure effort and effectiveness, be affordable, and involve quality assessment and control, peer review and cooperative data management.
- Links to restoration should include identification of restoration goals and vulnerabilities of restoration projects to NIS. Participants noted that prevention, early detection and rapid response to NIS led to the most successful restoration projects. Projects should quantify impacts of NIS and relate restoration to habitat processes and functions as well as protection of listed species.

This proposal will address several scientific needs of the ERP via targeted research and pilot projects regarding adaptive management and monitoring of weed control efforts in general and *Lepidium* specifically. Inventory and continued monitoring of existing *Lepidium* populations at the Cosumnes River Preserve (figure 1) by will provide the background data necessary to statistically analyze population change as adaptive management projects proceed (Objective 1). Targeted research on control of *Lepidium* will use a scientific hypothesis-testing approach to refine our conceptual model and guide adaptive management actions (Objective 2). This research is explicitly designed to add to existing knowledge about relationships between management techniques and ecosystem structure and function by testing current hypotheses concerning weed control and ecosystem restoration (Objective 3).

Existing models of *Lepidium* control and the response of physical and biotic system components (figures 2-3) (Blank & Young 1997; Blank et al. 2002; Renz 2002) are currently unable to answer key questions regarding the impact of *Lepidium* management on soil physical and chemical parameters and the response of surrounding vegetation. This targeted research will help to solve these unknowns. Results will then be used in an adaptive management framework to guide full-scale implementation of *Lepidium* management at the Preserve, as well as being incorporated into a framework for meta-analysis of related projects in the CALFED region.

Current database and GIS-based systems of tracking have been identified as insufficient for maintaining complex records integrating management records with weed population change over time. Participants in the workshop "Mapping: Setting priorities and communicating scope" at the 2003 CALIPC conference came to the conclusion that the California weed mapping community lacks a standardized database model for successive observations that can deal with non-discrete units of shrinking and swelling populations. National initiatives to provide standards are well-

under way under leadership of the National Invasive Species Council, the Federal Interagency Committee for the Management of Noxious and Exotic Weeds, the North American Weed Management Association, and the National Biological Information Infrastructure. ICE has been funded by the Resources Agency, USGS, and NSF to further specify and implement the emerging national standards in California. We propose to use the TNC/Cosumnes Preserve Lepidium study as a test and demonstration project for the separately-funded information technology effort (see Objective 3 below).

A-2,3. Approach & Justification

Objective 1. Monitoring and analysis of population patterns and trends

Since 2001, we have conducted annual or more frequent GPS-based pilot surveys of *Lepidium* in selected portions of the Cosumnes Preserve, notably near the headquarters and visitor area, within oak restoration sites, and in the intensively studied experimental floodplains that are core sites for the current CALFED grant research in the Cosumnes. Many of these were unfunded TNC volunteer or UCD student projects, but they have established that *Lepidium* is a growing problem on sensitive habitats within the Preserve boundaries.

We will continue to intensively monitor *Lepidium* populations within the restored "upper and lower floodplain" area of the Preserve, and expand the monitoring into new adaptive management experimental areas described below. Monitoring at these sites currently includes recording of location (via Global Positioning System), patch size (area and perimeter), and *Lepidium* stem count within each geographically distinct patch. We will continue to monitor established populations each year, and we will begin documentation of new populations each year. Future monitoring will also include surveys of surrounding vegetation, density estimates of *Lepidium* using both visual and digital image methods, as well as site-specific records and photo-series of management actions and outcomes. These methods have been and will continue to be validated by calibrated methods of density estimates. A number of these same parameters have been recorded in other studies on *Lepidium* patches in the Bay-Delta area (Renz 2002). Maintaining similar monitoring protocols and recording equivalent parameters will allow meta-analysis of *Lepidium*, and other invasive weeds, in the future (see below).

Beginning in Spring 2004 (Year 1) we will inventory *Lepidium* populations throughout unsurveyed riparian and floodplain areas of the Cosumnes River Preserve. At these locations we will record GPS location, patch size (area and perimeter), surrounding vegetation type, and an ocular estimate of *Lepidium* density.

In order to further inform tracking efforts and research capabilities, we will test the ability to age existing stands of *Lepidium* using underground stem rings. Aging perennial forbs by staining of roots has proven to be an effective means of determining the age of weed infestations in both North America and Europe (Dietz & Schweingruber 2002; Dietz & Ullmann 1997). All six species within the Brassicaceae family that have been tested have shown clear or relatively clear root growth rings. We will follow the phloroglucinol–HCl root staining procedures used in these studies. If successful, aging of *Lepidium* patches could help establish rate and mode of spread. Predominant mode of spread remains an unsolved problem in *Lepidium* research and one that could prove valuable in prioritizing target areas for management.

To aid in surveys of surrounding vegetation we will develop a handbook of local floodplain vegetation for use in plant identification by interns, volunteers and CRP staff. This will be the continuation of a "virtual herbarium" project begun in summer 2003. This project indexes digital

photographs by species name and location within the preserve. We will collaborate with Calflora to use existing photos when available and to contribute to Calflora new photos taken by ICE and CRP staff for the virtual herbarium. A handbook of locally common floodplain plants will be printed for field use, and the virtual herbarium will be made available online to the general public through the CRG II website. In the course of the project, it will be migrated to Electronic Field Guide technology (under development with NSF and National Biological Information Infrastructure support for national application to invasive species surveys and on-line mapping – see *http://www.cs.umb.edu/efg/*). This technology will allow coordinated real-time access to palmtop, web, and probably wireless forms of the data, keys, maps, and images.

We will integrate new population data into our ArcGIS-based tracking system to assess expansion or decline of *Lepidium* populations on the preserve relative to site characteristics and management actions. We will continue to refine conceptual models of *Lepidium* spread using geographic information system technology to investigate relationships between population trends, physical site characteristics, and geographic location such as proximity to roads or waterways. To better inform analysis of physical site factors (e.g., digital elevation and canopy height at 36cm vertical resolution, standard 2 food FEMA contour interval) we will acquire archived LIDAR imaging of the entire central preserve area from Airborne1 (El Segundo, CA). These data will allow calculation of relative elevation (a surrogate for flooding frequency) and canopy heights throughout the project area; these data were collected by Airborne1 in 2001 and are available at a reduced fee. This information will be shared with Cosumnes Research Group II hydrologists modeling flow and transport, and CRP staff. These valuable data will provide critical inputs to not only model hydrological regimes on the preserve, but also to address the role of canopy cover in determining invasion success.

As described below, the investigators are working with USGS (NBII) and the Resources Agency to address the ongoing need within the GIS weed tracking community by developing a standardized, geographically-based database framework for this and other weed control projects. The framework builds on existing distributed databases and emerging "semantic web" technology, and will enable data sharing and meta-analysis of multiple CALFED projects. On the level of individual projects, this framework will help to streamline data storage, project assessment and statistical evaluation of results. The invasive species applications of this technology will be developed by the investigators in coordination with State Weed Coordinator Steve Schoenig, ongoing Team Arundo efforts, and the California Legacy Program. Funding for the technology development *per se* has been obtained from USGS, the Legacy program, and the National Science Foundation, which will mostly cover the costs of developing the *Lepidium*-specific application.

Objective 2. Targeted research on *Lepidium* control

Targeted research on the effective control of *Lepidium*-infested riparian and floodplain sites is a necessary first step in a series of experiments that will inform full-scale implementation of the adaptive management of *Lepidium* at the preserve. Objective 1 (above) will help to clarify the extent of the *Lepidium* problem at the preserve through expanded inventory and monitoring. CRP staff have set their ecosystem goal to improve the ecological health of riparian and floodplain habitats in the Delta and Eastside Tributaries Ecozone by eradicating *Lepidium*. Specific objectives towards this goal include implementation of control strategies to reduce the cover of *Lepidium* on the Cosumnes River Preserve, and monitoring of treated areas to determine if follow up management is necessary to increase native species covers once *Lepidium* has been

controlled in small patches. Objective 2 of this proposal will inform the first of these objectives by providing scientific guidance on the best control strategies for different ecological settings on the preserve.

We will use a stratified random block design at four different sites on the Preserve to experimentally determine the efficacy of targeted cut stem application versus broadcast spraying of chlorsulfuron or glyphosate on large and small *Lepidium* infestations. Our experimental design will consist of 3 replicates per treatment for a total of 72 plots at each of four sites (blocks). Because duration of inundation has significant effects on *Lepidium* growth, we will stratify our randomized block design by floodplain position to control for effects of flooding period. Classification of floodplain position ("wet" or "dry") will be determined by LIDAR-derived elevational data. Through this stratification we will be able to distinguish results due to flooding versus experimental treatments. This is to address preliminary results (unpublished research) at this site and the findings of others (Chen et al. 2002; Renz 2002) that indicate degree of flooding at a site can affect the invasibility of *Lepidium*.

Experimental Design

	Low Density *Lepidium*	
	Chlorsulfuron	
	Wet	Dry
Cut Stem		
Broadcast		
	Glyphosate	
	Wet	Dry
Cut Stem		
Broadcast		
	Control	
	Wet	Dry
Cut Stem		
No treatment		

	High Density *Lepidium*	
	Chlorsulfuron	
	Wet	Dry
Cut Stem		
Mow + Broadcast		
	Glyphosate	
	Wet	Dry
Cut Stem		
Mow + Broadcast		
	Control	
	Wet	Dry
Cut Stem		
Mow		

no thatch removal thatch removal

Seasonal flooding has been demonstrated to effectively eliminate *Lepidium*, but only in areas with a short growing season and long durations of inundation (Renz 2002). *Lepidium* populations in low-lying areas with long inundation periods in the Lower Klamath area (Cascade/ Modoc bioregion) did not expand over 2 years, and one infestation in this area declined (Renz 2002). Extended periods of flooding at a study site in Reno, Nevada appeared to inhibit but not prevent growth of *Lepidium* (Chen et al. 2002). *Lepidium* populations currently being monitored at the Cosumnes River Preserve show a decreased growth response in areas that experience greater periods of inundation. In a multiple regression analysis, floodplain position significantly affected change in stem count between 2001 and 2002 (Adjusted $R^2 = 0.75$, $p < 0.001$, DF = 167).

We have designed our experimental treatments to build on previous research, which indicates that different management techniques are needed in dense versus establishing stands of *Lepidium* (DiTomaso 2003; Renz 2002). Based on the recommendations of these researchers, we will apply different treatments and analyze both separate and combined results for experimental treatment of low-density versus high-density stands of *Lepidium*. Renz (2002) found that stand

density had a significant effect on the effectiveness of both glyphosate and chlorsulfuron treatments on *Lepidium* control. We distinguish high-density stands as having >85% cover of *Lepidium* (Renz 2002)and low-medium density stands as having <50% *Lepidium* cover based on ocular density estimates in the central 1 m^2 of the stand.

Mowing and thatch removal are necessary prior to broadcast spraying in dense *Lepidium* patches based on the results of Renz (2002). Mowing was found to be unnecessary in establishing, low-density *Lepidium* patches (Renz 2002). Mowing of plants causes an alteration in the architecture of regrowth that positively affects the depositional pattern of sprayed herbicide solution (Renz 2002). By mowing and allowing regrowth of plants before spraying, herbicide application is timed to synchronize with maximal translocation of carbohydrates to below ground structures (Renz 2002). Thatch removal is necessary in high-density stands to allow full coverage of plants during herbicide application. Thatch removal is also important in treated areas that have large Lepidium stands, as litter accumulation from *Lepidium* may lead to excessive salt accumulation at the soil surface (Blank & Young 1997; Renz 2002).

We will follow the same protocols used by Renz (2002) for mowing and broadcast application of herbicides in order to maximize comparability of data between projects. Mowing in dense infestations will take place around late May using weed-eaters or flail mowers to mow stems to a 2 to 5 cm height from the soil surface. We will use a backpack sprayer for broadcast application of herbicides when shoots that bolt after mowing resprout to the flowerbud stage. We will use rakes to manually remove cut and mowed vegetation in treated high-density plots. Broadcast herbicides will be applied at rates of 0.104 kg ai/ha chlorsulfuron (which resulted in 100% control in treatment of floodplain populations by Renz 2002) and 3.33 kg ae/ha glyphosate (which resulted in 62.4 % reduction in *Lepidium* density in floodplain populations, Renz 2002). Both herbicides will be applied in Years 1 & 2. If 90% control is achieved by the end of Year 2, no herbicides will be used in Year 3. Otherwise, herbicides will be applied in Year 3.

We will be investigating a new method *Lepidium* control with out cut stem herbicide application treatment. We hypothesize that cut stem herbicide application will have less detrimental effect on surrounding vegetation than broadcast spraying, with or without prior mowing, due to the reduced chemical and physical impact of this method on surrounding vegetation. As glyphosate is a nonspecific herbicide, it has obvious short-term effects on surrounding vegetation. Chlorsulfuron is specific to broad-leaf plants, and is reported to have strong effects on many less invasive species found at our sites including smartweed (*Polygonum amphibium*) and cocklebur (*Xanthium strumarium*)(PMEP 2003). Renz (2002) found that incorporation of mowing into the management of *Lepidium* reduced species diversity at a site with low densities of *Lepidium*, suggesting that some resident plant species were negatively affected by mowing, and had reduced coverage as a result.

Cut stem application of herbicides will take place twice in the growing season: once for early-season culms in June and once for late-season culms in August. Renz (2002) found that phenologically this maximum accumulation occurs between full flower and fruiting stages. Young and others (1998), however, found best control from broadcast herbicide applications at the flower bud to early flowering stages. Wilson (2003b) found that application of glyphosate was not effective in the rosette stage but was highly effective in the flower bud stage, whereas chlorsulfuron was effective in both stages. To maximize herbicide accumulation rates into below ground reproductive structures, yet prevent seed drop, we will time our cut stem applications of

both herbicides after flower bud set and before fruiting of culms for both yearly applications. We will use "kut-n-kill"™ shears to immediately apply herbicide to cut stems.

Herbicide selection was based on results and recommendations from previous researchers. Glyphosate was chosen because it is a non-residual herbicide, which has proven effective in control of dense *Lepidium* patches in floodplain sites (Renz 2002). Treatment with 2,4-D was ruled out because of its inconsistent results in mowing + broadcast application tests by Renz. Unpublished trials of Garlon, which has similar properties to 2,4-D, at the Cosumnes River Preserve, were ineffective in *Lepidium* control, leading land managers at the reserve to prefer trials with glyphosate for further experiments. Chlorsulfuron was selected due to its high success rates in control of *Lepidium* at multiple sites throughout the West (Renz 2002; Wilson 2003a; WRIC 2003; Young et al. 1998). Chlorsulfuron is also a preferred herbicide for *Lepidium* control for its low toxicity to humans and animals and its good target specificity. Chlorsulfuron is in the sulfonylurea class of herbicides, which interfere with protein synthesis via a biochemical pathway present in plants and micro-organisms, but not in animals (Boschin et al. 2003).

Accumulation of the herbicide chlorsulfuron in soils is a strong concern and is one reason for our trial of cut stem application. Chlorsulfuron is associated with the water-soluble fulvic acid fraction of soils and is therefore highly mobile in soil-water-plant pathways (Boschin et al. 2003; Guo & Sun 2002). Phytotoxicity has been observed in crops planted in soils with aged chlorsulfuron residues, which may be due to the tendency of chlorsulfuron to accumulate with time in the soil humin fraction (Guo & Sun 2002). We suspect that cut stem application of chlorsulfuron will have less effect on surrounding vegetation than broadcast application. We will conduct both cut stem application and broadcast spraying to test this hypothesis. We will test both chlorsulfuron and glyphosate to test which herbicide is more effective at *Lepidium* control while allowing recruitment of desirable species.

We will assess the impacts of our experimental treatments on surrounding vegetation in order to inform restoration management decisions. Literature on revegetation following *Lepidium* control is inconclusive and suggests strong dependence on individual site characteristics. Young and others (2002) found that chlorsulfuron inhibited regrowth of all vegetation for 2 years following treatment (application rate of 0.071 kg/ha). Renz (2002)found no problems with revegetation after chlorsulfuron treatment (application rates of 0.104 and 0.052 ai kg/ha). Young and others (Young et al. 1998) reported immediate growth of meadow foxtail (*Alopecurus pratensis*) or saltgrass (*Distichlis spicata*) in some of their replications (application rate of 0.6 kg ai/ha). Site-specific soil conditions (low to neutral pH) and direct application to cut stems should reduce the concentration of residual herbicide in soils and decrease the possibility of negative effects on desirable vegetation.

Vegetation response will be evaluated in Years 2 & 3 by comparing percent cover of species and life history classes (annual dicots, annual grasses, and herbaceous perennials) within treatment areas to cover in adjacent, non-infested areas. Yearly variation in species composition due to natural environmental fluctuation will be recorded in three non-infested 0.25 m^2 quadrats located in random directions 5 m away from the perimeter of each treated *Lepidium* infestation. Percent cover within treatment areas will be sampled in three randomly placed 0.25 m^2 quadrats per treatment area. Ocular density estimates of individual species will be recorded in these quadrats in Years 1, 2 and 3. These survey protocols follow those used by Renz (2002)and will therefore allow meta-analysis of our combined results.

Non-chemical control options for *Lepidium* are limited due its perennial nature combined with the many characteristics typical of invasive weeds (Baker 1974) which this species exhibits. However many of the habitats where the species occurs do not allow chemical treatments, such as environmentally sensitive areas and lands adjacent to organic crops. The suite of non-chemical methods typically used has not provided adequate control. Discing alone has been shown to effectively spread rather than reduce *Lepidium* populations (Young et al. 1998). Mowing alone does not significantly reduce pepperweed abundance either (Renz 2002).

Tarping is becoming increasingly popular as a non-chemical control option (Horowitz 2003). Tarping is the use of black plastic, or like material, to cover the soil surface for a prolonged period with a goal of depleting a plant's carbohydrate reserves. While efficacy with herbaceous perennial weeds has not been widely studied, tarping has been shown to be as effective as fresh cut stump treatments with Garlon 4 for an invasive tree species, *Acacia dealbata* (Horowitz 2003). Mulching, even with 4 layers of hay, was ineffective in controlling *Lepidium* in one person's anecdotal experience (CALIPC 2003). No tarping or solarization experiments have been reported for *Lepidium*. Given the rigorous nature of pepperweed growth, tarping alone would likely reduce pepperweed density and vigor immediately following treatment, but might not provide long-term control. If the carbohydrate stores could be reduced to smaller units via either discing or mowing, followed by tarping, treatment efficacy should improve.

We will research the efficacy of multi-year tarping to control *Lepidium* infestations in areas where herbicides cannot be used. Four treatments will be applied: tarping alone, discing followed by tarping, mowing followed by tarping and untreated controls. Mowing and discing will be conducted prior to tarping, in early to mid spring. All treatments will be applied with replication. Plots will be 3m X 3m. Each plot will be tarped with 3 meter wide 10 mm thick black plastic, doubled over for each treatment. Each plot will be covered with oilcloth canvas to prevent tarp deterioration. Canvas will be removed for 2 weeks in late July/early August to elevate temperatures below the tarp, thereby eliminating any *Lepidium* seeds in the soil seed bank. Tarps will remain in place for 2 full growing seasons. Treatment effects will be analyzed statistically with appropriate tests (i.e., ANOVA). Plots will be evaluated for *Lepidium* control and community recovery.

Lepidium has been shown to lower soil pH (Blank & Young 2002), which may actually aide in the breakdown of chlorsulfuron. Chlorsulfuron degradation is sped by low soil pH and organic matter presence (Boschin et al. 2003). In sodic soils with high pH located in Reno, Nevada, Blank & Young (2002) found inhibition of revegetation efforts in chlorsulfuron-treated areas. Most soil types in target areas of the Cosumnes River Preserve range from moderately acidic to neutral (Galt, San Joaquin, Clear Lake, Cosumnes, Columbia series), with only one soil type (Dierssen) in the slightly alkaline range (USDA-NRCS 2003). Sodicity of soils on the Preserve is unknown. By testing pH and sodicity at a subsample of our treatment and control sites at the start and end of the study, we will be able to determine the effects and suitability of chlorsulfuron use on the soil types found on Central Valley floodplains.

Lepidium has been shown to modify the soil profile to favor its own growth and survival (Blank 2002). In a study by Blank and Young (2002) comparing soil beneath *Lepidium* and *Elytrigia elongata* (tall wheatgrass), soils beneath *Lepidium* infestations had increased levels of C, N, Mg, P, K, Ca, greater nitrogen availability down to depths of 86+ cm (Blank 2002), lower pH, and lower sodium adsorption ratios. These soil alterations may lead to "improved" soil physical properties including amelioration of sodic soils, increased aggregation, and increased effective

rooting depth (Blank & Young 2002). The authors caution that excessive salt accumulation on the soil surface due to litter decomposition may reduce the potential for plant growth. To date, no data is available to support or refute their hypothesis that *Lepidium* may increase soil surface salinization (Blank & Young 2002). Our study will test this hypothesis through testing of salinity measurements at sites with and without *Lepidium*.

We will determine the relationship between soil type and *Lepidium* growth response, and the impact of experimental control methods on soil salinity, by evaluating soils at each of the four treatment sites before treatment in Year 1 and after treatment in Year 3. Five soil samples from under *Lepidium* invasions and five samples from non-invaded areas will be collected at each of the four treatment sites in each sampling year (n = 10 samples x 4 sites x 2 years = 80 samples). We will follow the protocol of Blank and Young, avoiding sampling in a >5-m buffer zone at the invasion front and taking soil surface samples at 0-5 cm. Soils will be evaluated at the UC Davis DANR lab. Tests will include bulk density, soil particle size, and the lab's "salinity package" which includes saturation percent, pH, EC, Ca, Mg, Na, Cl, HCO_3, and CO_3.

By combining existing geographic and population monitoring data with data resulting from this project, we will use standard statistical methods (e.g. MANOVA) to assess relationships between site-specific characteristics and response of *Lepidium* and surrounding vegetation to control measures.

Objective 3. Adaptive Management Framework

In July 2003, CALFED sponsored a workshop at UC Davis on adaptive management of invasive species. The investigators were all on the organizing committee for the conference, and moderated and reported on the breakout sessions. The adaptive management framework recommended by the workshop (Qualset *in prep.;* Webb 2003) includes:

- A framework for integrated early detection of, and rapid response, to new invasions
- An experimental design for evaluating management options, including multiple alternatives, experimental controls, and outcome assessment
- Multiple-scale analysis of occurrences, spread, and control of invasive populations
- A GIS and modeling framework for identifying sites at particularly high risk
- A distributed information system linking multiple experiments and restoration sites and groups.
- Meta-analysis to extract statistical patterns from the collection of experiments beyond those detectable in individual experiments

This study will address each of these elements at least at a pilot level.

Early Detection/Rapid Response – Both ICE and TNC are active participants in both state and federal initiatives to establish early warning/rapid response (EDRR) networks, and will use this project as a field test of emerging proposed standards from the National Invasive Species Council (through several partner agencies) on how to share EDRR information over the Internet. With USGS funding, ICE has taken a leadership role in data interoperability standards. The TNC Wildland Invasive Species Team (*http://tncweeds.ucdavis.edu/*) headed by TNC National Invasive Species Coordinator (and former Cosumnes River Preserve Scientist) John Randall is the leading on-line source of species identification and control method data. However these capabilities have not been combined, nor used in the context of site risk assessments to target high-risk sites for early detection activities. In this study, we will develop protocol for wider application with *Lepidium* in which we will use the NBII risk-modeling framework (see below)

to identify sites with high susceptibility to invasion in the study area, test them (vs. control sites chosen randomly) for *Lepidium* occurrences, as detected by UCD students and TNC volunteers using the TNC's identification tools, help sheets, and related online materials. Those findings will be automatically reported into the prototype EDRR network under development at USGS as it becomes available, and to state partners John Randall (TNC), and Steve Schoenig (Invasive Species Coordinator, Cal. Department of Food and Agriculture). In another proposal, Dr. Schoenig and we are seeking funds to share the data for *Lepidium* and 6 other high-profile weeds with 5 county agricultural commissioner offices in the Delta region (for target control efforts by counties.)

Experimental Design – The experimental design for occurrence and control methods is described in the previous section. Note that we treat multiple causes of *Lepidium* mortality, both natural (e.g., inundation, soil, shading), and through control methods, constrained or not constrained by limitations on chemical use, in a partial factorial design. Depending upon the outcomes of those experiments, sequential follow-up will be adaptively targeted to the part of the full factorial design space that promised to give the greatest information to managers (i.e., where the variance in outcomes is greatest). Much of the follow-up will be after the period of this study, but it is TNC's intention - as they did with oak restoration (Keller 2002) - to continue incremental experimentation on restoration methods and outcomes over the long term.

Multiscale Analysis – The proposed analysis occurs on the nested scales, individual (blocked) control method experiments on a meter-scale, inundation frequency/duration and related soil properties (i.e., depositional vs. erosional sites on the floodplain), which in the Cosumnes vary on scales of hectares to square kilometers, and watershed scale. At this stage, the watershed-scale assessment is in the design phase, and will come both from data sharing with other projects (TNC, CDFA, the Team Arundo group) and remote sensing. Remote sensing will probably be the most effective means of change detection for *Lepidium*. However this will require validation of methods our group, along with the UC Davis Center for Spatial Technology and Remote Sensing (CSTARS), has developed for other taxa (e.g., coastal Arundo and iceplant, see (DiPietro et al. 2002; Underwood et al. 2002; Ustin et al. 2002) and additional funding, which we will seek from NASA. CSTARS may receive funds for the appropriate hyperspectral imagery in 2004-5 for an area immediately adjacent to the study area, and extending into the Delta. If so, we will be able to work with them to test the methods on *Lepidium* in Nature Conservancy holdings on the McCormack-Williamson tract (for which Keller and students in Quinn's classes have done vegetation surveys) and Staten Island.

Additional scale questions arise in transport of *Lepidium* (and most other new invasive plants). Using standard GIS methods, we will be able to statistically test for proximity of infestations to roads, disced vs. undisced fields, levee breaks, and other disturbances that might break up and transport roots.

GIS and Modeling Framework – Geolocated (GPS) *Lepidium* patches are already entered into the extensive GIS framework established by ongoing CALFED projects on the Cosumnes floodplain (*http://watershed.ucdavis.edu/crg/*). Under other funding (USGS), we are constructing statistical models that use regression-like methods to predict probabilistic distributions of species from their recorded point occurrences and mapped predictors (elevation, soil, vegetation type, inundation time, distance from road, distance from levee breach). By the end of Year 1, we expect to be able to apply at least 4 models of this kind, for example decision tree, logistic regression, GARP (Anderson et al. 2003; Stockwell & Peterson 2002), and co-kriging (Chong et

al. 2001). "Pixels" for which a high probability of occurrence is calculated should represent optimal habitat for the invader. Those with high probabilities in which ground studies show the species is absent should represent the locations with the highest risk – on which both early detection/rapid response efforts should be concentrated.

Once the risk-prediction framework is in place, it can be used both to target on the ground management controls, and to experimentally test efficacy. (For example, it is likely that hectare-plus infestations in pepperweed-friendly habitats have escaped economically feasible control – managers may choose a triage approach in which a combination of habitat value and lower pepperweed suitability make control efforts attractive.) Such capabilities are a long-term goal of this research program.

Distributed Data System – (see Data Handling and Storage)

Meta-analysis – Ultimately, ecosystem-scale adaptive management experimentation in general, and control of invasive species in particular, can only be assessed across the full domain of the interacting localities. Not only is an individual locality (even one as extensive as the Cosumnes floodplain) not isolated from population sources outside its boundary, but it may lack the full range of environmental conditions needed to conduct full experimental tests of hypothesis about what controls the distribution and growth of critical (invasive, keystone, T&E) species. Medical and epidemiological researchers have successfully combined multiple experiments addressing different influences on disease or public health to statistically increase effective sample sizes and partition variance among competing influences. Despite the structural similarities between disease and invasive species analyses, few if any formal meta-analyses currently exist to combine experimental data on invasive species spread and control methodologies.

The information needs for successful meta-analyses are partly technical – datasets need to be converted to the same controlled vocabularies and measures, and composite unmanipulated "control" sets may need to be constructed. These are all feasible under the distributed-information strategies contemplated in this study. There is also a social element in an effective regional system for meta-analysis. Investigators can increase statistical power and contribute more to overall understanding by coordinating with other experimenters (e.g. by sharing controls or experimenting with a variable held constant in another study). Keller (2002, in prep) investigated the opportunities for meta-analysis of the success of valley-oak restoration in the Cosumnes and similar Central Valley settings, and concluded that managers would have had a much stronger basis for predicting success of plantings with a small increment in additional plots and treatments.

It is pre-mature to construct a meta-analysis for *Lepidium* spread and control with existing information, but we propose to formally analyze the data availability and unmet needs, propose a data and statistical model to address them, and create a report on how meta-analysis could be structured and used to strengthen adaptive management for floodplain and riparian invasive species in the Central Valley region.

A-4. Feasibility

Invasive species control on the Preserve has been carried out over the last 6 years. In that time, Preserve staff and volunteers have demonstrated the ability to control and monitor those plants identified in the Preserve's Weed Management Plant as the highest threat to the Preserve's goals. The exception has been *Lepidium*. Although some control techniques have been tested and proven effective by researchers (Renz 2002; Young et al. 1998) control efforts at the Preserve

have been hampered by insufficient resources. As this plant is a hardy weed, capable of germinating and growing even in extreme temperature conditions (Miller et al. 1986), we do not expected weather to hamper our ability to inventory, monitor or apply control methods to *Lepidium* populations. This project will allow the hiring of sufficient support staff to inventory and monitor populations on the Preserve, and to scientifically develop an adaptive management strategy for *Lepidium* control in multiple riparian floodplain settings.

Monitoring and GIS-based analysis of *Lepidium* populations at the Cosumnes River Preserve has been conducted for the last two years by staff at the UC Davis Information Center for the Environment (ICE). This proposal will simply provide support to expand ongoing efforts to allow researchers to answer more broadly applicable management questions. This support will be in the form of additional staffing (programming, student assistants and PGR I) and necessary data acquisition (soils testing and LiDAR imaging). ICE has considerable expertise in experimental design and implementation, data analysis, GIS-based technology, database design and data management, and will provide all machines, general software licenses (especially for ESRI GIS software), connections to the Internet, and system administration needed for the data management, statistical analysis, mapping, and website serving the project

Work will be conducted on the Preserve under the aegis of the Preserve's Cooperative Management Agreement, which gives management authority for all Preserve lands to the Preserve Manager, Rick Cooper (BLM). Activities will only be carried out on lands within the Preserve.

TNC and BLM will prepare the necessary environmental documents: an environmental assessment (EA), a decision record (DR), and a pesticide use proposal (PUP). These documents will closely follow the content and format of an existing EA, "Limited Herbicide Use at Cosumnes River Preserve", and related documents prepared in 1999 by BLM's Folsom Field Office. The scope of the documents will need to be expanded to include approximately 20,000 acres (four times that covered by the existing documents). It also will be necessary to initiate informal consultation with the Fish and Wildlife Service (FWS) with respect to the giant garter snake and the valley elderberry long-horned beetle.

A-5. Performance Measures

Objective 1. Monitoring and analysis of population patterns and trends

Performance of Objective 1 will be assessed on the basis of number and extent of sites inventoried and monitored. Priority sites for inventory and monitoring efforts are those areas that will be sites of the targeted research of Objective 2. Performance of Objective 1 will be considered successful if monitoring is completed in Years 1-3 at ongoing *Lepidium* monitoring sites in the Upper and Lower Floodplain, and if all sites undergoing experimental treatment in Objective 2 have been inventoried in Year 1.

Successful performance of Objective 1 will also include performance and subsequent reporting of trials of *Lepidium* stem aging and completion of a handbook of common riparian and floodplain plants on the Preserve.

Objective 2. Targeted research on *Lepidium* control

Successful implementation, statistical analysis, and write-up of results of the experiments outlined in the Approach & Justification, Objective 2 section (above) will constitute successful performance of this objective.

Objective 3. Adaptive Management Framework

As with the earlier Cosumnes Research Group projects, this part of the proposed work is research and set of pilot applications, and contributes more toward the CALFED adaptive management mission primarily by developing criteria and information systems that can be applied to adaptive management of on-the-ground restoration elsewhere. A major goal of this section of the research is publications describing AM protocols, analytical methods, and software that can help guide land managers in Cosumnes and in other managed grasslands and wetlands infested with *Lepidium.* We anticipate that the results will be sufficiently general to be applicable to most perennial terrestrial invasive plants.

Early detection and rapid response – The major accomplishment expected is tested field protocols, software and digital help materials to permit fieldworkers, especially TNC volunteers and university students, to efficiently locate and reliably identify *Lepidium* (and other co-occurring priority weeds) and communicate them semi-automatically to TNC managers, CDFA, and one or more invasive species clearinghouses and map services. Success in this demonstration would permit straightforward scaling up to other invasive species, restoration sites and land managers.

Experimental Design – The main test of the experimental design is described above in the performance measures for the field experiments. However we also plan to publish protocols and assess the utility of competing designs for land managers in the peer-reviewed scientific literature.

Multi-scale analysis – Inferring lessons for management on landscape scales from experiments on plot scales is a central problem in ecology for which we will achieve no general solutions. We expect the data collection and management protocols to express and display data on multiple scales in a way that permits managers to visualize the implications of experimental results for landscape-scale management. The principal performance measures is that science actually gets used by the land managers (in multiple agencies and private holdings) in evaluating options for invasive species management within the Cosumnes Preserve. A second measure is that the analytical framework is adopted by CALFED-related projects outside the Cosumnes coalition (at least for managing *Lepidium*.)

GIS Framework – The performance measures are 1) successfully integrating *Lepidium* experimental and monitoring data into the CRG GIS system for the study region; 2) successfully running and comparing the results of 4 or more models mapping habitat suitability and/or invasion risk in the region; and 3) supplying maps from the most successful models to managers (presumably on-line).

Distributed Data System – Successful implementation will include a database structure that is consistent at the reporting level with both the scientific needs of the project and with state and national uses as feasible. At a minimum, we will develop and implement a formal ontological implementation (probably using the semantic web language OWL) that is capable of reporting results for inclusion in a Bay-Delta (BDAT), state (CalWeed), federal (CRISISMaps) multi-organization information system.

Meta-analysis – This portion of the work is exploratory. Performance measures include both successfully running a meta-analysis using both Cosumnes and outside data that significantly improves our understanding of *Lepidium* biology and control, and publishing the methodology and software in a way that is adopted elsewhere in the Bay-Delta restoration process. In the long

run, we expect to succeed with both, but may only achieve a design level of achievement in this project.

A-6. Data Handling and Storage

The primary copies of all data will be held at the UC Davis Information Center for the Environment (ICE), but will be freely available to TNC and all participants in the Cosumnes River Preserve and Cosumnes Research Group (CRG). ICE operates an extensive GIS and remote sensing data warehouse, with an active website, as part of the CRG (*http://watershed.ucdavis.edu/crg*), and all geospatial data will be added to that system. Once analyzed, it will be displayed, and will be downloadable using the CRG mapserver.

Lepidium and experimental data will be kept in a custom relational database, but exposed (made available) several ways. ICE has NSF funding to develop "semantic web" tools for biodiversity data, using next-generation web languages, including XML, RDF, DAML, and OWL (see http://mindswap.org/). These can be viewed as a hybrid of webpages and databases, and make the data system viewable and searchable using an ordinary browser. This is an expansion on the systems such as EML and Morpho used by many large ecological study sites such as LTERs, and should ensure interoperability with other field station networks. We also believe we can build a straightforward mechanism to upload the population data into DWR's BDAT system.

ICE already provides metadata for Cosumnes floodplain research and other CALFED-sponsored activities into a variety of clearinghouses, including FGDC, CERES and the UC Digital Library, and will ensure that data from this project is represented in all (and is thus easily found through most agency and library search facilities, as well as in the usual web searches).

ICE and TNC are both partners of the National Biological Information Infrastructure (NBII), which is a federal interagency body providing standards and tools for storing and accessing government information on biological resources. NBII has a particularly strong presence in invasive species information (see *http://isin.nbii.gov*, *http://invasivespecies.gov*, and *http://kiowa.colostate.edu/cwis438/niiss/index.html*). ICE participates in all of these, and can ensure that the *Lepidium* data are incorporated into the national invasive species datasets. It also hosts the California "node" of NBII, which includes an invasive species catalog and mapserver (*http://cain.nbii.gov/crisis*), which will provide another route for access to the species data generated by the project.

A-7. Expected Products/Outcomes

Objective 1. Monitoring and analysis of population patterns and trends

A report including inventory protocols and mapped populations on the Preserve will be completed at the end of Year 1. A report analyzing population patterns and trends over the three-year project will be completed at the end of Year 3. Results will be presented at relevant professional conferences and symposia, including CALIPC annual meetings and the Bay-Delta Science Conference. Results will also be posted online (see Data Handling and Storage).

A report of trials of *Lepidium* stem aging will be prepared, and results will be submitted for peer-reviewed publication, by Year 3.

A handbook of locally common floodplain plants will be printed and made available to project and Preserve staff for field use beginning in Year 1 with updates through Year 3. The "virtual

herbarium" will be made available online to the general public through the CRG II website, and photos will be shared with Calflora as they become available (ongoing throughout Years 1-3).

Objective 2. Targeted research on *Lepidium* control
A report of results and implications to *Lepidium* control from these targeted research experiments will be completed at the end of Year 3. Results will be published online (see Data Handling and Storage) and will be submitted to appropriate peer-reviewed journals for publication.

Objective 3. Adaptive Management Framework
Our goal is disseminate the results of the study both through peer-reviewed publications and internet services. After the first year, we expect 2-3 publications per year (or more) in the peer-reviewed literature. At least some will be targeted to the newly established free on-line electronic journal San Francisco Estuary and Watershed Science (*http://repositories.cdlib.org/jmie/sfews/*), which is intended to provide a communications forum specifically for scientists and restoration managers in the CALFED region. The investigators have taken a substantial role in getting the journal started, and Quinn is a co-editor in chief (along with R. Brown and F. Nichols.) However, we will probably target some more general publications, including Restoration Ecology, Natural Areas Journal, or perhaps Conservation Biology.

Internet access will include all of the invasive species location data on one or more interactive map servers (e.g., CRISIS -- *http://cain.nbii.gov/crisis/crisismaps*), field forms and identification resources for volunteers, students, other members of the interested public (at least through the Cosumnes Research Group, CRG -- *http://watershed.ucdavis.edu/crg*), and fact sheets and guidelines for weed managers (broadly distributed, but at least through CRISIS, CRG, and TNC's Wildland Invasive Species Team -- http://tncweeds.ucdavis.edu/, and probably through UC Cooperative Extension.)

Presentations will be made opportunistically, but after the first year, at least at the annual Bay-Delta Science Symposium and California Invasive Plant Council (formerly Exotic Plant Pest Council, CalEPPC) meetings. We also plan to present results in Year 3 at appropriate professional society meetings, e.g., the Society for Ecological Restoration and the Ecological Society of America. All of the investigators regularly give public seminars by invitation at agencies and on college campuses, and will continue to do so throughout the project period.

This is not primarily a technology project, but the investigators will apply a variety of new technologies they are developing for invasive species analysis under grants from NSF, USGS, the Resources Agency Legacy Program, and others. These are coordinated with other users in the region in part through the steering committee and data group of the Bay-Delta Science Consortium, on which Quinn represents UC Davis.

The project is a complementary part of a larger research program in the Cosumnes floodplain which has already produced 8 Ph.D. theses and dozens of undergraduate projects in the part 3 years. It will also contribute outreach materials to TNC and other Cosumnes Preserve Partners, which can be made available to the increasing numbers of visitors to the public parts of the preserve.

B. Applicability to CALFED ERP and Science Program Goals and Implementation Plan
B-1. ERP, Science Program and CVPIA Priorities.

CALFED has recognized the potential for "massive ecological and biological disruptions associated with non-native species", and that perennial pepperweed (*Lepidium latifolium*) is a species needing special attention (CALFED 2001). *Lepidium* occurs throughout the Delta, and is at risk of spreading to an even greater extent beyond its current range. The Cosumnes River Preserve, which has been identified by CALFED as a high priority area for restoration, has a significant number of *Lepidium* occurrences. Control of these plants will protect the investment in restoration already made at the Preserve. *Lepidium* control at this site has already been identified by ERP as a subject for directed action.

This proposal directly addresses CALFED's 2002 Delta and Eastside Tributary priority of implementing "actions to prevent, control, and reduce impacts of non-native invasive species; including methods for comprehensive mapping, system-wide surveys and/or ongoing monitoring of specific invasive species actions" (DR-5,CALFED 2001). It also addresses CALFED's 2002 Multi-region priority action for non-native invasive species control and eradication (MR-1).

The CALFED ERP draft Stage 1 PSP priorities addressed by this project include:

Goal 2: Ecosystem Processes and Biotic Communities – Research into the correlation between *Lepidium* infestation and physical site characteristics (hydrology, geographic position and soil properties) in restored floodplains at the Cosumnes River Preserve will help to inform future rehabilitation of natural processes in the Bay-Delta system to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities.

Goal 4: Habitats – Research and implementation of *Lepidium* removal actions will increase the extent and quality of potentially available habitat to native and at-risk species by reducing stressors (i.e. competition from non-native invasive species). Communities that will benefit include valley oak riparian forest, mixed riparian forest, permanent and seasonal wetlands and associated uplands. This will potentially benefit native and at-risk species that depend on these habitats, such as giant garter snake, Swainson's hawk, and neotropical migratory songbirds. Complete recovery of treated sites (e.g. revegetation with native species) likely will not occur within the time frame of the grant, and therefore this is not included as a measurable goal in this proposal.

Goal 5: Non-native Invasive Species – Controlling occurrences of *Lepidium* on the Preserve will have a positive impact on control efforts downstream in the Delta, as well as limiting the plant's movement upstream into new areas.

Goal 6: Sediment and Water Quality – Concerns over the impact on sediment and water quality of effective herbicides have motivated this study to examine how to best control *Lepidium* while improving and/or maintaining water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta watershed and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.

This proposal directly addresses the goals of CALFED's Science Program in relation to the Ecosystem Restoration Program. Priorities of the Science Program that will be implemented by this project include:

- *Developing performance measures*. We will conduct scientific studies to demonstrate, pilot test, and establish performance measure monitoring.

- *Conducting adaptive management experiments*. Conducting specific adaptive management experiments to lead to improved floodplain restoration management approaches and a better understanding of restoration impediments. This project addresses the Science Program goal of finding ways to retrofit elements of adaptive management and/or monitoring to existing projects, ecosystems, or watersheds where multiple projects are occurring.
- *Establishing integrated science programs in complicated field settings*. Integrated, interdisciplinary studies such as this proposed project advance process understanding and attack relevant restoration questions in a complicated field setting. This project addresses the goal of the Science Program to establish intensive site-, multi-site- or watershed-specific interdisciplinary programs in every region.
- *Comparing relative effectiveness of different restoration strategies.* Results from this project will lead to more effective floodplain restoration by furthering understanding of constraints and opportunities, then analyzing how different restoration strategies overcome or take advantage of those in a specific setting.
- *Advancing the scientific basis of regulatory activities*. This project will address uncertainties in the science used for management, and advance the knowledge that can be applied to management, allowing adaptation of regulatory activities as knowledge improves.
- *Coordinating and extending existing monitoring.* High priority is necessary for environments where monitoring programs are least well developed, such as riparian zones, floodplains and wetlands. This project will continue, improve and extend ongoing monitoring of these target habitats at the Cosumnes River Preserve.
- *Taking advantage of existing data.* This project fits the stated goal of the Science Program to encourage projects that develop questions that can be addressed by interpreting existing data and that can build from that data to develop indicators and better understanding of processes, species and communities.

B-2. Relationship to Other Ecosystem Restoration Projects

The Cosumnes River Preserve partners are committed to controlling non-native invasive species such as *Lepidium*. This project will further restoration on lands that have been previously acquired with CALFED funds, such as Whaley, Denier, Castello [Park], and Shaw. This project builds on previous smaller-scale efforts at the Preserve by applying lessons learned in the effectiveness of various methods of weed control. The Preserve will continue to control non-native invasive species as necessary to benefit wildlife and native plant species. Development of a weed GIS database for the Preserve, to document locations of pepperweed infestations and their fate following control measures, will help refine control efforts at the Preserve and may prove useful for regional weed control planning.

B-3. This is not a request for next phase funding.

B-4. Previous Recipients of CALFED Program or CVPIA funding

This project builds on a larger, paired-basin study of the Cosumnes and Mokelumne River Watersheds (*http://watershed.ucdavis.edu/crg/*) led by UC Davis with active collaboration with The Nature Conservancy in particular, and the multiple partners and landholders (BLM, Fish and Game, Ducks Unlimited, PRBO Conservation Science, and Sacramento County, as well as numerous local farmers and ranchers) in the Cosumnes River Preserve in general. Those projects were more directed to native faunas and floras than to invasive species, and none of the funding

supported the hands-on invasive species science and experimental management proposed for this project.

The Cosumnes Research Group has completed detailed baseline assessments of the restored Cosumnes River floodplain. Six key floodplain findings in the completed CALFED Project #99-N06 (1999-2003) include:

- Primary productivity on floodplains is tied to seasonal variation in the timing, duration and hydraulic residence time of flood flows, as well as nutrient limitations and grazing pressures.
- Zooplankton production is essential for native larval and juvenile fish and appears linked to residence time, temperature, and grazing pressures.
- Native fish spawn and rear on the floodplain and respond to complex hydrologic and water quality cues.
- Thermal and chemical heterogeneity of floodplain water may play an important role in fish use of varied floodplain habitats.
- Natural flood hydrology appears to discourage non-native fish, while promoting natives.
- Late winter/early spring pulse flows maximize primary and secondary productivity and increase zooplankton subsidies to the North Delta.

The results of ERP #99-N06 were presented to CALFED during the summer of 2003 and have been published or are being published in peer-reviewed scientific journals.

In 2001, the Cosumnes Research Group was awarded contract ERP # 01-NO1 to evaluate the response of floodplain and riparian forest plant and animal communities to restoration of seasonal flooding. Final approval of the contract occurred in August, 2002. The current contract supports a range of activities focused on: identifying foodweb and energetic links between aquatic and terrestrial ecosystems of the Cosumnes floodplain; impacts of terrestrial vegetation on seasonal water balance; and the development of new methods for assessment of restoration success.

The first project provided an understanding off flood processes, soils, and some nutrient dynamics that will be essential to understanding the spread of *Lepidium* and other floodplain invaders, and, to date, the second has mapped the terrestrial vegetation and provided insight into the establishment of canopy species, including Valley oak, cottonwoods, which both provide habitat for and compete with the invasive species. The GIS and database framework has been supported by both projects. UCD graduate students Kaylene Keller and Wendy Trowbridge collaborated with the TNC lead investigators for this project, Rebecca Waegell and Ramona Swenson in preliminary mapping of Lepidium stands as a side project from their thesis work on riparian forests. This collaboration helped define the site selection and experimental design for this project. However, to date, there has been no direct funding for *Lepidium* research and control activities *per se*.

B-5. System-Wide Ecosystem Benefits

Perennial pepperweed, *Lepidium latifolium*, is a highly invasive perennial herb that can thrive in a wide range of habitats including riparian areas, wetlands, marshes, and floodplains (Bossard et al. 2000; Young et al. 1995). *Lepidium* has already invaded many habitats throughout the San Francisco Bay-Delta area, and is of particular concern in areas where active restoration is underway. Once established this plant creates large monospecific stands that displace native

plants and animals and can alter soil composition by concentrating salts at the surface (Blank & Young 1997; Renz & DiTomaso 1998; Young et al. 1995). It interferes with regeneration of cottonwood and willow species, as well as key herbaceous species, in riparian and wetland areas (Young et al. 1995). It is on the A-list of the California Invasive Plant Council's (formerly CalEPPC) list of Exotic Pest plants of Greatest Ecological Concern in California, and on the California Department of Food and Agriculture's B list of noxious weeds due to its highly invasive nature. This species is considered a high-ranking threat to critical habitats within the Cosumnes River Preserve (CRP 2002). It is a priority for control efforts because of its highly invasive nature, the threat it poses to native habitats including valley oak riparian forest, mixed riparian forest, seasonal and permanent wetlands and associated uplands, and because potential for its control is considered high.

C. Qualifications

James F. Quinn has degrees from Harvard (A.B. Biology, 1973) and the University of Washington (PhD, Zoology, 1979). He joined the faculty of the University of Pennsylvania in 1979, and moved to the UC at Davis in 1981, where he is now a full professor. He has worked on habitat fragmentation on species diversity and extinction risk, strategies for inventory and monitoring studies, the design of systems of nature reserves, and estimation of demographic rates for fisheries management, and is the author of more than 60 scholarly publications. Dr. Quinn also directs in the Information Center for the Environment (ICE) at UC Davis. Under his direction, the ICE has developed has developed an extensive internet accessible database and GIS data catalog of CA watershed information, and the principal biodiversity databases for U.S. National Parks, UNESCO Biosphere Reserves worldwide and a variety of public and private lands in California. ICE works closely with over 20 public agencies on monitoring information, databases, and Web services (http://ice.ucdavis.edu) involving biodiversity, water quality, and land use, both in California and internationally.

Joshua H. Viers received his Ph.D. in Ecology from the University of California, Davis (2003). His research interests and projects investigate the spatial relationships of ecological phenomena. He has published on a variety of subjects, including watershed analysis methods, serpentine endemic plant distributions, riparian vegetation restoration and salmon conservation, land use and river geomorphology, invasive fishes, and most recently alien plants and extinction risk in California flora. His current research focuses on predictive modeling for resource management; these efforts encompass non-native invasive species, the spatial effects of land use activities on riparian and aquatic habitat heterogeneity, and the integration of high-spatial resolution, hyperspectral data into resource inventories.

Ingrid B. Hogle, Vegetation Ecologist at the UC Davis Information Center for the Environment, received her M.S. in Ecology from UC Davis (2002). She has independently designed and conducted experiments in rare plant ecology and wetland biogeochemistry for the USFWS and the Smithsonian Institute. She has conducted weed mapping and prepared weed management recommendations for the UC Natural Reserve System. Her current research involves development of a monitoring plan for riparian restoration sites at the Cosumnes River Preserve, and digitally updating the National Wetlands Inventory for the north coast of California.

Rebecca Waegell is a Project Manager with The Nature Conservancy at the Cosumnes River Preserve. She has been at the Preserve for the last 8 years and has worked closely with the Preserve Manager to carry out management activities on all lands within the Preserve. She is the lead person in charge of exotics control at the Preserve and has successfully implemented efforts

to control such highly invasive weeds as fig, tree of heaven, locust and osage orange. In addition to her activities at the Preserve she is on the board of directors of the California Exotic Pest Plant Council and is a member of the Sacramento Weed Abatement Team. She has a B.S. in zoology from the University of California at Davis and is a Certified Pesticide Applicator.

Rick Cooper has worked in natural resource management for 24 years with the Bureau of Land Management. He graduated from California State University Humboldt with a B.S. degree in Range Management in 1978. Mr. Cooper became the Preserve Manager of the Cosumnes River Preserve in 1995. Mr. Cooper has successfully led an interdisciplinary staff of Nature Conservancy and BLM employees in achieving habitat management objectives for the Preserve. He has been effective working with local ranchers and farmers to integrate and implement wildlife-friendly agriculture on Preserve lands and has created an effective mechanism for the coordinated management of lands with nine different land owning partners.

D. Cost

D-1. Budget

The University of California requests $419,996 for full-scale implementation of this restoration and research project. The detailed budget and budget justification are provided in the attached forms.

D-2. Cost-Sharing

The Bureau of Land Management will contribute one work month of Rick Cooper (Preserve Manager) for project support and oversight, ~$6,500.

E. Local Involvement

Invasive weed control has been supported by all of the Preserve's seven landowning partners, which include county and state agencies. *Lepidium* control is a high priority for the Sacramento Weed Abatement Team, the County Agriculture Commissioners, the Natural Resource Conservation Service and the local Resource Conservation Districts. Outreach will be made to local groups interested in weed control issues. For example, maps and results will be provided in a report to the Sacramento Weed Abatement Team and the county agriculture commissioner's office. Articles describing the action and results will be submitted to the California Exotic Pest Plant Council, the California Department of Food and Agriculture and the Native Plant Society.

ICE has a long history involvement and coordination with local organizations working on issues in the Cosumnes watershed. Collaborators at UC Davis include the Cosumnes Research Group II, the Center for Spatial Technologies and Remote Sensing (CSTARS), and the weed science lab of Dr. Ted Foin. Collaboration with these organizations includes data sharing and technical assistance with Cosumnes- and *Lepidium*-related projects. We will continue to coordinate our efforts with ongoing state and national weed control activities through collaborations with Steve Schoenig, CDFA State Invasives Species Coordinator, and Jon Randall, TNC National Invasives Species Coordinator. Because we host the California Node of the National Biological Information Infrastructure (*http://cain.nbii.gov*), we will also be well positioned to track and adapt to invasive species information standards under development by the federal government (see *http://invasivespecies.nbii.gov*).

F. Compliance with Standard Terms and Conditions

The project will comply with all state and federal terms and conditions as identified in the CALFED Proposal Solicitation Package Attachments D and E.

G. Literature Cited

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Figure 1 – Project site at Cosumnes River Preserve

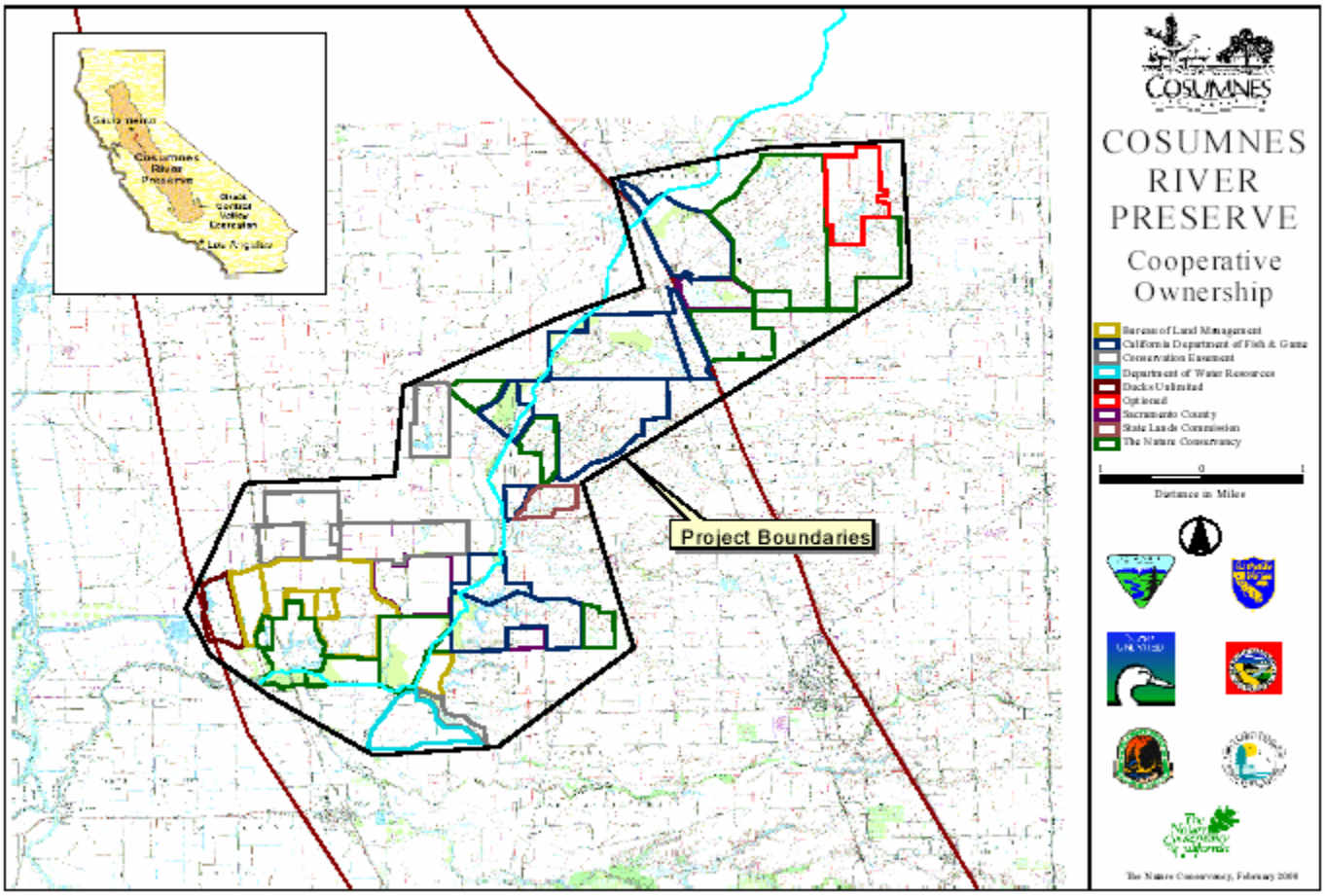

Figure 2 – Conceptual model of perennial pepperweed control using physical control methods (from Renz)

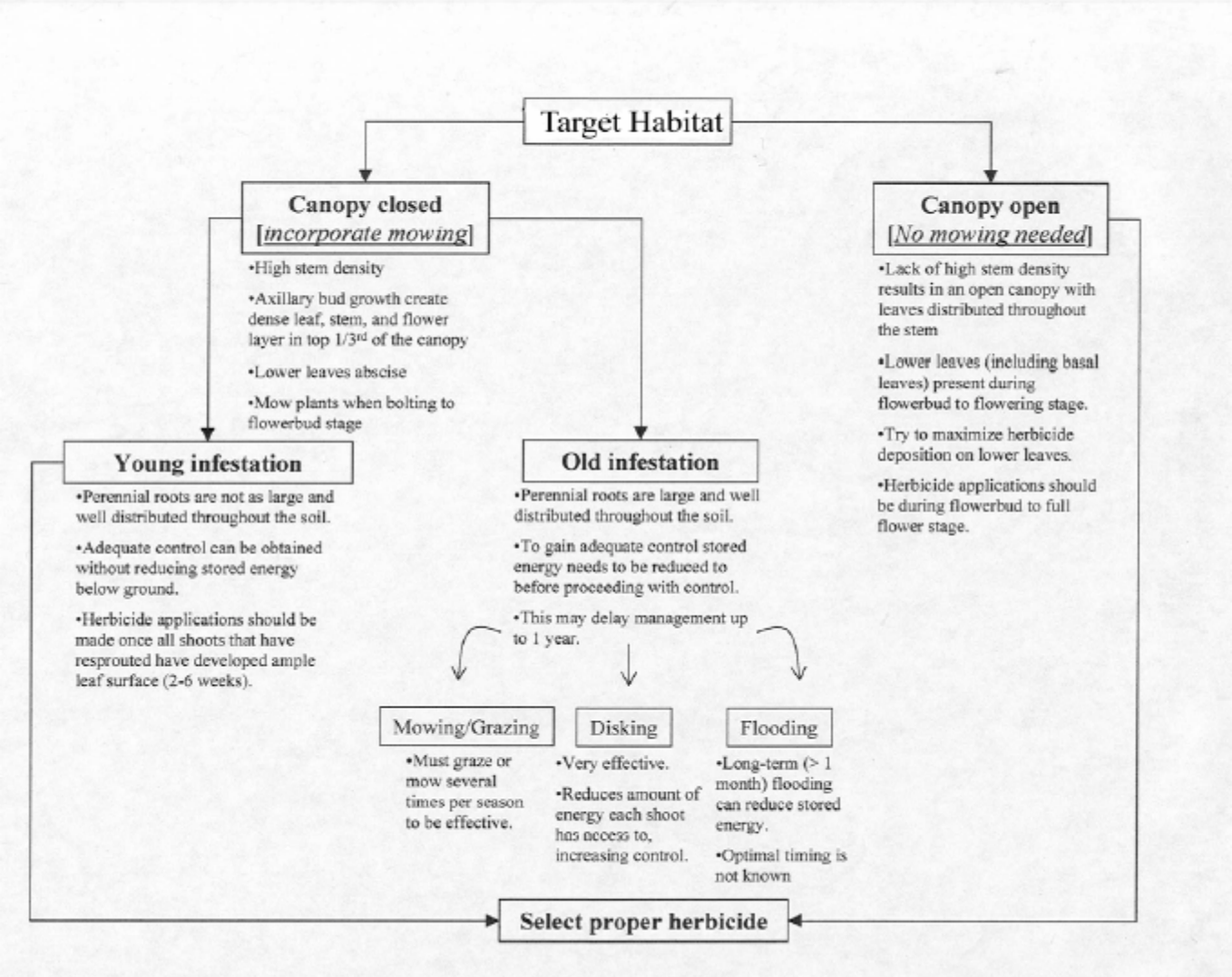

Figure 3 - Conceptual model of perennial pepperweed control using chemical control methods (from Renz)