PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Stochastic Life Cycle Model Technical Assistance

BPA project number: 9303701
Contract renewal date (mm/yyyy): 11/1999 ☒ **Multiple actions?**

Business name of agency, institution or organization requesting funding
Paulsen Environmental Research Ltd

Business acronym (if appropriate) PER Ltd.

Proposal contact person or principal investigator:

Name	Charles M. Paulsen
Mailing Address	16016 SW Boones Ferry Rd Suite 4
City, ST Zip	Lake Oswego, OR 97035
Phone	503-699-4115
Fax	503-699-4117
Email address	cpaulsen@teleport.com

NPPC Program Measure Number(s) which this project addresses
3.2.A, 3.2C, 3.2.F , 4.2a, 4.3, 7.1E

FWS/NMFS Biological Opinion Number(s) which this project addresses
NMFS Hydrosystem BO RPA 13; RPA A17

Other planning document references
Multi-Species Framework Briefing Nov. 1998: Analytical Approach page 21, NMFS Recovery Plan task 0.3.b and 2.11.b

Short description
Provide technical assistance to PATH participants in statistical analyses of hypotheses regardings past declines of ESA-listed stocks, design of adaptive manegement actions, and the future effects of salmonid management actions

Target species
Columbia-basin salmonids

Section 2. Sorting and evaluation

Subbasin
System-wide

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type

Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☒ Anadromous fish ☐ Resident fish ☐ Wildlife	☒ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☐ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9600800	State, Tribal and U.S. Fish and Wildlife Participation in PATH	PATH scientific support
8910800	Modeling PATH/ BPA technical support Univ. of Washington	PATH scientific support
9203200	USFS modeling support	PATH scientific support
9601700	Hydrosystem Work Participion A. Giorgi	PATH scientific support
9600600	Facilitation, Technical Assistance And Peer Review Of Path	was in umbrella table

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1996	Performed data reconnaissance, acquisition and refinement prior to completion of retrospective analyses of specific hypotheses	yes
1997	For Snake River spring and summer chinook salmon, performed detailed retrospective analyses for hypotheses related to hydrosystem decisions, and the relevant hypotheses concerning climate, habitat, harvest and hatchery factors.	yes
1998	Performed and documented a Snake River Spring/summer chinook Decision Analysis for hydrosystem management alternatives	yes

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Determine the overall level of support for key alternative hypotheses, and propose other hypotheses and/or model improvements that are more consistent with existing data.		
		a	Refine statistical relationships between land use indices and parr to smolt survival
		b	Develop simplified passage model using Snake River PIT-tag survival estimates
		c	Compare life-cycle survival of mid (upper) Columbia spring chinook to that of Snake River spring/summer chinook
2	Analyze management actions to restore endangered salmon stocks to self-sustaining levels of abundance		
		a	Complete work related to 1999 decision on Snake River chinook and steelhead, 1a - 1b.
		b	Complete prospective and decision analyses for Upper Columbia, working with PUD's and other agencies, based on 1c, above.
		c	Complete prospective and decision analyses for Lower Columbia salmon and steelhead stocks.
		d	Complete and publish prospective and decision analyses for Multi-species Framework.
3	Assess the ability to distinguish among competing hypotheses from future information, and advise agencies on research, monitoring, and adaptive management experiments that would maximize learning		
		a	Complete design of experimental management options for Snake River stocks involving hydro, harvest, habitat, and hatchery actions (4 H's), and detailed monitoring and evaluation programs
		b	Develop candidate experimental management options for Upper Columbia and Lower Columbia stocks, in response to tasks 2b and 2c (evaluate in FY2001).

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	11/1999	10/2000	Quantitive foundations for (2) and (3)	Peer-reviewed, published retrospective analyses	60%

2	11/1999	10/2000		Published decision analysis results	20%
3	11/1999	10/2000		Published experimental management plans	20%
				Total	100.00%

Schedule constraints
Litigation among agencies. Unexpected delays in 1999 decision on Snake River. uncertain. Unexpected problems with run reconstructions and model development.

Completion date
Unclear. Many agencies (NMFS, NPPC, CoE) have identified an ongoing need for a coordinated, peer-reviewed, regional analytical work group.

Section 5. Budget

FY99 project budget (BPA obligated): $174,280

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel		%83	150,000
Fringe benefits		%0	
Supplies, materials, non-expendable property		%2	3,000
Operations & maintenance		%0	0
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	0
NEPA costs		%0	0
Construction-related support		%0	0
PIT tags	# of tags:	%0	0
Travel		%4	7,000
Indirect costs		%0	0
Subcontractor		%11	20,000
Other		%0	
		TOTAL BPA FY2000 BUDGET REQUEST	$180,000

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		%0	
		%0	
		%0	
		%0	
		Total project cost (including BPA portion)	$180,000

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$185,000	$190,000	$195,000	$200,000

Section 6. References

Watershed?	Reference
☐	Paulsen, C. and T. Fisher, 1997. "Ocean Distribution of Coded Wire Tagged Spring/Summer Chinook," report to PATH, July, 1997.
☐	Botsford, L. and C. Paulsen, 1997. "Chapter 2: Covariability in Abundance among Index Stocks of Columbia River Spring/Summer Chinook Salmon," PATH report, July 1997. Submitted to CJFAS, 09/1998
☐	Paulsen, C., T. Fisher, and R. Hinrichsen, 1997. "Chapter 4: Effects of Climate and Land Use on Index Stock Recruitment," PATH report, June, 1997.
☐	Paulsen, C., T. Fisher, and R. Hinrichsen, 1997. "Over-wintering Survival of Snake River Spring and Summer Chinook PIT-tagged fish," report to PATH, May, 1997.
☐	Paulsen, C. and T. Fisher, 1998. "Statistical testing and validation of relationship between spring-summer chinook parr-to-smolt survival and indices of rearing habitat, quality," in review, Transactions of the American Fisheries Society.
☐	PATH Scientific Review Panel. (Drs. S. Carpenter, J.Collie, S. Saila, C. Walters). 1998. Conclusions and Recommendations from the PATH Weight of Evidence Workshop. September 8-10, 1998. Edited by C. Peters, I. Parnell, D. Marmorek, R. Gregory, T. Eppel.
☐	Marmorek, D.R, I, Parnell, L. Barnthouse and D.R. Bouillon. 1995. PATH: Results of a Workshop to Design Retrospective Analyses. Prepared by ESSA Technologies Ltd. Vancouver, BC for BPA. 278 pp.
☐	Marmorek, D.R. and C. Peters, editors. and 31 co-authors. 1998. PATH Final Report for Fiscal Year 1998. December 1998. Report compiled and edited by ESSA Technologies Ltd., Vancouver BC. 254 pp.
☐	Lee, D. C., and 20 co-authors, 1997. Broadscale assessment of aquatic species and habitat. Chapter 4 in Quigley, T. M., S. J. Arbelbide, Tech. Eds., 1997. "An assessment of ecosystem components in the interior Columbia basin.." Gen. Tech. Rep. PNW-GTR-
☐	Lebreton, J-D., K. P. Burnham, J. Colbert, and D. R. Anderson, 1992. "Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies", Ecological Monographs 62(1): 67-118.
☐	Paulsen, C., T. Fisher, and R. Hinrichsen, 1997. "Chapter 4: Effects of Climate and Land Use on Index Stock Recruitment," PATH report, June, 1997.
☐	

PART II - NARRATIVE

Section 7. Abstract

Project 9303701 will provide analytical support to several PATH activities in FY2000. These include extensions to existing analyses of habitat quality influence on overwintering survival (Objective 1a), a relatively simple empirical passage survival model (Objective 1b), and an analysis of differences in mid-Columbia vs. Snake River spring chinook population dynamics (Objective 1c). Results from these analyses will be incorporated into population projection models (Objective 2) and models to assess the learning that is possible under various adaptive management experiments (Objective 3). The project is one component of the PATH umbrella proposal (project 9600600).

The PATH process address NPPC measures 3.2.A, 3.2C, 3.2.F , 4.2a, 4.3, 7.1E, NMFS Hydrosystem BO RPA 13; RPA A17, and will also provide analytical support for the multi-species framework.

The methods used for objectives 1a-1b are general linear model (GLM) models of Cormack-Jolly-Seber (CJS) survival estimates. Previous, related work under this project has been favorably peer-reviewed by PATH participants, the Scientific Review Panel (SRP) and is presently undergoing peer review for journal publication.

Expected products will be peer-reviewed PATH publications, with potential publications in peer-reviewed journals.

Section 8. Project description

a. Technical and/or scientific background

See Project 9600600 for PATH background.

Although much has been accomplished under PATH projects over the past three years, three broad areas will require additional analyses in FY2000. These include:

1. Using existing information to refine and test key hypotheses about the past;
2. Analyzing proposed management actions throughout salmonid life cycles to predict their effects on survival and recovery of stocks above Bonneville Dams, and
3. Assessing the ability to distinguish among competing hypotheses from future information, including adaptive management experiments.

While all three areas build on existing information, they will do so in different ways. Under (1), existing information will be used to assess the direction and strength of relationships between past management practices (e.g., land use, mainstem dam operations, hatchery releases) and survival, whether across the entire life cycle (from spawners to returning adults) or within life stages directly affected by those practices (e.g., parr-smolt, or smolt survival through the hydrosystem). Work under (2) will use previous PATH work and information developed under (1) to project the likely effects of management actions on future population abundance of different salmonid stocks. Work under (3) will use relationships from (1) and (to a lesser degree), (2), to evaluate how much regional managers could learn from monitoring of different management experiments. See “Objectives” and “Methods” sections for details.

b. Rationale and significance to Regional Programs

See Project 9600600 for PATH rationale and relationship to regional programs.

c. Relationships to other projects

See Project 9600600 for general information on relationships among PATH projects.

Work under this project will proceed in close cooperation with projects 9601700, 9600600, 9600800, 9770320, 9700200, and 9800100. Beyond mutual review and commentary on project analyses and reports, the we anticipate the following specific relationships:

9601700 Utilize Al Giorgi’s expertise with passage and PIT tag data.
9720320 Utilize Eastside assessment data and habitat quality predictions.
9800100 Use Hinrichsen’s statistical expertise in methods development.

Work under all three FY2000 objectives will involve review of related work done under other PATH projects, and review of work under this project by other PATH participants and the PATH Scientific Review Panel (SRP).

d. **Project history** (for ongoing projects)

See Project 9600600 for general history for PATH.

Project number and title are unchanged, although title should probably be modified to a more accurate description for FY2000.

Selected reports, 1998:

"Testing the Hypothesis that Extra Mortality of Wild Snake River Spring/Summer Chinook Varies with the Releases of Snake River Hatchery Fish," June, 1998 (with Richard Hinrichsen). This report demonstrates a negative relationship between smolt releases and wild chinook survival, after accounting for the effects of dams, transportation, and density-dependent mortality.

"Snake River Chinook Parr-Smolt Survival And Habitat Quality Indices," June, 1998. Shows a strong statistical relationship between two different indices of habitat quality (road density and vegetation/land management) and overwintering survival of PIT tagged wild chinook parr. Submitted in revised form to AFS (Paulsen and Fisher, 1998)

Comments and extensions of PATH analyses, 1998:

"Weighting and sensitivity analysis difficulties with an unbalanced design ," April, 1998 (with Richard Hinrichsen). Suggests problems with PATH analysis of "critical" uncertainties, and methods to improve them.

"Testing the Hydro-Related Extra Mortality Hypothesis," June, 1998 (with Richard Hinrichsen). Demonstrates that there is almost no relationship between inriver mortality and post-hydrosystem mortality, as postulated for many PATH retrospective and prospective analyses.

"An Empirical Approach to Identifying and Weighting Critical Uncertainties," April, 1998 (with Al Giorgi and Jim Anderson. Points up additional tests (see above) for hypotheses developed under PATH, and their potential implications for prospective analyses.

"Snake River spring-summer chinook survival and habitat Quality: Current BSM Implementation and Additional habitat hypotheses," June, 1998. Critique of methods by which habitat enhancement are incorporated into current PATH analyses.

"Observations regarding the Steelhead SAR analysis," March, 1998 (with Al Giorgi). Outlines potential problems with Raymond et al's estimates of steelhead smolt-to-adult (SAR) estimates in setting standards for Snake River steelhead persistence and recovery.

Selected reports, 1997:

Paulsen, C. and T. Fisher, 1997. "Ocean Distribution of Coded Wire Tagged Spring / Summer Chinook," report to PATH, July, 1997.

Botsford, L. and C. Paulsen, 1997. "Chapter 2: Covariability in Abundance among Index Stocks of Columbia River Spring/Summer Chinook Salmon," PATH report, July 1997

Paulsen, C., T. Fisher, and R. Hinrichsen, 1997. "Chapter 4: Effects of Climate and Land Use on Index Stock Recruitment," PATH report, June, 1997.

Paulsen, C., T. Fisher, and R. Hinrichsen, 1997. "Over-wintering Survival of Snake River Spring and Summer Chinook PIT-tagged fish," report to PATH, May, 1997.

Past Costs:

FY	Cost
94	43,500

95	76,500
96	215,105
97	174,820
98	175,000
99 (Projected)	174,280

e. Proposal objectives

Most of these objectives are drawn from the PATH umbrella project (9600600). This section address tasks specific to this project. Especially for objectives (2) and (3), work proposed will depend on both cooperation with other PATH projects and direction form the I. T. and other management entities. Therefore, work under these objectives cannot be defined in detail at this writing (December 1998).

The first objective of the project is to use existing data to determine the overall support for key hypotheses, and propose other hypotheses or model improvements that are more consistent with existing data. Three tasks are proposed in support of this objective:

a. Refine statistical relationships between land use indices and parr-to-smolt survival;
b. Develop a simplified passage model for Snake River spring chinook and steelhead using Snake River PIT-tag survival estimates;
c. Compare life-cycle survival of mid/Upper-Columbia spring chinook to that of Snake River spring/summer chinook, and propose and test hypotheses that may explain any differences between them.

Work under task 1a extends ongoing FY1999 analyses, which in turn further work described in Paulsen and Fisher (1998). Although PATH has performed a series of sensitivity analyses on the effects of habitat enhancement on spring/summer chinook survival and jeopardy probabilities, the effects of habitat enhancement are based mostly on professional judgement. This was necessary because no quantitative information is available on the relationship between habitat management (e.g., riparian buffers, improved road construction and maintenance) and fish survival. Work under this task will help develop such information, using Cormack-Jolly-Seber (CJS) survival estimates for PIT-tagged chinook and steelhead parr, land use indices from the Eastside Assessment, and histories of enhancement activities in individual subbasins. This should help bring much-needed replicable, quantitative measurements of the effects of habitat enhancement activities into the PATH modeling arena. In addition, it may be useful for work done under the Multi-Species Framework.

Work under task 1b addresses a concern raised by the PATH Scientific Review Panel (SRP, 1998). The SRP notes that the passage models used in PATH (CRiSP and FLUSH) are both very complex, and that the details of how the models work is not well understood by most PATH participants. Since PATH began in 1996, however, a wealth of PIT tag release and detection data has been developed, with approximately 2.5 million tagged parr and smolts released from 1995-1998 (based on work in progress under this project). Under this task, we would develop a passage model base directly on the PIT tag data, including release information and detections at mainstem dams, trawls below Bonneville Dam, detections of PIT tags at Rice Island and other bird colonies, and adult detections at Bonneville Dam and Lower Granite Dam. The objective would be a relatively simple model, based on readily available data, that would describe the survival of smolts through the mainstem and estuary in considerable detail. The survival from smolts in the estuary to returning adults would of necessity be far less detailed, given the modest number of adult detections to date (approximately 2,000, based on work in progress).

Work under 1c would extend earlier PATH retrospective analyses to Upper or Mid-Columbia spring chinook (Marmorek et al 1995, Chapter 5). Previous work on Snake spring/summer chinook showed that the decline in spawner-to-recruit survival was approximately contemporaneous with the construction of the Lower Snake hydrosystem: as the Snake dams were completed, the stocks declined quickly relative to lower Columbia spring chinook. Preliminary work in progress for the Entiat, Methow, and Wenatchee spring chinook stocks suggest a different pattern: although the last mid-Columbia run-of-river projects were completed in the late 1960's, the stocks did not show a significant reduction in spawner-to-recruit survival until the early 1980's, almost three chinook generations later. The objective of this task is to develop and test hypotheses to explain both the mid-Columbia decline, and the differences between Mid-Columbia and Snake population dynamics.

The second objective is to analyze management actions to restore endangered salmonid stocks to self-sustaining levels of abundance. Two tasks are proposed in support of this objective:

a. Complete work related to 1999 decision on Snake River chinook and steelhead;
b. Complete prospective decision analyses for the Upper Columbia, working with PUD's and other agencies.

The objectives for these tasks is to provide information from 1a-1c to population projection models for Snake and Upper Columbia chinook and steelhead stocks. This will be done in cooperation with other PATH participants, mid-Columbia PUD personnel, the I. T. and other regional management bodies. Since the management alternatives, projection models, and results from 1a-1c have not yet been developed, we cannot presently specify what will be involved in detail, especially for work under 2b. Much work under 1a has been done in FY1998, and more will be completed in FY1999 (Marmorek and Peters, 1998). In all likelihood, work in FY2000 will consist primarily of sensitivity analyses and other extensions to work done previously.

The third objective is to develop methods to assess out ability to distinguish among competing hypotheses from future information, and provide advice on research, monitoring, and adaptive management experiments that would maximize learning. Two tasks are proposed:

a. Complete design of experimental management options for Snake River stocks, including hydro, hatchery, harvest, and habitat, and detailed monitoring programs;
b. Develop candidate experimental management options for the Upper Columbia and Lower Columbia stocks.

Work under these objectives is discussed in detail in the FY2000 proposal from project 9600600. Work under project 9303701 will utilize information developed under 1a-1c, as well as data developed in FY1999, to help set bounds on the effects of management actions and how much might be learned from experimental management actions and associated monitoring activities.

f. Methods

Methods and data for task 1a (parr-smolt survival and habitat indices) will be extensions of methods employed in past years. Each summer and fall, wild spring/summer chinook and steelhead parr are tagged in subbasins above Lower Granite Dam. When the fish migrate past Granite and other projects the following spring, survivors are detected by PIT tag detectors at Lower Granite, Little Goose, McNary, and mainstem Columbia projects. From these detections, one can calculate Cormack-Jolly-Seber (CJS) survival estimates (Lebreton et al 1992). The usual CJS assumptions apply. From data developed as part of the Eastside Assessment (Lee et al 1997), one can extract many measures of vegetation cover, land management, road density, and other possible correlates with fish habitat quality. This information is incorporated into log-linear general linear models (GLM's) to separate the effects of habitat quality from other potential influences on survival (e.g., parr size at tagging, distance from tagging site to Lower Granite dam, etc.).

Work in FY1998 (Paulsen and Fisher, 1998) show significant relationships between Snake chinook overwintering survival (from summer tagging to the detection of smolts the following spring) and both road density and land use. Work in FY1999 will extend this to additional stocks, and test model predictions for fish tagged in 1997. Work proposed for FY2000 will extend this further, to include 1999-2000 outmigrants, and will examine relationships between historical and ongoing habitat enhancement activities and overwintering survival. In addition, we will incorporate these relationships into population projection models and adaptive management models, to assess the effects of habitat enhancement activities on life-cycle survival, and the degree to which one might learn from management experiments within subbasins. We assume that current levels of parr tagging will continue.

Methods and data for 1b (PIT-tag based passage model) will primarily involve tagging and detection data from PITAGIS, and CJS estimates of survival (Lebreton et al 1992). Work in progress for FY1999 shows that, with the PIT tag detections from experimental towed arrays and Rice Island bird colonies, one can obtain reasonably reliable (low standard error) measures of in-river survival for Snake spring/summer chinook and steelhead from release at or above Lower Granite Dam to below Bonneville Dam, for 1996-1998. Assuming that tagging continues at recent years levels (500,000-1,000,000 fish tagged per year) through 2000, we would then have at least five years of passage survival data in hand for the Lower Columbia, and 10-12 years of data available for survival through the Snake River projects. Using this information, one could then construct an empirical passage model using only PIT tag survival estimates, without needing to rely on the complex passage simulation models currently used in PATH (CRiSP and FLUSH). Note that data on fall chinook is much sparser, due to much more modest numbers of fish tagged and released.

An empirical passage model would have a number of advantages for work in PATH under objectives (2) and (3). These include:

1. Statistically straight-forward estimates of reach survival, which could be used in both life-cycle projects (objective 2) and as information to ground experimental management experiments (objective 3).
2. A simple model structure, based on CJS survival estimates, that would be both comparatively easy to understand (for technical audiences) and easily explained for management audiences.
3. The model would be relatively free of the political overtones associated with both existing passage models, such that discussion could focus on technical merits directly. The survival estimates, being based on recent data, would be readily reproducible by anyone with knowledge of PITAGIS data and retrievals and CJS statistics.

Obviously, such a model would need a number of assumptions in order to use it in population projection and adaptive management research. In addition to the usual CJS assumptions (Lebreton et al 1992), these would include:

1. Survivals have been estimated across a sufficiently wide range of flows, spill, and other operating conditions to be representative of future conditions. 1996-98 have been relatively high flow years, although 1989-93 (when one can estimate Snake survival) were not.
2. Populations used to estimate survival are representative of future populations with respect to size, fitness, and other indices that might effect survival. Note that an empirical model shares this assumption with the CRiSP and FLUSH simulation models.
3. If future conditions change dramatically (e.g., drawdown of one or more projects) survival under those future conditions can be extrapolated from some current portion of the system (e.g., survival in current free-flowing Snake reaches).
4. Recent levels of PIT tagging and detections (especially in the lower Columbia) must continue to produce reliable estimates of in-river survival and adult recoveries.

In addition, an empirical model probably could not be used directly to predict the effects of small changes in hydrosystem configuration and operation. For example, a model based on historical data could not be used to project the effects of small changes in fish guidance efficiency or spill patterns. To address these types of issues, one would either need to use data from field experiments (where available) or relative changes in survival from subsets of current passage models.

Work under 1c (comparison of mid-Columbia and Snake spring chinook life cycle survival) is a straight-forward extenuation of work done previously (Marmorek et al 1995, Chapter 5). Work in progress using the Delta model (op. Cit.) shows that for the Entiat, Methow, and Wenatchee spring chinook, their survival from spawner to adult recruit (to the mouth of the Columbia) was roughly the same as lower Columbia spring chinook until about 1983-84. After that point, their decline in survival has been similar to that of the Snake River spring/summer chinook. The question, of course, is why their population dynamics differed from the Snake for 16-17 years after completion of the mid-Columbia projects (Wells Dam was completed in 1967). Under this task, we will use multi-variate regression techniques [similar to those in Paulsen et al (1997)] to explore how much of the survival difference for mid-Columbia stocks can be explained by direct passage mortality (obtained either form passage simulation models or from 1b, data permitting), hatchery influences, and other potential causes. Results will be incorporated into work under objectives (2) and (3).

Methods for work under objectives (2) and (3) are explained in the proposal for project 9600600. Work under project 9303701 will primarily involve incorporating results from 1a-1c into population projection models and adaptive management simulation models. Because those models (especially for adaptive management) have not yet been developed, it is not possible at this time to specify how this will work in detail.

g. Facilities and equipment

See Project 9600600 for PATH facilities, etc.

No special facilities will be required for project 9303701.

h. Budget

The budget is a 3% increase over FY1999 funding, to allow for inflation. It assumes that slightly more that one FTE will be required to complete work for the three objectives, with the majority of the effort (60%) devoted to retrospective analyses and development of an empirical passage model (Objective 1). The remaining 40% is divided evenly between incorporating results from Objective 1 into prospective simulation models (Objective 2) and experimental management models (Objective 3).

Section 9. Key personnel

The principal investigator, Mr. Paulsen of Paulsen Environmental Research, will have lead responsibility for data analysis. Mr. Fisher of Beak Consultants will take the lead on data collection for PIT tag and other data required for the project. Mr. Paulsen will devote approximately 80-85% of his time to the project; Mr. Fisher will be employed approximately 15-20% on the project.

***Resume of*:** Charles Michael Paulsen
***Education*:** Duke University, Durham, NC.
Master of Environmental Management, 1979.
University of Kentucky, Lexington, KY.
B.A. in Political Science, 1974
National Merit Scholar, 1970 - 1974

***Professional Experience*:**

1994 - Present Independent Consultant, Paulsen Environmental Research, Ltd.
1991 - 1994 Fellow and Environmental Management Program Manager, Resources for the Future (RFF)
1989 - 1990 Research Associate, RFF
1985 - 1988 Chief, Computer Services, RFF
1984 - 1985 Programmer-Analyst, RFF
1983 - 1984 Programmer-Analyst, Fien-Marquardt, Baltimore, MD
1980 - 1983 Research Assistant, RFF

Consultancies

Bonneville Power Administration
Chelan County Public Utility District
The World Bank
International Institute for Applied Systems Analysis
Harvard Institute for International Development

Relevant Publications and Reports

"Ocean Distribution of Coded Wire Tagged Spring/Summer Chinook," (with Tim Fisher), report to PATH, July, 1997.

"Chapter 2: Covariability in Abundance among Index Stocks of Columbia River Spring/Summer Chinook Salmon," (with Lou Botsford), PATH report, July 1997

"Chapter 4: Effects of Climate and Land Use on Index Stock Recruitment," (with Tim Fisher and Rich Hinrichsen), PATH report, June, 1997.

"Over-wintering Survival of Snake River Spring and Summer Chinook PIT-tagged fish," (with Tim Fisher and Rich Hinrichsen), report to PATH, May, 1997.

"Cost-Effectiveness Analysis for Complex Natural Systems: An Application to the Columbia River Basin," (with Kris Wernstedt), *Journal of Economics and Environmental Management* , Vol. 28 No. 3, May, 1995

"Economic and Biological Analysis to Aid System Planning for Salmon Recovery in the Columbia River Basin," (with Kris Wernstedt), *Journal of Environmental Management* , Vol. 43 No. 4, June, 1995

"Recovery Planning for Endangered Salmon: A Multiple Attribute Analysis,", (with Jeffrey B. Hyman, and Kris Wernstedt), Bonneville Power Administration, April, 1994

"Evaluating Alternatives for Increasing Fish Stocks in the Columbia Basin," (with Kris Wernstedt and Jeffrey B. Hyman), *Resources,* Fall 1992.

"Design of Studies for Development of BPA Fish and Wildlife Mitigation Accounting Policy," (with Allen V. Kneese, Danny C. Lee, and Walter Spofford, Jr.), Bonneville Power Administration, August, 1988.

TIMOTHY R. FISHER

Senior Fisheries Biologist

EDUCATION

M.S., 1990, University of Idaho, Fishery Resources

B.S., 1987, Pennsylvania State University, Ecology

MEMBERSHIPS

American Fisheries Society, Pacific Fishery Biologists (President 1994-1995)

EXPERIENCE

BEAK CONSULTANTS INCORPORATED, 1995 to present. Mr. Fisher's areas of expertise include salmonid life cycle and hydropower dam passage modeling, Endangered Species Act consultations, biotic integrity of stream communities, and fisheries data analysis.

Project Manager, BPA Chinook Stock Assessment. Mr. Fisher led a team of biologists in gathering environmental and fisheries data for a coast-wide chinook stock assessment being conducted by a group of state agency and tribal biologists and consultants with funding from the Bonneville Power Administration.

Project Manager, Dioxin Bioaccumulation Study. Mr. Fisher is managing a project to carry out fish sampling for Potlatch Corp. in the Lower Granite Reservoir area on the Snake River in Idaho and Washington.

Task Leader, Mid-Columbia Habitat Conservation Plan Overview Document. Mr. Fisher is responsible for writing a comprehensive overview and analysis of the system-wide issues and concerns which affect the ability of the project owners to limit their take of potential Threatened or Endangered Species of anadromous salmonids.

Fish Passage Modeler, Snake River Coalition. Mr. Fisher performed a CRiSP salmon smolt passage survival modeling exercise for a coalition representing upper Snake River irrigation districts and the State of Idaho.

Fisheries Biologist, Port of Kennewick Expansion. Mr. Fisher participated in the study design and field sampling of the Columbia River for establishing the presence and habitat use of fall chinook salmon smolts in Clover Island marina and adjacent habitats.

Fisheries Biologist, Yuba River Fisheries Evaluation. Mr. Fisher wrote a summary of the literature concerning fall chinook salmon life history as related to freshwater environmental conditions such as water temperature, flow, and habitat for a comprehensive restoration plan for the anadromous fish of the Yuba River in California.

BONNEVILLE POWER ADMINISTRATION, 1990 to 1995. Division of Fish and Wildlife, Fisheries Biologist. Mr. Fisher dealt exclusively with analysis of Columbia River Basin anadromous salmonid fish populations, especially the endangered Snake River chinook and sockeye salmon populations. His duties included analysis of current population status and the effects of actions, primarily hydrosystem and harvest, under the National Environmental Policy Act (NEPA), the Endangered Species Act, and court-ordered proceedings, using state-of-the-art computer models.

Section 10. Information/technology transfer

Results will be disseminated in a series of PATH workshops and presentations to the I. T. and other regional management and policy-making groups. See Project 9600600 for details on workshop and presentation formats and schedules. In addition, we anticipate that selected results (especially from Objective 1) will be published in peer-reviewed journals.

Congratulations!