# PART I - ADMINISTRATIVE

## Section 1. General administrative information

**Title of project**

Fertilization Of Kootenay Lake And Arrow Reservoir

**BPA project number:** 20009
**Contract renewal date (mm/yyyy):** 10/1999 ☒ **Multiple actions?**

**Business name of agency, institution or organization requesting funding**
B.C. Ministry of Environment, Lands and Parks

**Business acronym (if appropriate)** MELP

**Proposal contact person or principal investigator:**


| | |
|---|---|
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**NPPC Program Measure Number(s) which this project addresses**
10.1, 10.6, 10.6C.1

**FWS/NMFS Biological Opinion Number(s) which this project addresses**
FWS 1995 Biological Opinion for Salmon

**Other planning document references**
N/A

**Short description**
Fertilize Kootenay Lake and Arrow Reservoir to mitigate impacts of providing flow augmentation for lower river salmon migration.

**Target species**
Kokanee, rainbow trout, bull trout, white sturgeon, burbot and a wide range of other species common to the Kootenay/Columbia watershed.

## Section 2. Sorting and evaluation

**Subbasin**
Kootenai and Mainstem.

### *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<br>☒ Resident fish<br>☐ Wildlife | ☐ Multi-year (milestone-based evaluation)<br>☐ Watershed project evaluation | ☐ Watershed councils/model watersheds<br>☐ Information dissemination<br>☐ Operation & maintenance<br>☐ New construction<br>☒ Research & monitoring<br>☒ Implementation & management<br>☐ Wildlife habitat acquisitions |

## Section 3. Relationships to other Bonneville projects

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

| Project # | Project title/description |
|---|---|
| | N/A |
| | |
| | |
| | |

### *Other dependent or critically-related projects*

| Project # | Project title/description | Nature of relationship |
|---|---|---|
| | N/A | |
| | | |
| | | |
| | | |

## Section 4. Objectives, tasks and schedules

### *Past accomplishments*

| Year | Accomplishment | Met biological objectives? |
|---|---|---|
| | N/A | |
| | | |
| | | |
| | | |

### *Objectives and tasks*

| Obj 1,2,3 | Objective | Task a,b,c | Task |
|---|---|---|---|
| 1 | Fertilizer aquisition | a | Purchase lake fertilization material |
| | | | |
| | | | |
| | | | |

### *Objective schedules and costs*

| Obj # | Start date mm/yyyy | End date mm/yyyy | Measureable biological objective(s) | Milestone | FY2000 Cost % |
|---|---|---|---|---|---|
| 1 | 10/1999 | 10/2009 | Historic productivity | N/A | 100.00% |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | **Total** | 100.00% |

**Schedule constraints**
If approval of funding does not occur before October, 1999, fertilizer purchases cannot be made in time for 1999 applications. Thus, the earliest use of this material would occur in the spring of 2000.

**Completion date**
This project is expected to be ongoing, at least until such time as flows for juvenile salmon migration are no longer required.

## Section 5. Budget

**FY99 project budget (BPA obligated):** $0

### *FY2000 budget by line item*

| Item | Note | % of total | FY2000 |
|---|---|---|---|
| Personnel | | %0 | |
| Fringe benefits | | %0 | |
| Supplies, materials, non-expendable property | fertilizer costs | %100 | 175,000 |
| Operations & maintenance | | %0 | |
| Capital acquisitions or improvements (e.g. land, buildings, major equip.) | | %0 | |
| NEPA costs | | %0 | |

| | | | |
|---|---|---|---|
| Construction-related support | | %0 | |
| PIT tags | # of tags: | %0 | |
| Travel | | %0 | |
| Indirect costs | | %0 | |
| Subcontractor | | %0 | |
| Other | | %0 | |
| **TOTAL BPA FY2000 BUDGET REQUEST** | | | $175,000 |

### *Cost sharing*

| Organization | Item or service provided | % total project cost (incl. BPA) | Amount ($) |
|---|---|---|---|
| Columbia Basin Fish and Wildlife Compensation Program | Arrow Reservoir fertilization | %33 | 342,000 |
| Columbia Basin Fish and Wildlife Compensation Program | Kootenay Lake fertilization | %20 | 211,000 |
| Columbia Power Corporation | Arrow Reservoir fertilization | %11 | 114,000 |
| MELP | Arrow and Kootenay fertilization (not including in-kind support) | %1 | 13,000 |
| BPA | Arrow and Kootenay fertilization | %17 | 175,000 |
| | **Total project cost (including BPA portion)** | | $1,030,000 |

### *Outyear costs*

| | FY2001 | FY02 | FY03 | FY04 |
|---|---|---|---|---|
| **Total budget** | $1,017,000 | $1,017,000 | $1,017,000 | $1,017,000 |

## Section 6. References

| Watershed? | Reference |
|---|---|
| ☐ | Korman, J., C. Perrin, R. Wiegand, R. 1990. The feasibility of fertilization of Kootenay Lake, North Arm. Rept. prep. for B.C. Min. of Environment, Lands and Parks, Nelson, B.C. |
| ☐ | Yang, J. R., F. Pick, P. B. Hamilton. 1997. Phytoplankton Biomass, Composition and Size Distribution of Kootenay Lake, B.C. Following Experimental Fertilization. Year 5 (1996). Rept. prep. for B.C. Min. of |

| | |
|---|---|
| | Environment, Lands and Parks, Nelson, B.C. |
| ☐ | Rae, Rowena, F. Pick, P. B. Hamilton, K. Ashley. 1997. Effects of Fertilization on Phytoplankton in Kootenay Lake, British Columbia. B.C. Min. of Environment, Lands and Parks, Nelson, B.C. |
| ☐ | Ashley, K., L. Thompson, Lasenby, D. 1997a. Restoration of an Interior Lake Ecosystem: the Kootenay Lake Fertilization Experiment. Water Qual. Res. J. Canada. Vol. 32, No. 2, 295-323 |
| ☐ | Ashley, K., L. Thompson, P. Warburton, Y. R. Yang. 1997b. Kootenay Lake Fertization - Year 4 (1995/96) Report. Fish. Proj. Rep. No. RD 58. Min. of Environment, Lands and Parks, University of British Columbia, Fisheries Centre , Vancouver, B.C. |
| ☐ | Walters, C., J. DiGisi, J. Post, J. Sawada. 1991. Kootenay Lake fertilization response model. Min. of Environment, Lands and Parks, University of British Columbia, Fisheries Centre , Vancouver, B.C. |
| ☐ | Vollenweider, R. A. 1968. Scientific Fundamentalsof the Eutrophication of Lakes and Flowing waters, with Particular reference to Nitrogen and Phosphorus as Factors in Eutrophication. Rep. Organisation for Economic Cooperation and Development, Paris |


# PART II - NARRATIVE

## Section 7. Abstract


Kootenay Lake and Arrow Reservoir have been negatively impacted by dams located upstream, which have reduced the productivity of these lakes by trapping phosphorus and nitrogen. Kokanee, bull trout, rainbow trout, white sturgeon, burbot and a variety of other species have been affected in both basins. A large scale, experimental lake fertilization project was initiated on Kootenay Lake in 1992 to address this problem. A significant increase in phytoplankton, zooplankton and kokanee abundance has been noted to date. A similar fertilization and associated monitoring program in now planned to begin on Upper Arrow Reservoir in 1999 to address the same problem in that area.

This proposal mitigates for additional impacts caused by increased summer flows required for juvenile salmon conservation in the U.S. Increased flushing rates further reduce nutrient availability during the critical growing season. Additionally, plans to employ the associated "Arrow- Libby swap" flow management strategy, aimed at maintaining reservoir levels for recreation on the Kootenay (Libby) system, will further reduce productivity on Arrow Reservoir by moving even more water through that basin.


## Section 8. Project description

### a. Technical and/or scientific background

Productivity in Kootenay Lake has been strongly influenced by Duncan Dam, located in B.C. at the northern end of the lake, and especially Libby Dam, situated on the Kootenai River in Montana. The reservoirs formed by these impoundments trap nutrients (i.e., phosphorus and nitrogen), reducing productivity in downstream waters. Serious concerns over this issue were first raised in the late 1980's, when patterns of declining growth and numbers emerged for Kootenay Lake kokanee, bull trout and rainbow trout.

Intensive study, modelling and a review of options to address this problem were begun in 1990 (Korman *et al* 1990, Walters *et al* 1991). A large scale, experimental lake fertilization project was subsequently implemented in 1992. BC Hydro and the B.C. government (MELP) have provided funding and in-kind support. In the seven years since initiation of this program, a significant increase in phytoplankton, zooplankton and kokanee abundance has been noted in the lake (e.g., Ashley *et al* 1997a, Ashley *et al* 1997b, Rae *et al* 1997, Yang *et al* 1997). Adult kokanee escapement to the Meadow Creek Spawning Channel and Lardeau River increased from a historic low of 300,000 fish in 1991 to 2.1 million fish in 1998. Bull trout and rainbow trout abundance and growth have also increased. Although the lake contains Mysis shrimp, which compete for the same food sources as kokanee, they have not responded to the extra food supply to the point of significantly impacting kokanee stocks thus far.

A similar situation exists on Arrow Reservoir. This impoundment is impacted by a series of three dams: Keenleyside Dam, which formed Arrow Reservoir from Upper and Lower Arrow Lakes, and Mica and Revelstoke dams, located upstream of the Arrow basin. These dams have permanently changed the flow dynamics and nutrient loading of the reservoir, and influenced native fish populations by flooding and/or blocking migration to spawning and rearing habitat, altering water quality and decreasing reservoir productivity. Kokanee stocks in Arrow Reservoir have shown a dramatic decline in spawner escapement and size over the last several years. As in the case of Kootenay Lake, this decline is a result of decreased nutrient loading to the system as a result of both the Mica and Revelstoke dams, which are retaining nutrients that historically entered Upper Arrow Lake.

During the past 2 years, a detailed limnological program has confirmed the ultra-oligotrophic status of Arrow Reservoir, and confirmed that nutrient loading is considerably below historic levels. A full-scale fertilization and associated monitoring program is therefore planned to begin on the Upper Arrow basin in 1999 to address this problem.

To date, impacts on reservoir productivity caused by increased summer flows required for juvenile salmon conservation have not been considered in the above-noted projects. Salmon flows increase flushing rates at a time of year when nutrient uptake is highest. Given that flushing rates are inversely related to nutrient availability (Vollenweider 1968), moving additional water through either of these reservoirs during August will significantly impact productivity. A further impact is also expected as a result of the "Arrow-Libby swap" flow management strategy, in which additional water will be passed through Arrow Reservoir to avoid excessive drawdowns of Koocanusa Reservoir (formed by Libby Dam). The Libby drawdown issue is a recreational concern, but the end result of such a flow "swap" is an additional reduction in productivity on Arrow Reservoir.

Given that fertilization projects are already underway in both the Kootenay and Arrow basins, existing activities could simply be augmented to mitigate these impacts. This proposal describes such a program, in the form of fertilizer acquisitions to reflect the impact of passing 1 million acre feet of water through either reservoir during the month August.

## b. Rationale and significance to Regional Programs

Section 10 of the 1994 Fish and Wildlife Program planning document ("Resident Fish") clearly identifies the importance of resident fish populations and the need for basinwide coordination among resident fish projects. Although Measures have not been developed to specifically identify this project as yet, this proposal is strongly in keeping with the intent of Section 10. The fish populations are weak yet apparently readily recoverable, based on results already observed with fertilization of Kootenay Lake. The project addresses the entire reservoir ecosystem, benefiting bull trout, white sturgeon, burbot, kokanee, rainbow trout and numerous other species. These fish are all native to the basins under consideration and are valued sport fish. By considering impacts upstream of the U.S. border, this project is in concert with the Council's requirement for a "systemwide approach".

## c. Relationships to other projects

This project is currently supported by a partnership between the B.C. government (MELP), B.C. Hydro and the Columbia Power Corporation. With the addition of U.S. funding described in this proposal, full recognition of all dam-related impacts, including salmon flows, will be established. The success of a number of projects hinge on the benefits of fertilization. Major spawning channels for kokanee on both the Arrow and Kootenay systems, and a bull trout hatchery on Arrow Reservoir are affected.

## d. Project history (for ongoing projects)

N/A

## e. Proposal objectives

1. Fertilizer Purchase

Regular, agricultural grade, liquid fertilizer with the formulation 10-34-0 (ammonium polyphosphate) and 28-0-0 (urea-ammonium nitrate) is used for this work. Fertilizer formulations will be adapted seasonally to minimize the response of blue-green algae and encourage the development green algae, which are better suited as a zooplankton food source.

## f. Methods

Existing plans call for continued fertilization of the North Arm of Kootenay Lake for at least the next three years (1999-2001). Monitoring of water chemistry, phytoplankton, zooplankton, mysids and kokanee populations will be undertaken on an ongoing basis as part of this work. Results to date suggest current methods show great promise as a long-term mitigation measure and it is reasonable to expect this work will continue indefinitely.

Arrow Reservoir fertilization will enter its first year of operation in summer, 1999 and will be very closely monitored over the next 5 years to assess benefits. The experimental design calls initially for treatment of only the Upper Arrow Lake basin. Based on results during the first 5 years, methods will be reviewed and modified as required, and a decision will be made regarding the need to fertilize the Lower Arrow basin. Experience from the Kootenay Lake fertilization experiment suggests that fertilization of the upper basin may be sufficient to increase productivity in the lower basin, negating the need for direct treatment of the lower basin. In addition, based on the Kootenay Lake experience, Upper Arrow nutrient loading requirements may be significantly reduced after year 5 due to retention of nutrients in the ecosystem.

### g. Facilities and equipment

All facilities and equipment required to complete this work are already incorporated in the budgets of partnering agencies/organizations. This proposal describes fertilizer costs only.

### h. Budget

The exact amount of fertilizer required to address the movement of 1 million acre-feet of water through the Arrow and/or Kootenay basins is unclear at this time. Even in the case of Kootenay Lake, which is in the seventh year of fertilization and study, nutrient requirements are very difficult to calculate precisely. Natural variations in the hydrograph, temperature, turbidity, lake mixing and other factors affecting productivity are not easily modeled or predicted. In the case of Arrow Reservoir, fertilization is only now being initiated and exact nutrient requirements are even more complex to determine. For these reasons, a suggested value for this work has been presented, reflecting our perception of the relative impact of the salmon flow and Arrow-Libby swap issue. Once further experience and data are available to draw on, a more precise estimate of the exact impact and cost can be established.

## Section 9. Key personnel

Costs of personnel involved in this work are not included in this proposal and are covered in the budgets of partnering agencies/organizations.

## Section 10. Information/technology transfer

All work described in this proposal will be incorporated in annual progress reports. These will be distributed to partnering agencies, universities and other interested parties as they are completed. Publications in the primary literature have already resulted from Kootenay Lake fertilization, and more can be expected as that project continues and work in the Arrow basin progresses. MELP has a Web server in the Kootenay Regional Headquarters office (Nelson, B.C.), and will also offer progress reports through such media. All data will be stored in MELP-standard databases whenever possible. Georeferencing of sample sites will allow attachment all information to spatial databases. The Kootenay Regional Headquarters office of MELP is further advanced that most of its other regional counterparts in the areas of data management and GIS, enabling us to perform analyses rapidly as questions arise from interested parties within or outside the agency/province.

## Congratulations!