NARRATIVE & BUDGET

HCP Measure 6.3.1 – BIOLOGICAL MONITORING

Long-term Objective: The major long-term objective of biological monitoring is to monitor changes to habitat availability and population abundance of the Covered Species that may result from Covered Activities. A concurrent objective is to continue data collection aimed at filling important gaps in the ecological knowledge of the Comal and San Marcos springs and river ecosystems. The collection of data aimed at filling data gaps through biological monitoring will be coordinated with the applied environmental research (HCP Measure 6.3.4) to be conducted at the USFWS National Fish Hatchery and Technology Center (NFH&TC) and conducted in a manner to inform the ecological model development described in HCP Measure 6.3.3.

Introduction/Overview: The Comprehensive and Critical Period Monitoring Program to Evaluate the Effects of Variable Flow on Biological Resources in the Comal and San Marcos Springs Aquatic Ecosystems (Variable Flow Study) was initiated in Fall 2000. The development of the Variable Flow Study was a collaborative effort starting as a prospective study within the Edwards Aquifer Optimization Program (EAOP) in the late 1990's. During the late 1990's, a Technical Advisory Group (TAG) for the EAOP was formed consisting of resource specialists / scientists from multiple entities (see BIO-WEST 2007). The TAG developed the framework for the Variable Flow Study and a workshop was held in May 2000 to discuss a proposed sampling protocol for both springs systems. The workshop was attended by resource professionals from the Edwards Aquifer Authority, TPWD, USFWS Austin Ecological Services (ES), USFWS NFHTC, and scientists from the Edwards Aquifer Research and Data Center (EARDC), and Texas State University (TSU). Discussions were conducted at the workshop, and subsequently, comments were incorporated into a final sampling program which was further reviewed and accepted by the USFWS and TPWD during late summer 2000.

As discussed in HCP section 6.3.3, the Variable Flow Study will provide the core for biological monitoring associated with the HCP. As proven over the past decade and evident by the extensive use of this data for the preparation of the HCP, the Variable Flow Study has provided an excellent framework for tracking the ecological response of both the Comal and San Marcos systems over time. However, to increase the robustness of the program and answer additional questions posed during HCP development, several additional components to the Variable Flow study will be added as described below. As specified in the HCP, the scope of the Variable Flow Study currently can be modified on a yearly basis as provided in the Funding and Management Agreement (FMA) with agreement by the USFWS.

Target for 2013: Continue the Variable Flow Study program along with implementing new study components as described below.

Protocol: The Variable Flow Study program consists of the on-going Comprehensive monitoring that is currently being conducted. A detailed description of activities is presented in BIO-WEST (2007) and summarized as follows:

- VARIABLE FLOW STUDY
    - Aquatic Vegetation mapping – GPS mapping – Conducted Spring and Fall.
        - Representative study reaches - 4 reaches at Comal Springs and 3 reaches at San Marcos Springs.
    - Texas wild-rice mapping – GPS mapping – Conducted annually (Summer)
        - Full System mapping at San Marcos
    - Fish sampling – Drop Netting – Conducted Spring and Fall.
        - Same reaches as aquatic vegetation mapping (note: the Spring Lake Dam reach at San Marcos is added for Drop Net sampling as a new activity)
        - All darters collected are visually examined for evidence of gill parasites
    - Fountain Darter specific sampling – Dip Netting and SCUBA surveys – Conducted Spring and Fall.
        - Dip netting involves timed surveys as well as Presence/Absence surveys in specified reaches throughout the spatial extent of both systems.
        - SCUBA surveys include area surveys in fixed locations in Landa Lake and Spring Lake.
    - Comal springs riffle beetle sampling - Cotton lure sampling – Conducted Spring and Fall.
        - Spring Run 3, Western Shoreline, and Spring Island area – Comal Springs
    - Comal Springs Riffle Beetle, Peck's cave amphipod and Comal Springs dryoptid beetle sampling – Drift Net – Conducted Spring and Fall.
        - Spring runs and Western Shoreline – Comal Springs
    - Salamander sampling – Snorkeling and SCUBA surveys – Conducted Spring and Fall
        - San Marcos Salamander – 3 locations (1 below Spring Lake Dam [snorkel] and 2 within Spring Lake [SCUBA])
        - Comal Salamander – 3 locations (Spring runs 1 and 3, and Spring Island area)
    - Comal Springs Discharge measurements – Conducted Spring and Fall.
        - Conducted at Spring runs 1, 2, and 3, upper spring run reach, and Old Channel at Elizabeth Street.
    - Water quality – standard parameters and fixed-station temperature loggers
        - Standard parameters conducted spring and fall throughout each system.
        - Temperature data via continuous data loggers.
    - Fixed station photography – Conducted Spring and Fall.
        - Both Comal and San Marcos systems

The Variable Flow Study also consists of additional flow-triggered Critical Period Sampling to be conducted when flows reach predefined trigger levels (both high and low)(BIO-WEST 2007). This sampling consists of a repeat of all the study components described above in addition to water quality sampling for conventional parameters (nutrients, alkalinity, and total suspended solids) at 15 sites in the Comal system and 18 sites in the San Marcos system; additional Texas wild-rice physical habitat mapping; and predation/gut content studies associated with extreme low-flow events.

Additional components for inclusion in Variable Flow Study program for 2013 include:

- Full system – aquatic vegetation mapping – GPS. The full system vegetation mapping is being added to ensure the representative study reaches remain representative of the system as a whole as the HCP moves forward.
    - San Marcos (Spring Lake to confluence with the Blanco River) and Comal (Upper spring run reach to confluence with the Guadalupe River). This includes both the physical mapping in the field and map preparation using GIS.
    - Conducted in Spring 2013, then every 5 years.
- Full system sweep for exotic aquatic and riparian plant species. This measure is being added to identify and contain potential invasive threats before they become established in either system.
    - A trained botanist will conduct a full system sweep via kayak, snorkel, and/or SCUBA to search for potential new invasive plant species both within the water and on the adjacent banks.
    - Conducted annually (Spring)
- Expand fish sampling (Dropnet) in San Marcos to include the Spring Lake Dam reach. This measure is being added to maximize the efficiency of the aquatic vegetation data currently being collected and add robustness to the fountain darter data set for the San Marcos River.
    - Using the standard dropnetting techniques established for the Variable Flow Study, conduct dropnet sampling in duplicate within 3 main aquatic vegetation types in the Spring Lake Dam study reach.
    - Conducted Spring and Fall, and during any Critical Period Sampling.
- Additional flow partitioning within Landa Lake during each Variable Flow Study Comprehensive and Critical Period sampling effort. This measure is being added to provide a better understanding of the spring flow influence within Landa Lake as upwelling flow within Landa Lake is imperative to Comal Springs riffle beetle survival during low-flow events.
    - Using an Acoutistic Doupler profiler or similar device, measure the flow patterns and current velocities from Spring Island through the upper portion of Landa Lake concurrently with Variable Flow Study discharge measurements at Comal Springs.
    - Conducted Spring and Fall.
- Macroinvertebrate food source monitoring within representative reaches. This measure is being added to better understand the food source base for

fountain darters in each system and how that food base responds to varying flow conditions. It may turn out that fountain darter food sources are depleted long before aquatic vegetation dies off (meaning current HCP flow requirements may be presently under protective), or that food sources remain long after aquatic vegetation decay which may mean current requirements are over protective. Regardless, this component is currently a major unknown that has the potential to affect long-term biological goals for the fountain darter.

  - Conduct macroinvertebrate sampling using a modified surber sampler, modified stovepipe sampler or similar device within each of the 7 study reaches (4 at Comal and 3 at San Marcos) to characterize food sources available for fountain darters.
  - Samples will be collected in triplicate from 3 vegetation types (based on majority present or adjusted based on fountain darter habitat quality) within each of the 7 study reaches for a total of 63 samples per event. Activity includes macroinvertebrate sample processing.
  - Additionally, the macroinvertebrate sampling will assist in gathering baseline data on the two non-listed macroinvertebrate species, the Edwards Aquifer diving beetle, and Texas troglobitic water slater that are covered in the HCP.
  - Conducted during Spring and Fall Variable Flow Study monitoring.

- Fish Sampling – multiple gear types for native fishes – Spring and Fall. This component is being added to provide a more holistic fisheries evaluation of the overall aquatic ecosystem. The information may assist in describing cause and effect relationships with fountain darter abundances over time.
  - Using seines and SCUBA perform fisheries surveys in both the Comal and San Marcos as follows.
    - Two locations within Spring Lake associated with San Marcos Salamander surveys (Big riverbed and hotel area) will be sampled for fish via SCUBA transect surveys in conjunction with the Variable Flow study sampling. Five locations spatially located between Spring Lake dam and the confluence of the Blanco River will be sampled by seining to evaluate and track native fish populations in the San Marcos River over time.
    - Similarly, one location in Landa Lake associated with fountain darter belt transect surveys will be expanded to include a transect survey for all fish via SCUBA. Additionally, 3 locations (Upper Spring Run, New Channel, and Old Channel) will be sampled via seines to evaluate and track native fish populations in the Comal River over time.
  - For seine samples, fish will be collected in each identifiable mesohabitat within a sample reach length of 40 times the mean wetted width (or one full meander wavelength). Physical measurements will be made in association with each seine haul and will include current velocity, depth, substrate composition, and

instream cover (large woody debris, boulders, undercut banks, macrophytes, velocity shelters, etc.). Notes on climatic conditions and mesohabitat typing will also be recorded. Released fish will be identified, measured, and examined for disease and other anomalies. Voucher specimens will be preserved in 10% formalin. In all cases, fish sampling will continue as long as additional species are being collected. Seining (minimum 10 effective seine hauls) will be conducted in various habitats using a variety of seines sizes and seining techniques (e.g., riffles kicks). It should be noted that a seine haul where zero fish are collected is considered an effective seine haul if the haul was not impeded (i.e. snagged), allowing fish to escape. Examples of commonly used seines include a 9.1 m x 1.8 m x 7.6 cm (30' x 6' x 1/4") mesh seine for sampling pools and open runs and a 4.6 m x 1.8 m x 5.7 cm (15' x 6' x 3/16") mesh seine for sampling riffles, runs, and small pools. Seines will be constructed of delta weave mesh with double lead weights on the bottom line. Seine size used, seine haul length, site information, and personnel will be recorded. Fishes collected from each seine haul will be processed independently.

- Underwater observation transects will occur from downstream to upstream with 5 meter transects arranged parallel to the shoreline. Underwater observers will work each 5 m transect from the downstream position moving upstream (i.e., moving into the flow). Fishes within each transect will be identified and counted.
- Spring and fall sampling in coordination with Variable Flow study sampling.
- All non-native fishes collected during seine hauls will be removed from the system per scientific permit requirements.

Allocated funds for 2013: $400,000 combined for Comal and San Marcos systems

Estimated 2013 Budget broken down per activity:

- Existing Variable Flow Study Comprehensive Sampling:
  - Total Cost: $250,000
- Existing Variable Flow Study Critical Period Sampling: $0 - As these events are flow-triggered and unpredictable relative to occurrence, funding for the Critical Period sampling component will be provided under EAA endangered species contingency funding.
- Full system aquatic vegetation mapping
  - Total Cost: $35,000
- Full system invasive plant species sweep
  - Total Cost: $7,500
- Expanded fish sampling (Dropnet) in San Marcos to the Spring Lake Dam reach
  - Total Cost: $7,500

- Additional flow partitioning within Landa Lake during sampling efforts.
    - Total Cost: $9,500
- Macroinvertebrate food source monitoring within representative reaches.
    - Total Cost: $57,500
- Fish Sampling – multiple gear types for native fishes assessment
    - Total Cost: $33,000 in 2013 with the potential for additional funding in other 4 years as full aquatic vegetation mapping won't be conducted.

HCP Measure 6.3.1 – ECOLOGICAL MODELING

Long-term Objective: The long-term objectives of this measure are to develop a predictive ecological model for the individual Covered Species, to estimate potential adverse ecological effects from Covered Activities, and to quantify the magnitude of such effects if they occur. Additionally, the predictive tool will assist the Applicants in developing alternative approaches or possible mitigation strategies, if necessary.

Introduction/Overview: The other HCP measures are designed to continue tracking the ecological systems over time (biological and water quality monitoring), improve habitat and Covered Species conditions (restoration and non-native controls, etc.), and increase the understanding of the ecological interactions (applied research at the experimental channel, gill parasite research, ERPA, etc.) relative to the Covered Species. These are all necessary and informative activities. However, until a repeat of the drought of record occurs or extended periods of drought (as modeled for the proposed HCP alternative) are encountered, none of these activities can predict what impacts are likely to occur, and ultimately, whether the proposed Action is protective. As such, there is a critical need to develop a predictive tool to evaluate potential scenarios using the best available data to date and the data collected via the Adaptive Management Plan (AMP).

The development of mechanistic ecological models is a fast-developing field that has seen many successes and failures in the past decade. As repeatedly documented in the literature, the results coming out of any model are only as good as the data going in. As such, data collection and coordination amongst each HCP measure need to be designed to the degree practicable to provide inputs to the ecological models. This will be particularly important for the following HCP Measures: biological monitoring, applied research, Old Channel ERPA, gill parasite research, expanded water quality monitoring, non-native species control and monitoring on both systems, Texas wild-rice restoration and monitoring, and native aquatic vegetation restoration and monitoring on both systems.

Target for 2013: Develop a mechanistic ecological model for the fountain darter specific to Comal Springs through the initial development of a conceptual model and proof of concept model runs as described below.

Protocol: The development of a mechanistic ecological model for every individual component of a complex, karst driven aquifer is likely unattainable. However, the proposed effort focuses on the ecological aspects of the Covered Species and springs environment using a three-phased approach.

Phase 1 will be the preparation of a detailed conceptual model for the fountain darter at Comal Springs. The influence diagrams produced for the HCP will serve as a starting point for this exercise, followed by the development of a more detailed conceptual model. At this point, a group of biologists who have conducted research on the fountain darter over the years will be convened for a one-day workshop focused on describing and defining the ecological linkages that could be addressed within a mechanistic ecological model. The available data will be examined in detail and

discussions will focus on how the ongoing HCP measures could be designed to further answer questions for data input into the ecological model. From the results of the workshop, the conceptual model will be refined and serve as the framework for mechanistic model development.

Phase 2 will involve the development of the model framework and grid within the established model boundary. For the proof of concept exercise in 2013 the model boundary will include Comal Springs and the associated watershed areas directly affecting surface water runoff into Comal Springs. Groundwater flow dynamics will not be recreated for simulation, but rather MODFLOW or an updated EAA groundwater model will be linked to the ecological model to provide the groundwater discharge input. Additionally, a basic rainfall, runoff model will be incorporated to allow for the introduction of potential surface water contaminants into the springs environment at a larger spatial scale. The focus will be to incorporate those larger scale inputs into a local depiction of Comal Springs on a much finer scale. It is anticipated that cell size over the watershed would be approximately 40 m by 40 m, whereas the spring environments would be modeled on a 5 m by 5 m grid with specific areas including 1 m by 1m grids.

Phase 3 will be to build several of the key model linkages established during phase 1 into the model and run the model on a proof of concept level. At the conclusion of 2013, the proof of concept model runs will be presented to the HCP implementing committee and any established scientific body established during the AMP. It will be understood that all of the model components (in fact, many of the key aquatic vegetation, gill parasite, ERPA, etc. interactions) simply won't be known at the conclusion of 2013. Full model development for the fountain darter at Comal Springs will be completed in 2014. However, at the 2013 meeting, a decision will be made whether a proof of concept level approach should be extended in 2014 for development of a Comal Springs riffle beetle model. Expanding the fountain darter model to San Marcos Springs and adding a Texas wild-rice proof of concept model development would occur in 2015.

Allocated funds for 2013: $175,000

Estimated 2013 Budget broken down per activity:

- Phase 1 - Development of conceptual model and workshop.
    - Total Cost: $22,500
- Phase 2 – Establishment of model boundary and framework.
    - Total Cost: $115,000
- Phase 3 – Inclusion of basic linkages and proof of concept model runs.
    - Total Cost: $37,500

HCP Measure 6.3.4 – APPLIED RESEARCH AT USFWS NATIONAL FISH HATCHERY AND TECHNOLOGY CENTER (NFH&TC)

Long-term Objective: The long-term objective of this measure will be to conduct applied research relative to the ecological dynamics of the Comal system, particularly under low flow conditions. The ultimate objective will be to inform Phase II decisions regarding the Covered Species and, to the extent possible, adjustments to conservation Measures during Phase I.

Introduction/Overview: As part of the AMP, there are several HCP measures designed to track the condition of the ecological systems over time (biological and water quality monitoring), and to improve habitat and Covered Species conditions (restoration and non-native controls, etc.) to prepare the systems for future low-flow conditions. However, these activities alone will not be sufficient to address the questions of whether the flow-regime and long-term biological goals presented for Phase I of the HCP are protective and/or appropriate for the Covered Species. As such, additional applied research is critically necessary to support answering these overarching questions. Simply stated, are the HCP measures and long-term biological goals protective or not? Without this answer, limited guidance if any regarding adjustments for Phase II will be available which would likely be viewed as unacceptable for HCP continuance. These overarching questions cannot be answered alone by the applied research proposed for the HCP, but the knowledge gained through this applied research will be used in conjunction with information gathered via the aforementioned monitoring and restoration activities to drive the mechanistic ecological model (HCP Measure 6.3.3), and thus, to assess the questions regarding potential HCP effectiveness.

The main focus of the applied research will be to evaluate the effects of low-flow on Covered Species and their habitat. Considering the Phase I schedule and the need to first get this facility designed and constructed, it is likely that only five years will be available for Phase I experimentation in the actual experimental channels. As such, key questions will need to be addressed during this time period, which will require a strict schedule and intense focus. During the design and construction period, several studies using existing NFH&TC facilities will be initiated to inform the AMP as well as future studies in the research channels. As described in the HCP (6.3.4.2), the applied research at the NFHTC facility for Phase I will focus on the fountain darter relative to Comal (although research should be transferable to the San Marcos system) and the Comal Spring riffle beetle, as these are the two species with the greatest potential for impact relative to the Phase I package. This applied research will be further divided into three tiers. Tier A will focus on habitat requirements and responses; Tier B will focus on direct impacts of low-flows; and Tier C will investigate the implications of the timing, frequency, and duration of multiple events in varying sequences and include specific research efforts designed to assess ecological model predictions (e.g., model validation).

Target for 2013: The target for 2013 is to complete detailed landscape and construction designs for the applied research channel(s) and initiate construction during the later portion of the year. Additionally, initiate Tier A research on 1) the effects of flow, temperature, and CO_2 on the

development and subsistence of native aquatic vegetation over extended periods of low-flow conditions, and 2) how low-flow conditions and changing water quality might affect fountain darter food sources (aquatic macroinvertebrates).

Protocol: As described above, the main focus in 2013 will be to get the research channel(s) designed and under construction, along with initiating applied research at the NFH&TC with existing facilities.

- Design and construction plans – Although a conceptual design is currently envisioned for the applied research channels, a formal landscape and construction design will need to be prepared during winter/spring of 2013. A workshop with scientists will be conducted in January 2013 (if not sooner) to solicit input for design components that will be necessary to conduct the research outlined in the HCP within the operational constraints of the NFH&TC. From that workshop a preliminary design will be completed for review by the Implementing Committee in early 2013. Following review and comments, a final construction plan will be prepared in Spring 2013.
- Initial construction – Upon receipt of the final construction plans, on the ground activities will be initiated in 2013 to start modification of existing NFH&TC facilities where necessary and start construction on new research channel components to the degree supported by the remaining 2013 funds. The primary focus of 2014 will be to complete the construction phase of the research channel(s).
- Applied Tier A research to be conducted with existing NFH&TC facilities is an independent task relative to design and construction and will be initiated starting in January 2013. Several of the studies proposed can be conducted simultaneously depending on available space within the NFH&TC greenhouse and ponds. Tier A studies proposed for initiation in 2013 are described below:
    - *Laboratory versus field comparison of flow conditions for native and non-native aquatic vegetation*. The specific purpose of this study is to test flow velocity as the driving variable in aquatic vegetation growth as well as investigate the nuances between laboratory and in-situ results. For this evaluation, potted plants including replicates for *Ludwigia, Cabomba*, *Sagittaria*, and *Hygrophila* will be placed in up to four select flow conditions (eg. Zero flow, 0.5 gallons per minute (gpm), 2 gpm, and 5 gpm) within the laboratory, and then replicated within similar velocity fields in the Old Channel ERPA. Potted plants will be used in both the laboratory and field investigations. Water quality conditions (dissolved oxygen, temperature, pH, conductivity, and CO_2) measured within the Old Channel study area will be replicated within each of the laboratory flow treatments via the use of heater/chiller units, aerators, etc.. To the degree possible, plants will be obtained from the NFH&TC greenhouse and/or raceways. Any plants collected from the Comal system will be treated and held as per NFH&TC protocol to ensure all snails and other organisms are removed prior to placement in experimental tanks. All species will be placed in the containers to

be used during experimentation and moved into tanks prior to initiation of the experiment for acclimation and observation. Only plants of similar length with green, crisp, unbroken leaves will be used. In addition, plants with observed reproductive structures will not be selected. At the beginning of the experiment, five plants from each species will be dried and weighed to get a "before-treatment" biomass measurement. Since the biomass of experimental plants cannot be measured before the experiment, similar sized plants will be used to estimate the mean before-treatment biomass. These plants will be placed in the same conditions in the acclimation tank prior to drying and weighing. The study will be conducted for a period of six weeks. During this time frame, water quality parameters and depth/velocity will be measured three times per week within each treatment. At the end of the six-week study period, growth of each species will be measured as changes in total, above-ground, and below-ground biomass (dry weight in grams for all plants).

- *Closed system pH drift experiment to evaluate bicarbonate utilization of Hygrophila, Ludwigia, Sagittaria, and bryophytes under CO_2-stressed conditions*. Bicarbonate use of Texas wild-rice has been previously studied by Power and Doyle (2004), but no information has been collected on other important native or non-native vegetation from these systems. Bicarbonate utilization under CO_2 stressed conditions can serve as an indicator of the tolerance that a plant may have under extreme low-flow conditions. Understanding the tolerance of aquatic vegetation to environmental conditions is a critical step in predicting system response to low-flows. In particular, *Hygrophila* is targeted for non-native removal in the AMP but will likely remain in each system at some capacity. Considering that Hygrophila may be extremely tolerant and the fact that it does provide suitable habitat for fountain darters, additional study of low-flow tolerance of this species is warranted. As such a pH drift study following the same protocols of Power and Doyle (2004) will be performed using this non-native and the aforementioned native species.
- *Low-flow thresholds evaluation of native and non-native aquatic vegetation conducted in aquaria and ponds*. This study will focus on the effects of low-flows on water temperature, CO_2, and algal buildup on aquatic vegetation. The initial trials will be conducted within the greenhouse, followed by a revised trial using potted plants within one of the available NFH&TC ponds. An initial laboratory experiment will use replicates of *Ludwigia,* Bryophtes (*Amblystegium* and *Riccia*), and Comal *Vallesneria*. Extreme conditions anticipated to be expected during a repeat of the drought of record (or worse) will be simulated over time to investigate the threshold at which, and the rate at which, each species begins to decline and ultimately die. Replication and starting plant numbers will be sufficient to sacrifice individual plants over time to evaluate decay rates relative to biomass. A follow-up laboratory experiment using a

larger variety of aquatic vegetation (e.g. replicates of *Ludwigia, Sagittaria*, Bryophtes [*Amblystegium* and *Riccia]*, Texas wild-rice, *Cabomba, Hygrophila,* and Comal *Vallesnaria*) will be conducted. Finally, during summer 2013, a NFH&TC pond will be used to conduct a summer time experiment to evaluate minimal or no flow conditions over time and the effects on aquatic vegetation growth at a larger scale.

- *Laboratory study to evaluate the effects of low-flow on amphipod populations within select aquatic vegetation types*. This experiment will be built upon the results obtained from the aquatic vegetation studies described above and the aquatic macroinvertebrate sampling as part of the Variable Flow study during spring 2013. As such, the first step in this study will be to complete the formal study design in late spring 2013. It is anticipated that aquatic vegetation most suitable for amphipod growth and survival (e.g. bryophytes, *Ludwigia*, *Hygrophila*, and *Cabomba*) will be used for testing. Sustainable populations of amphipods will be established in each aquatic vegetation type, followed by a series of experiments regarding low-flow and/or changing water quality to evaluate impacts to amphipod populations.

Allocated funds for 2013: $750,000

Estimated 2013 Budget broken down per activity:

- Design and construction plans
  - Total Cost: $125,000
- Initial Construction
  - Total Cost: $375,000
- Tier A applied research
  - Total Cost: $250,000 - costs include labor and non-labor expenses, and operational costs associated with water and electricity use to support the specific study activities.
    - Laboratory vs. field comparison
      - $57,500
    - pH drift experiment
      - $17,500
    - Low-flow thresholds evaluation
      - $115,000
    - Food-source threshold study
      - $60,000