American Fisheries Society
Bioengineering Section
Emerging Technology Committee

INNOVATOR INITIAL CONTACT INFORMATION AND QUESTIONNAIRE

April 2007

INNOVATOR INITIAL CONTACT INFORMATION AND QUESTIONNAIRE

(April 2007)

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SECTION 1
INTRODUCTION

In April of 2007, the AFS Bioengineering Section (BES) announced the formation of an *Ad Hoc* committee to help individuals realize the full potential of their innovative fish passage and protection technologies. The stated goal of this Emerging Technology (ET) Committee is as follows:

> *"Provide strategic support and technical guidance for those who are pursuing either the development of new fish passage and intake protection technologies or the use of existing technologies in unusual conditions"*

The committee will accomplish this by:

- Assisting Innovators
- Reviewing Concepts
- Fostering Communication
- Highlighting New Technologies
- Encouraging a Holistic Environmental Approach
- Identifying Potential Funding Sources

The enclosed ET Committee Bylaws (Attachment III) outlines how the committee will operate and lists ways that the committee hopes to support innovators and new technology development. Also included (Attachment IV) is the document,"*Guidelines for Evaluating Fish Passage Technologies"* (developed by another BES committee in 2000) that we encourage innovators to use as a tool to help bring their new technologies into practical application.

SECTION 2
COMMITTEE EVALUATION CRITERIA CONSIDERATIONS

In evaluating technologies, the ET Committee will apply the following evaluation criteria:

- Is the technology innovative?
- Does the technology have the potential to advance the state-of-the-art in fish passage/protection?
- Is it likely that the technology can be brought to practical application?
- What challenges (technical and acceptance) face the innovator?
- What additional data/information does the innovator need to develop/provide to demonstrate the potential effectiveness of the technology?
- Where can the innovator look for additional support (technical and/or financial)?
- Is the technology appropriate for presentation to the ET Committee and AFS peers at the AFS Annual Meeting?
- Is it the informal opinion of the Committee that the innovator should pursue this technology?

Based on the committee's evaluation of the above information, we will respond back to the innovator per the objectives identified in the committee bylaws referenced in the previous section.

SECTION 3
QUESTIONNAIRE TO BE SUBMITTED BY THE INNOVATOR

To assist you - the innovator - the ET Committee has developed a questionnaire (see Attachment I) that should be completed and submitted to the committee Secretary. (See Attachment II for a listing of ET Committee members). Submitting the questionnaire will initiate the ET Committee evaluation process.

SECTION 4
WHAT HAPPENS NEXT?

After the committee receives and reviews the questionnaire, one of the committee members will get in touch with you to discuss what happens next including discussing a timeline for the ET Committee to complete the evaluation process.

ATTACHMENT I

INNOVATOR QUESTIONNAIRE

American Fisheries Society / Bioengineering Section (AFS-BES)
Emerging Technology (ET) Committee
Innovator's Questionnaire
(April 2007)

Question	Response
1. Innovator's name(s)	
2. Questionnaire Date	
3. Contact Information (voice, email, web site)	
4. Mailing Address	
5. What is the name of your innovation[1]?	
6. Is the innovation confidential?	
7. Is it a new concept or a variation of an existing concept?	
8. What is its intended use?	
9. How does it operate / function including its integration with biology and / or fish behavior?	
10. To what species and life stages is it targeted?	
11. Why do you believe it is innovative (briefly)?	
12. Has the technology been applied or tested?	
13. Has any party expressed an interest in testing it?	
14. How much further development/refinement is needed before it can be applied / tested?	
15. How many months/years are needed to develop the concept?	
16. Are you seeking funding to develop/test your innovation?	
17. If so, by what individual / organization?	
18. Please provide any additional information (including pictures) that may assist the Committee's review of your innovation.	

[1] * attach drawings, sketches, and narrative descriptions for Committee use; all materials will be considered confidential

ATTACHMENT II

ET COMMITTEE MEMBER CONTACT INFORMATION

American Fisheries Society, Bioengineering Section (AFS-BES)
Emerging Technology (ET) Committee Member Contact Information
(April 2007)

(Note: **Chairman** designated with "**" / **Secretary** designated with "*")

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ATTACHMENT III

AMERICAN FISHERIES SOCIETY / BIOENGINEERING SECTION
EMERGING TECHNOLOGY COMMITTEE
BYLAWS

(Final Draft, April 2007)

American Fisheries Society/Bioengineering Section (AFS-BES)
Emerging Technology (ET) Committee
Bylaws

(Updated March 2008)

(Note: The following describes the interim bylaws of the BES-Emerging Technology Committee. The interim bylaws include mission, objectives, committee structure and operation, and new technology evaluation criteria. The committee was established as an *ad hoc* committee by the BES President effective January 2007. The interim bylaws will be evaluated on a quarterly basis and modified as necessary based on results of *ad hoc* operation).

I. MISSION[1].

Provide strategic support and technical guidance for those who are pursuing either the development of new fish passage and intake protection technologies or the use of existing technologies in unusual conditions. Accomplish this by:

- Assisting Innovators.
- Reviewing Concepts.
- Fostering Communication.
- Highlighting New Technologies.
- Encouraging Holistic Environmental Approach. (Including AFS–BES Guideline Recommendations)
- Identifying Potential Funding Sources.

II. OBJECTIVES.

A. Assisting Innovators that present ideas that have significant potential for advancing new fish passage concepts and designs by:

- Providing practical guidance to process, research, and development related questions.
- Directing to contacts that might facilitate development.

[1] It is not the intent of the ET Committee to serve as any type of technology approval or certification process or otherwise official sanctioning of a technology by the American Fisheries Society, this committee, or the organizations with which the members are employed. The ET Committee will not endorse or promote any technology, nor do the results of our discussions represent an endorsement, explicit or implicit, of any technology.

B. Reviewing Concepts to encourage the development of high potential ideas (including providing insights on specific applications) by:

- Separating worthy, well-planned and potentially effective concepts from misguided, mismatched, or fatally flawed projects.
- Recommending concepts for uses with the highest potential for success.
- Providing knowledgeable reviewers (impartial and free of any potential conflicts of interest) for evaluating innovative or emerging technology test cases.

C. Fostering Communication between innovators and knowledgeable experts in various fields by:

- Encouraging and facilitating communication and synergy within communities of practice and with new concept developers.
- Informing innovators if ideas being pursued may already exist.
- Providing a means for peer reviews to insure quality of new concept designs and / or of unusual applications of existing technology.
- Publicizing the existence of the AFS-BES ET Committee as a resource for supporting new technology related development.

D. Highlighting New Technologies using the influence of AFS in possible combination with other organizations in order to encourage new development by:

- Promoting the advancement of fish passage and protection technologies by drawing attention to innovative new concepts.
- Increasing awareness and visibility of worthwhile new technologies as a way to potentially increase funding and political profile for fish passage and protection research in general.

E. Encouraging Holistic Environmental Approach to solving fish passage problems by:

- Supporting consideration of riparian constituents and biotic community, not just target fish.
- Encouraging process-based habitat restoration and longitudinal, life history approaches to population recovery and protection.
- Advocating procedures and recommendations contained within "Guidelines for Evaluating Fish Passage Technologies" (AFS-BES, January 2000) as a tool for bringing new technologies into practical application.

F. Identifying Potential Funding Sources by:

- Directing innovators to possible funding sources.
- Articulating specific research needs to the innovator and (when appropriate) to agency decision makers, the funding community, and elected representatives.

III. ET Committee Structure and Operations.

A. Members.

ET Committee members will have educational and professional backgrounds in fisheries science with experience in the development, evaluation, or use of fish passage, protection and restoration technologies. The ET Committee will ordinarily be composed of six members who will be drawn from various professional sectors.[2] While employed by organizations in these sectors, the members will serve as independent experts with no committee-related ties to their employers. The composition of members from the different sectors may vary at the discretion (by a two-thirds vote) of standing ET Committee members.

ET Committee membership recruitment will be through an annual solicitation through the BES ListServe. Prospective members will be selected by the standing ET Committee

[2] 1) national regulatory services (e.g., National Marine Fisheries Service, Fish and Wildlife Service [FWS], Environmental Protection Agency [EPA], Canada Department of Fisheries and Oceans; (2) national regulated services (e.g., Bureau of Reclamation, Bonneville Power Administration); (3) national research laboratories (e.g. Department of Energy, FWS; (4) state and tribal regulatory service or permit authority (e.g., Ohio EPA, Virginia Department of Environmental Quality; (5) environmental consulting industry; and (6) non-governmental (e.g. Electric Power Research Institute, University of Massachusetts)

members. Members will serve two-year terms with half the membership turning over each year.[3] At the discretion of the standing ET Committee (by a two-thirds vote), members may serve consecutive terms, or having already served and departed, return to serve again.

The ET Committee may solicit in special situations additional short-term ad hoc members to serve as technical experts in areas outside the immediate expertise of the standing ET Committee.

B. Officers.

The ET Committee will have two officers, a Chairman and a Secretary, both elected by majority ET Committee vote. Each will serve a one-year term, with an option for an additional year of service with ET Committee concurrence. The Chairman will set the quarterly business agenda and may implement an AFS session or symposium if deemed appropriate (see Section III. C.). The Secretary will be responsible for: (1) Recording of all ET Committee discussions; (2) Distributing draft minutes for ET Committee review, comment and approval; and (3) Submitting (as necessary) final quarterly business meeting minutes to the BES Section Chair for archiving.

The ET Committee currently does not anticipate the need for a dues structure or to otherwise handle funds that would require a Treasurer to manage. However, the ET Committee reserves the right to develop financial activities and designate a Treasurer during future business activities.

C. Operation.

The ET Committee will meet on a quarterly (seasonal) basis with the first quarter starting April 1 and the last quarter ending March 31. Unless otherwise agreed upon by the ET Committee, three meetings will be by conference call and the fourth meeting in association with the AFS Annual Meeting. The meeting in association with the AFS Annual Meeting will be structured around the BES business meeting.

[3] Initial committee operation commenced January 2007. Organizing/exploratory committee members (Conyngham, Dixon, Reese, Taft, and Whitman) are serving a one-year term and will become the initial turnover group.

Occasionally, a session or AFS symposium might be appropriate to permit innovators of fish passage, protection, and restoration technologies to review and discuss their innovations and to interact with a larger peer group. The ET Committee will propose the symposium, when necessary, to the annual AFS organizing committee and be responsible for its organization, implementation and moderation. Inquiries and questions associated with normal operation of the ET Committee will be directed to the Chairman and Secretary.

D. ET Committee Products and Interactions with Innovators.

ET Committee products will primarily be in the form of documentation of activities through business meeting minutes. Additional documentation, at the discretion of the ET Committee, may be in the form of an edited symposium proceeding for public purchase.

ET Committee members will be required to maintain strict confidence in their dealings with other members and with those pursuing new technologies in order to protect the confidentiality of the innovator’s intellectual property. Summary technology evaluation results (see next paragraph) will become a part of the ET Committee’s official record. Summary evaluations will be available to anyone who requests the information.

Once the ET Committee has completed its evaluation of the innovator’s concept or technology, all input from Committee members will be compiled and sent to the innovator along with any specific ideas on how the innovator might further develop his/her concept or technology. At that point, the work of the Committee with that innovator will be completed. The innovator shall then be free to pursue further interaction with individual Committee members, if desired, with the understanding that these Committee members are acting as agents independent of the Committee. If the innovator subsequently makes substantial improvements to the concept or technology and wants to receive further Committee evaluation, he/she will be required to follow the formal submittal process as if this is a new submittal. In this circumstance, any Committee member who has been working independently with the innovator on the concept or technology will be required to disclose that interaction and excuse him/herself from the evaluation process.

IV. NEW TECHNOLOGY EVALUATION CRITERIA.

Evaluation criteria to be considered by the ET Committee when assessing new fish passage and intake related technologies include:

- Is the technology innovative?
- Does the technology have the potential to advance the state-of-the-art in fish passage/protection?
- Is it likely that the technology can be brought to practical application?
- What challenges (technical and acceptance) face the innovator?
- What additional data/information does the innovator need to develop/provide to demonstrate the potential effectiveness of the technology?
- Where can the innovator look for additional support (technical and/or financial)?
- Is the technology appropriate for presentation to the ET Committee and AFS peers at the AFS Annual Meeting?
- Is it the informal opinion of the Committee that the innovator should pursue this technology?

ATTACHMENT IV

GUIDELINES FOR EVALUATING FISH PASSAGE TECHNOLOGIES
(Initiative 23: Fish Passage Technologies Research Development Process)

(January 2000)

GUIDELINES FOR EVALUATING FISH PASSAGE TECHNOLOGIES
(Initiative 2: Fish Passage Technologies Research Development Process)

Prepared by the
American Fisheries Society Bioengineering Section

Committee Members:

Ned Taft (Chairman)
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January 2000

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SECTION 1
INTRODUCTION

Losses of fish at hydroelectric projects and water intakes for steam electric plant cooling, irrigation diversions and other municipal and industrial uses have led to the development of numerous alternative fish protection and passage technologies that mitigate this problem. Only a relatively small number of technologies are currently considered by the industry to be highly effective and/or are acceptable to the various agencies that are charged with protecting the resource. Fishery managers and other industry professionals typically greet new approaches to safe fish passage and diversion at water intakes with caution. There are multiple reasons for this caution, which include:

- The results of evaluations of some technologies have been equivocal, with inconsistencies in biological effectiveness both between different test sites and between test years at individual sites;

- Many of the studies conducted in the past have been reported in client reports and conference proceedings that are considered to represent "gray" literature; many professionals are reluctant to accept test results that are not presented in a peer-reviewed document;

- Inventors, manufacturers and/or sales representatives have a vested interest in the sale or use of their technology and may be considered biased in their claims of product effectiveness;

- Due to increasingly stringent requirements for biological effectiveness that have evolved over the last few decades, especially for listed species, "structural" technologies that physically exclude fish (e.g., diversion screens) are generally favored over behavioral barriers which may not be as effective in protecting a variety of fish under variable conditions.

Equivocal results in past studies have resulted from improper applications of technologies and differences in experimental design employed by different researchers with varying levels of experience in the conduct of fishery investigations. Variations in site conditions and fish species and sizes may also give different results. The reporting of results in gray literature, where original data are often lacking and data analyses are not clearly presented, also has added to the confusion over the biological effectiveness of certain technologies and contributed to the skeptical attitude that study results often are overstated. This is particularly true when results are presented or reported by parties with a vested interest in the success of a technology. However, it should be recognized that peer-reviewed documents are often not feasible due to time constraints. For example, license requirements may dictate a reporting schedule that will not provide adequate time for the peer review process. Therefore, gray literature will continue to be a source of information on which decisions will be based. This guideline attempts to address this issue by providing for a type of peer review throughout the process of developing a technology. In this way, even those with a vested interest in a technology, who deserve support for their inventiveness and enthusiasm, can expect to have their invention or product receive a fair and unbiased evaluation.

There is clearly a need for improving the process of evaluating fish passage and protection technologies such that there is greater consistency in experimental design and results and that the evaluation process is scientific and objective. The process also must provide evaluations that are relevant to regional and/or local fishery management objectives. As stated previously, there are still only a small number of technologies that are in common use and that are not considered experimental, despite decades of research and development efforts with a wide variety of technologies. Given the decline in fish stocks in some rivers and the inability to restore historic runs in others, it is in the interest of all parties involved in fishery management and technology development to develop a process that will lead to improved experimental design, increased communication, and, eventually, general consensus on the biological effectiveness (or ineffectiveness) of a technology. This process should replace the "trial-and-error" approach that often has been employed during past studies. The need for standardized guidelines is supported by a government report on fish passage technologies [Office of Technology Assessment (OTA) 1995] that identified a critical need for accepted scientific methods and independent evaluations for the successful development of new fish passage technologies.

At the 1997 Annual Meeting of the American Fisheries Society in Monterey, California, the Bioengineering Section met to discuss this issue. As a result of that meeting, a committee was formed to develop a guideline for improving the process by which fish passage and protection technologies are evaluated. The Committee comprised resource agency and industry professionals. This guideline is the product of the Committee's efforts. The guideline document is intended to provide standardized procedures for the development, evaluation, and application of technologies that will facilitate fish passage and/or protection through the development of sound scientific evidence. Subsequently, the guidelines are designed to assist technology developers, researchers and fishery managers and regulators in gaining approval of new technologies by providing general development and evaluation steps that have been peer-reviewed by agency and industry biologists and engineers. The proposed approach provides for an ongoing peer review process during technology development and testing that will permit further development and application of effective new technologies more reliably and consistently. Also, having a panel of experts involved from the beginning of technology development should aid in securing funding sources to support the development and evaluation process.

Naturally, while standardized procedures are desirable, any guideline must have a degree of flexibility that recognizes the diversity and varying complexity of fish passage and protection technologies and the methodologies available for evaluating them. Attempts have been made to build such flexibility into this Guideline. The Guideline is intended to serve as a tool for bringing new technologies into practical application. It is not a specific prescription for how new technologies should be evaluated and does not address the issue of what constitutes an aquatic impact and when fish passage or protection technologies are warranted to alleviate any such impacts.

SECTION 2
BACKGROUND INFORMATION

In developing the guidelines, it was considered important to address the following questions:

- What are the definitions of new, experimental, and existing technologies?
- What are the controversies and their causes regarding technology effectiveness?
- Can previously developed guidelines be incorporated into this guideline?

Answers to these three questions were explored to provide an understanding of the current problems with technology evaluations and to derive baseline information that would be helpful in producing a comprehensive scope for the guidelines. Having investigated the above questions, the following objectives were defined for the development of the actual guidelines and their subsequent application:

- Define a process for the development, evaluation, and acceptance of new technologies.
- Define specific procedures for evaluating new technologies.
- Provide information that will help guide those who need to evaluate and compare new technologies for possible application at a site.

Using the guidelines, researchers should be able to meet procedural criteria that will allow fishery managers to assess the potential for a technology to be successfully applied at specific sites based on rigorous and well-defined scientific evaluations. However, use of the guidelines is not intended to be a way of gaining unqualified acceptance of any given device. Every technology has ranges of effectiveness that are related to design, operational, biological, and environmental factors. Constraints or limitations associated with these factors need to be determined and addressed in any application of fish protection and passage technologies. Also, it should be recognized that effectiveness requirements vary by jurisdiction (i.e., between local, state, regional and federal agencies). These differences are due to differences in species, regional societal values, robustness of local stocks, fish management strategies, and regional histories of specific technologies. Therefore, it is possible that a given technology might meet acceptance criteria at one site or in a region but not at another site or another region. It is not within the purview of the guideline document to assess the reasonableness of existing effectiveness requirements. Rather, the document is intended to guide researchers in the conduct of studies that will determine the effectiveness of a technology with reasonable precision and accuracy, regardless of the effectiveness goal.

2.1 Technologies Defined

Fish protection and passage technologies that are candidates for evaluations conducted under the scope of these guidelines may be new, experimental, or variations of existing technologies. The introduction of *new technologies* in recent years has been rare. Examples include infrasound generators, Eicher and modular inclined screens and fish-friendly turbines (EPRI 1994,1999; Knudsen *et al.* 1992, 1994; Cook *et al.* 1997; Franke, *et al.* 1997). *Experimental technologies* include devices or systems that have demonstrated some potential for protecting or passing fish, but for which adequate scientific evidence has not been collected to verify effectiveness and gain agency acceptance or to be considered for general application. Behavioral fish protection devices, such as louvers, strobe lights and sound systems, are considered to be experimental by some resource agencies (NMFS 1994) but are accepted by others (Odeh and Orvis 1997). *Existing technologies* (e.g., diversion screens and fish ladders) often are modified to improve effectiveness or to meet site- or species-specific criteria. Modifications to existing technologies should be assessed to ensure that they meet required performance standards. These guidelines might be used to advance a given technology from a new or experimental status to an accepted status in a specific region and/or for specific species or age classes of fish.

These guidelines are intended to be general so they can be used with a wide range of devices. For the purposes of developing the guidelines, fish protection and passage technologies were divided into the following broad classifications and sub-categories:

Downstream Fish Protection and Passage Technologies

" Behavioral devices
" Physical barriers
" Fish collection systems
" Diversion devices
" Bypasses
" Fish pumps
" Spillways/sluices
" Turbines
" Trap and transport
"

Upstream Fish Passage Technologies

" Fish ladders
" Fish lifts (locks and elevators)
" Fish trap and transport
" Fish pumps
" Bypass channels
"

Tailrace Barriers/Adult Guidance

" Diffuser barriers
" Physical barriers
" Behavioral barriers
" Electrical barriers

Downstream fish protection and passage technologies encompass devices that are designed to reduce entrainment and possible mortality of fish at water intakes. This group of technologies includes devices that are used at hydro projects for downstream passage of fish and devices used at other types of water intakes (e.g., pumped storage, cooling water and irrigation diversions) to minimize entrainment and/or mortality. Upstream fish passage technologies include fish lifts and ladders and associated facilities. Tailrace barriers include devices that are used to improve upstream fish passage efficiency by diverting upstream migrants to passage facilities or bypass reaches, or to block access to tailrace areas (e.g., draft tubes) where fish can be injured or migrations delayed.

2.2 Controversial Issues

Many controversies with the application of fish protection and passage technologies have been associated with systems and devices that are used to repel or divert fish from water intakes or pass fish through turbines. Upstream fish passage technologies are better understood for applications with many species, although considerable developmental work is currently ongoing with additional species (e.g., sturgeon), small fishways and culvert passage; controversial issues generally have been related to site-specific designs. Tailrace barriers, although important at sites where there is a need, are required less often than upstream or downstream facilities, and the question of their need is usually more controversial than the technology selected for application.

Controversy associated with the evaluation and application of fish protection and passage technologies have been related to all aspects of evaluations as presented in Table 2-1. In general, controversies arise when industry, consultant, or vendor representatives conclude that a technology is effective and should be considered for general application when the responsible resource agencies or NGOs have concluded otherwise or do not have sufficient information to draw conclusions. Controversies can be associated with site-specific applications of a technology, or with the general application of a device to any given site. Most disagreements center on the issues listed above.

2.3 Existing Guidelines and Recommendations

There have been no formal guidelines published for evaluating fish passage and protection technologies similar to the guidelines presented in this document. There is literature available that presents general information on, as well as specific design and operating criteria for selected technologies (e.g., angled, fixed fish diversion screens); pertinent publications are presented in the List of References. However, standardized evaluation processes have not been developed to provide investigators and resource agencies with data derived from a rigorous scientific evaluation on which they can base judgements on the biological effectiveness of a technology and its potential for further application. The National Marine Fisheries Service Southwest Region (1994) and Northwest Region (1995) have issued Position Statements on the use of experimental fish guidance devices (refer to List of References). While these Position Statements address these devices relative to regional fishery issues, they also (1) reflect the philosophy of a key resource agency and (2) present guidance that is of general importance. Therefore, these Statements (and any others that might be developed by other agencies in the future) should be reviewed by any individual planning to conduct or sponsor a study of an experimental technology.

2.4 Guideline Implementation

Fish protection and passage technologies need to be evaluated and applied in a step-wise manner that will allow investigators and fishery managers to make application decisions using data and information from rigorous scientific assessments. An outline of an evaluation process that will improve the potential for industry and agency acceptance is presented in Table 2-2. A four-phase process is recommended for the development, evaluation and acceptance of a technology:
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> *Phase 1 - Conceptual Development*. Establishment of an Expert Review Panel and development of a study plan that outlines the biological and engineering basis of operation and expected effectiveness and presents an approach to initial evaluation. All alternative study methods that meet the objectives of the evaluation should be reviewed and considered.

> *Phase 2 - "Laboratory" Evaluation.* Initial evaluation of the technology at a reasonably small scale in a location where operational and environmental conditions can be controlled.

Phase 3 - Prototype Evaluation. Large-scale field evaluation where the sometimes subtle, yet critical, implications of real-world operational and environmental conditions can be fully understood.

Phase 4 - Application and Evaluation. The Expert Review Panel verifies, based on Phase 2 and 3, the conclusions of the evaluations relative to the degree or range of effective protection provided by the technology. The Panel should also verify that the stated conditions under which further applications can be considered (e.g., species, life stage, and hydraulic and environmental conditions) are valid and that any limitations of the technology are clearly defined.

Each phase is discussed individually in the following sections. It should be pointed out that this process may be an iterative one in which researchers may have to repeat earlier phases during the development of a technology. For example, problems discovered in a Phase 3 prototype study may best be resolved by returning to the laboratory.

SECTION 3
PHASE 1 – CONCEPTUAL DEVELOPMENT

The first step in the evaluation process involves the development of basic information regarding the intended design, operation, and biological basis of a technology that can be reviewed and commented upon by industry and agency experts. This step will act to ensure that the technology is based on reasonable engineering and biological principles and expectations, thereby improving the potential for acceptance following subsequent laboratory and/or field evaluations, as described in Section 4. The following presents the key elements of the technology development process.

Expert Review Panel. It is recommended that an expert review panel be assembled during the initial stages of a technology's development. The review panel should consist of a diverse group of professionals (e.g., fishery managers, engineers, research scientists) representing groups directly associated with the development of the technology (funding organizations/companies, consultants, regional resource agencies) as well as groups not directly associated with a technology's development but knowledgeable in the area of evaluating technologies (research universities, consultants, or resource agencies). The review panel should be consulted throughout the development and evaluation of a technology and be involved in assessing study plans, data analyses, and progress and final reports.

Literature Review. A thorough literature review should be conducted during a technology's development. Literature to be reviewed should include all publications that provide information on biological, environmental, and site parameters that are important to the design and operation of a technology. To the extent possible, the developer of a technology should provide information on the evolutionary, physiological and/or behavioral basis on which the developer believes that the technology will be effective. The literature review should address:

(1) whether the technology is targeted at certain species of fish,

(2) if its effectiveness is expected to be influenced by the behavior, physiology, swimming abilities, age, lifestage and size of the target species, and

(3) if its effectiveness is expected to be influenced by physical conditions such as water temperature, turbidity, salinity, velocity, etc.

All past evaluations and applications of similar devices, including successes and failures, will be important to presenting the concept of a new or modified technology and for providing justification for testing or application of an existing technology. Past failures or shortcomings of the technology and identifying reasons for these shortcomings should be fully disclosed. Lack of transparency on this issue has often generated controversy in the past.

Design and Operation. It is important that individuals who will be asked to support the use of a technology understand its basic design and operation, particularly as these factors may affect product reliability and maintenance costs. Any experience with operation and maintenance problems should be fully disclosed. An evaluation of the reliability of a technology should be an integral part of the study plan. If the technology is proprietary (e.g., the inventors plan to file for a patent), a confidentiality agreement or other form of legal protection should be prepared to allow the disclosure of the design on a "need to know" basis. Many stakeholders are very skeptical of "black boxes" that are accompanied with unsubstantiated claims of potential effectiveness.

General Plan of Study. A general plan of study should be prepared by the developer of the technology (or a qualified Contractor) and reviewed by the Expert review Panel. The general plan should describes the approach to be taken in the next phase of development, namely laboratory and/or field studies. The plan should include recommendations for test methods, possible test locations, test species and life stages, physical, environmental and hydraulic conditions, and data recording and analysis procedures. In essence, the general plan of study is a proposal for conducting an evaluation of a technology. Who will perform the study and how it will be financed are issues outside the purview of this Guideline Committee.

Depending on the technology, it may be appropriate to use physical or mathematical model studies to develop a concept prior to laboratory and/or field testing with live fish (e.g., a screen model to ensure that the design configuration chosen will meet established hydraulic criteria for safe fish passage). In the past, most modeling involved scaled physical models. Recently, computational fluid dynamic (CFD) techniques have been used in developing fish protection and passage technologies, as well as in addressing site-specific application issues. CFD allows for thorough analyses of flow dynamics using standard hydraulic principles and available flow and design data from a site and for the technology being assessed. CFD analyses can be conducted in lieu of physical model studies, or to provide additional information either prior to or after model studies have been completed.

Independent Review and Comment. All biological and engineering data from the technology development effort described above should be summarized in a comprehensive technology development report. The report should include the general plan of study and should be submitted to the Expert Review Panel for review and input. Input from the Panel could lead to improvements in the technology or allow for potential problems with design and operation to be identified early in the evaluation process.

SECTION 4
PHASE 2 - "LABORATORY" EVALUATION

The next step in the evaluation of a technology should be to conduct the laboratory and/or field studies discussed in the previous section of this Guideline. In the context of this Guideline, the term "laboratory" is not intended to describe a physical research laboratory facility *per se*. Rather, while the term encompasses such facilities, it also includes small-scale test facilities, such as test cages, land-based tanks and flumes that can be constructed or deployed at or near a potential site of application. The key distinction of "laboratory" studies is that they are conducted under a set of tightly controlled conditions.

Laboratory studies have been successful in the past in the development of various fish diversion screens that are now in full-scale use. For behavioral fish protection systems, laboratory studies allow researchers to determine the basic fish response to a stimulus under controlled conditions without interference from the many uncontrolled variables that occur in nature. On the other hand, laboratory studies are sometimes considered to be too controlled and unrepresentative of real world conditions. Therefore, the various advantages or disadvantages of laboratory versus field studies must be carefully weighed when deciding the location for the first evaluation of a technology. The decision on whether to begin with studies in the laboratory or to proceed directly to the field can be addressed by answering the following questions:

- Is the technology new or is it a variation of an existing technology (i.e., are data available from the existing technology that may be sufficient to obviate the need for laboratory testing)?

- Does the technology have numerous alternative configurations and/or operating conditions which need to be evaluated in order to identify optimum engineering design criteria and hydraulic performance prior to testing with live fish?

- Can the technology be "scaled" to a level where meaningful results can be obtained with live fish of the proper species and life stages in a laboratory test facility? ("scaled" refers to a small version of the technology rather than a true scaled model)?

- Will laboratory experiments serve to isolate the behavioral characteristic (e.g., phototaxis) responsible for the observed fish response to the technology (something that is difficult to isolate in the field)?

- Is the technology of such a design that it can be easily deployed on a small-scale basis at a field site?

- As a corollary, does a field test site exist that can provide (1) appropriate physical and hydraulic conditions, (2) target or representative species in sufficient abundance and duration to provide statistically meaningful results, (3) features that will permit the proper deployment of performance monitoring equipment (e.g., traps, nets, bypasses, hydroacoustics, telemetry), and (4) will allow testing without causing unacceptable impacts due to installation (e.g., riparian/upland destruction) or operation (e.g., entrainment of ESA listed species)?

These questions are addressed in the following discussions of laboratory and field evaluations.

Laboratory studies can provide a vital step in evaluating the effectiveness and future applicability of fish protection and passage technologies by providing a rigid scientific framework within which a technology can be studied under reasonably controlled conditions. Such studies are particularly useful in evaluating technologies that can have wide variation in design and operational parameters. For example, fish diversion screens can incorporate a range of screen angles and flow velocities that influence hydraulic conditions. In a hydraulic model, many variations can be evaluated quickly and inexpensively to determine which combination of parameters yields the optimal hydraulic conditions for effective fish diversion with minimal stress or injury. Similarly, laboratory test flumes are effective in evaluating the effectiveness of diversion devices (e.g., screens and louvers) with multiple species over a range of operating conditions in a short time frame.

The primary goal of laboratory investigations should be to collect data that will support the basic biological and engineering principle governing the potential effectiveness of a technology and provide clear evidence that future testing of a prototype at a field site is warranted. It should be clearly understood by all study participants that the results of the laboratory studies may indicate that a technology does not perform as expected and (1) that future testing is not warranted or (2) that major modifications in design or operation are needed. It is natural to expect that the first evaluation of a new technology may not produce the desired results. In such cases, researchers should review the results, make appropriate changes and re-evaluate the technology in the laboratory. In the past, market forces or the desire to proceed to the next level of testing have resulted in inappropriate applications of new technologies in field applications that have led to equivocal results. This approach has heightened the skepticism of many toward new technologies. The following discussion presents the key factors that need to be addressed in planning and conducting laboratory studies.

Goals and Objectives. It is critical to any research project that reasonable goals and objectives of the project are clearly defined and reviewed *a priori* by the Expert Review Panel, the researchers performing the study, and the inventor/supplier/manufacturer (vendors) of the technology. Poorly developed or understood study objectives can leave the door open to various and biased interpretations of study results. Properly worded goals and objectives also minimize the potential for false expectations among participants. The goals and objectives should pertain to the laboratory phase only. At this point in the development process, goals and objectives should not be related to site-specific needs that might arise in the future when the technology might be applied to meet a specific fishery management program objective or to conform to a regional biological effectiveness requirement.

Study Participants. The primary participants will be the researchers conducting the study. However, the Expert Review Panel and the vendor of the technology (if any) should be involved in a review capacity, providing input into the Plan of Study, any changes to the proposed testing protocols that may become necessary during the evaluation, the test results and the study report.

Test Facility. If the test facility is intended to develop optimum design and hydraulic performance parameters for a technology, it may be appropriate to use a scaled model for the evaluation. As mentioned, such models have been used successfully for the development of a variety of fish passage facilities. If testing with live fish is intended, the facility should be of suitable size that "natural" behavioral responses can be expected. For example, a fish diversion screen test flume should be wide enough that the test fish are not unnaturally crowded and should include a sufficient length of screen to ensure that fish have actively guided on the screen and have not merely passed directly into the fish bypass. Studies of repelling behavioral devices should be conducted in facilities that have adequate escape routes. Particular care must be taken when studying the effects of sound on fish to ensure realistic propagation of the sound signal without reverberation and large boundary layer effects. It should also be kept in mind that evaluations of some technologies on a "laboratory" scale might not be appropriate under any circumstance, requiring researchers to proceed directly to field studies.

If live fish are being tested, adequate fish holding facilities must be provided. Appropriate methods for handling and holding fish should be used at all times to minimize injury and stress to the test fish. Past studies of technologies have occasionally been negatively impacted by the inability of the researchers to maintain test fish in a reasonably healthy state. Unfortunately, the lack of effectiveness of a device has sometimes been attributed to "the poor condition of the test fish." Such statements have not helped to quell the skepticism of regulatory agencies asked to review the study data. If the test fish are in poor condition, it is recommended that they not be used. Rather, healthy fish should be used and, when the evaluation of a technology includes latent survival, control groups of fish should be held such that treatment and control survival rates can be calculated. In many cases, if control survival is reasonably high (e.g., greater than 80 percent), treatment survival can be adjusted for control mortality.

Holding facility design requirements and fish handling procedures vary by species and are not within the scope of this guideline. However, such information is widely available and can be obtained in other publications (EPRI 1997).

Quality Assurance Plan. A Quality Assurance Plan should be developed to describe and define objectives, experimental design, methods, personnel training requirements, data quality objectives and acceptability criteria, data reduction and analysis methods, and standard operating procedures for all aspects of the evaluation.

Test Species. Selection of appropriate test species and life stages (and related size) is one of the most critical components of a technology evaluation. If the technology development phase has been performed properly (see Section 3), it should be a straightforward task to select species/life stages on the basis of one or both of the following criteria:

- The species and life stages are of great enough importance at enough sites that might employ the technology (if effective) that they are appropriate for evaluation.

- There is an evolutionary, physiological and/or behavioral basis to expect that the selected species will adequately represent the performance of the technology for another species/life stage of interest.

To the extent possible, the species and life stages should be ones that are in need of protection. While it may be appropriate to use one species as a surrogate for another species, both species should be of importance and the surrogate should reasonably represent an important, known attribute of the other species (e.g., swimming capability, body shape, behavior). Also, it may be appropriate to use surrogate species in preliminary trials; however, detailed evaluation with target species must eventually be completed.

Test Conditions and Procedures. To the extent possible, tests should be conducted under the full range of (1) operating conditions of a technology (e.g., device settings, such as screen angle or sound amplitude) and (2) environmental conditions (e.g., water quality, lighting).

Data Analysis. Appropriate and adequate analyses of data are very important aspects of any scientific evaluation and will be vital in gaining acceptance of study results. Use of inappropriate statistical models can lead to erroneous conclusions. Consideration should be given to involving a professional statistician for assistance in developing the experimental design for laboratory studies, as well as in the analysis of data. It is incumbebt upon reviewers to have an understanding of the analysis techniques or to consult an authority on the specific statistical approach employed. Due to the natural vagaries in biological response, data often can be widely scattered, requiring a large number of replicates to produce statistically reliable results. The inclusion of a statistician on the Expert Review Panel is recommended. A well-defined plan for data collection and analysis can avoid the problem of "false positives" and "false negatives" that have occurred in past studies. A well-defined Quality Control/Quality Assurance plan should also be developed.

Reporting. Laboratory study reports should present all methods, collected data, statistical analysis results, and conclusions in a comprehensive and logical manner. A description of methods should include test facilities, equipment, procedures, and data analysis methods. Data summaries, trends, and statistical results should be presented in tabular and graphical formats in the body of a report and, to the extent possible, all raw data should be included in appendices. A lack of information pertaining to how a study was conducted, how data were analyzed, why some data may have been discarded, and thorough justification of all conclusions and recommendations often leads to controversy. Test data and information included in a report should be adequate to allow reviewers to independently replicate analyses and assess the validity of any conclusions or recommendations. The report should also include a summary of previous studies (if any) related to the technology and provide a complete bibliography.

Acceptance of Results, Recommendations, and Conclusions. The Expert Review Panel should review laboratory study results, conclusions, and recommendations and verify that the conclusions drawn are supported by the available data. The review panel would be responsible for submitting comments on draft reports and for confirming that the study was conducted according to the Plan of Study developed in Phase 1. Verification of the results is not an endorsement of the technology but rather a statement that (1) the methods used to evaluate the technology were appropriate and (2) the conclusions drawn are consistent with the results obtained. General considerations for accepting results of fish protection and passage technology evaluations are summarized in Table 4-1.

SECTION 5
PHASE 3 - PROTOTYPE EVALUATION

Prototype field studies represent the next logical step in evaluating technologies that have been shown in the laboratory to have the potential to protect or pass fish. Field studies should be designed to be a rigid scientific evaluation of a technology's ability to meet desired effectiveness levels at a specific site or at a site that is considered representative of expected applications.

A primary goal of prototype studies should be to collect data that will allow researchers and fishery managers to determine if a technology can be considered a viable option for general application at appropriate sites. As with laboratory studies, it should be clearly understood by all study participants that the study results may indicate that a technology does not perform as expected and (1) that future testing is not warranted or (2) that major modifications in design or operation are needed.

Study Participants. Generally, the participants will be the same as in the laboratory with the possible exception of the researchers. Field studies require different skills and are best performed by experienced field organizations. At this stage, resource agencies may be expected to have a greater role in defining acceptance standards.

Site Selection. Site selection criteria should be developed for identifying an appropriate site for field studies of a technology. The criteria will vary depending on the type of technology being evaluated, but general factors to be considered in the site selection process include the following:

- Species Availability: The species of interest must occur at the site in sufficient numbers and for long enough periods to provide statistically meaningful results. It should be demonstrated that the evaluation of a technology at a given site will not cause unacceptable injury or losses to the fish or other sensitive species involved.

- Site Representativeness: The site should be reasonably representative of other sites of intended future use of the technology relative to fish species and life stage present, site layout and operating conditions.

- Hydraulic Conditions: The existence of appropriate hydraulic conditions is one of the most critical requirements for site evaluations of technologies. Velocities that are appropriate for the species/life stages being evaluated are essential. If the technology's effectiveness is considered to be sensitive to hydraulic conditions such as non-uniform velocities, turbulence, and effects of debris loads, these factors need to be specifically included or avoided, depending on the objective of the field evaluation.

- Existing Features: Some technologies have specific power requirements, installation specifications and/or operational needs that cannot be met at all sites. If a site has existing design and operating features that can support these needs, considerable cost savings can be realized.

- Past Experience: Sites at which previous studies of fish protection or passage technologies have occurred offer two advantages - (1) many of the "unknowns" of a new site have been previously identified and (2) sampling equipment with proven capabilities might be available for use and may allow for side-by-side comparison.

- Ability to Modify Project Operations: Evaluations of some technologies require periodic modifications to normal operations at a test site (e.g., shutting down hydro units to permit sampling equipment installation or preferential operation of a unit). The need to modify operations should be identified prior to the site selection process and be made known to potential site operators.

- Access and Safety: Reasonable access to test and sampling equipment should be available to permit researchers to conduct the study in a safe manner.

Scale of Prototype Field Facilities. Many of the past studies that have produced equivocal or controversial results suffered from the selection of an inappropriate scale for the first field trial of a new technology. There has been a tendency to evaluate new technologies on too large a scale, which can make monitoring of performance difficult and expensive. During the site selection process, attempts should be made to identify sites, or areas within sites, where the technology can be installed for testing under appropriate physical and hydraulic conditions at a scale that is large enough to produce data that is representative of results that would be expected at larger scales. A common approach to prototype testing is to install a technology on one unit of an operating plant; if the technology is effective, it can be "scaled up" by installing it at the other units.

Test Conditions. Test conditions include the operation of a technology (e.g., device settings, such as screen angle or sound amplitude), operation of site facilities (e.g., hydraulic conditions, turbine operation, diversion intakes), and environmental conditions (e.g., water quality, debris load, lighting conditions). To the extent possible, all important variables and combinations of variables (both controlled and uncontrolled) should be evaluated. A phased approach to testing is recommended in which a wide range of test conditions is sequentially narrowed down to a few optimum performance conditions. Where possible, a bracketing approach to testing is recommended (e.g., starting at extremes in the ranges of particular variables). This approach could substantially reduce testing and analyses costs in some cases.

It should be recognized that natural variables outside of human control can confound test results or, in extreme cases, cause the loss of data. For example, high flow conditions at a hydroelectric project during the fish migration period of interest might result in the planned test fish bypassing the test facility (e.g., by passing through opened spill gates). Although such events are a fact of life, it is encumbent on planners and reviewers to adequately consider the potential for these events. Every effort should be made to minimize the likelihood that such events will occur or to minimize the impacts of the events on the data if they are unavoidable. When data are lost due to them, the loss should be acknowledged and subsequent analyses, if any are possible, should clearly state the limitations of the data and take those limitations into account.

Target Species. The species selection process for field evaluations is similar to that for the laboratory. Target species may include specific species for which a technology is designed, or representative species if a device is designed for application with many different types of fish. Target life stages (i.e., size classes) also will be important to the evaluation of most technologies. In some cases, interactions with predatory species may be important in prototype evaluations.

Quality Assurance Plan. A Quality Assurance Plan should be developed to describe and define objectives, experimental design, methods, personnel training requirements, data quality objectives and acceptability criteria, data reduction and analysis methods, and standard operating procedures for all aspects of the prototype evaluation.

Data Analysis. Appropriate and adequate analyses of data are very important aspects of any scientific evaluation and will be vital in gaining agreement on conclusions based on field study results. With more uncontrolled variables in the field than in the laboratory, the analytical techniques to be used should be developed *a priori* by individuals knowledgeable in the design and operation of test site features. As with the laboratory evaluations, consideration should be given to involving a professional statistician for assistance. It is encumbent upon reviewers to have an understanding of the analytical techniques used or to consult an authority on the particular approach employed. The inclusion of a statistician on the Expert Review Panel also is recommended.

Reporting. Study reports should present all methods, collected data, statistical analysis results, and conclusions in a comprehensive and logical manner. A description of methods should include site design, test facilities, equipment, procedures, and data analysis methods. Data summaries, trends, and statistical results should be presented in tabular and graphical formats in the body of a report and, to the extent possible, all raw data should be included in appendices. A lack of information on how a study was conducted, how data were analyzed, and why some data may have been discarded, coupled with an incomplete justification of all conclusions and recommendations, has led to most of the controversies that have been experienced in past evaluations and application of new and experimental technologies. Test data and information included in a report should be adequate to allow reviewers to independently replicate analyses and assess the validity of any conclusions or recommendations.

Acceptance of Results, Recommendations, and Conclusions. The Expert Review Panel should review study results, conclusions, and recommendations and verify that the conclusions drawn are supported by the available. The review panel would be responsible for submitting comments on draft reports and for confirming that the study was conducted according to the guideline criteria. Acceptance of the results is not an endorsement of the technology but rather a statement that (1) the methods used to evaluate the technology were appropriate and (2) the conclusions drawn are consistent with the results obtained. General considerations for accepting results of fish protection and passage technology evaluations have been summarized previously in Table 4-1.

It may be determined that the technology is limited in application to certain species, site-specific physical and hydraulic conditions, and other factors. Such limitations should be clearly identified in the report. If the limitations can be potentially removed through further study, the types of study efforts should be generally defined.

SECTION 6
PHASE 4 - APPLICATION AND EVALUATION

If results from Phase 2 and 3 laboratory and field tests have been verified by the Expert Review Panel and all study participants, and these results indicate that a technology has potential for effective application, then the technology should be considered as a candidate for application at appropriate sites and with species for which the device has been designed and successfully evaluated. Therefore, the types of sites, species, environmental conditions, etc. that are considered "appropriate" should be defined.

6.1 Site Assessment

When the application of a fish protection or passage technology is being planned for a given site, there are many issues related to biological, environmental, and engineering parameters that need to be addressed. The selection of an appropriate site is paramount to the "proof of concept" that is hoped to be achieved in the first full-scale application of a technology. Some past studies of experimental technologies have suffered from the selection of sites that have too many environmental, physical and/or hydraulic variables that confound the data and lead to equivocal results. It is recommended that the Expert Review Panel be involved in the site selection process and the studies that follow.

6.2 Review of Alternative Fish Protection and Passage Technologies

When a site owner is required to evaluate fish protection or passage technologies for a given site, it is advisable to objectively review the status of available alternatives. Available technologies should be assessed for applicability to a site using criteria that address biological, environmental, engineering, and cost considerations. The owner should understand from the outset whether the technology is considered experimental, how the resource agencies view the technology, and whether its experimental status will impact its potential for acceptance by the agencies if it is applied at a given site. Agency requirements vary by region and may change over time. Therefore, it is considered essential to involve the appropriate agencies in the process of selecting a technology, particularly if it is considered experimental.

6.3 Design, Operation, and Post-Installation Evaluation

After a technology is selected for application, site-specific design and operation criteria must be established and a study plan for a post-installation evaluation should be prepared. The Plan of Study should clearly identify specific fish passage/protection goals that can lead to ultimate acceptance of the installation. The Plan should also include a quality assurance program that describes and defines objectives, experimental design, methods, personnel training requirements, data quality objectives and acceptability criteria, data reduction and analysis methods, and standard operating procedures for all aspects of the post-installation evaluation.

Post-installation studies are typically necessary to determine site-specific performance and guide modifications if performance criteria are not met. The necessary rigor of a given post-installation evaluation will depend on many factors, such as the adequacy of the data from evaluations conducted during the developmental phases to predict effectiveness at a site and regional agency requirements for effectiveness. These studies can be especially important if major site-specific biological, environmental, design or operational differences exist relative to the prototype that was evaluated during field studies.

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Table 2-1
Controversial Issues Associated with Technology Evaluations

STUDY PARAMETER	ISSUE
Study scale	Has the appropriate scale been selected for the current level of development of the technology (laboratory, prototype, full-scale)?
Site selection	Is the site appropriate (physical, hydraulic, water quality, etc. conditions representative without unusual, confounding factors)?
Technology deployment	Has the system or device been configured and deployed in an appropriate manner that will maximize biological effectiveness?
Study design	Have appropriate protocols been developed to adequately address the goals and objectives of the study in a reasonable and cost-effective manner?
Data collection	Has the data been collected in a scientific manner by experienced and objective fishery scientists?
Species tested	Are the species tested the actual target species; if surrogate species are tested, are they representative of target species?
Test fish	Are the test fish of the appropriate age, size, condition (e.g., smolted vs. non-smolted)?
Conditions tested	Have a reasonable range of environmental conditions of proposed application been included (e.g., day vs. night, temperature, light, turbidity)?
Statistical analyses	Have appropriate techniques been selected to allow determinations of statistical significance with a measure of variance?
Reporting	Do results support conclusions?

Table 2-2
Process of Evaluation and Acceptance

Phase 1 - Technology Development

- Establish an expert review panel
- Review literature for information supporting the technology concept
- Describe design, operation, and intended effects (e.g., avoidance, attraction)
- Develop a general plan of study for laboratory and/or field evaluations
- Prepare a technology development report (include literature review, design and operation, and general plan of study)
- Submit draft final report for review and comment
- Submit copy of final report to AFS Bioengineering Section

Phase 2 - "Laboratory" Evaluation

- Prepare draft study plan
- Submit draft study plan for review and comment
- Finalize study plan
- Conduct studies
- Submit progress reports
- Prepare summary draft report
- Submit draft final report for review and comment
- Revise draft report and publish (*should AFS Bioengineering Section be involved?*)

Phase 3 - Prototype Evaluation

- Prepare draft study plan
- Submit draft study plan for review and comment
- Finalize study plan
- Conduct studies
- Submit progress reports
- Prepare draft final report
- Submit draft final report for review and comment
- Revise final report and publish (*should AFS Bioengineering Section be involved?*)

Phase 4 - Technology Selection and Application

- Site assessment
- Technology selection
- Review by Expert Review Panel
- Conduct post-installation evaluation
- Perform long-term evaluation with annual reports (*should AFS Bioengineering Section be involved?*)

Table 4-1
Considerations for Accepting the Results of Fish Protection and Passage Technology Evaluations

1. Test Facilities
Test facilities that are used during a laboratory or field study should meet design criteria that allow for precise or accurate and reliable testing of all proposed conditions and scenarios. Test facilities should be assessed for conditions that may introduce error or bias in data during an evaluation.

2. Test Equipment
Test equipment to be used during laboratory and field testing should be adequate to meet all study objectives related to device operation, conditions tested, and type and accuracy of data collected. The type and quality of test equipment should be assessed to verify that each item is appropriate for its intended purpose.

3. Testing Procedures
Testing procedures used for technology evaluations should be designed to collect data in a standardized, logical manner that minimizes the potential for error and bias. Testing procedures should be reviewed for inconsistencies and potential for influencing the outcome or study results (i.e., observed results that are an artifact of testing methods).

4. Experimental Design and Data Analysis Methods
Experimental design of technology evaluations should be based on study objectives, hypotheses to be tested, and the type of data to be collected (e.g., diversion or survival rates, time fish take to ascend a ladder). Data analysis methods should be appropriate for the type of test conducted and data collected. Statistical tests and models should be robust with respect to assumption violations. A full discussion of the validity of each assumption should be provided in study reports. Where possible, assumptions should be tested. Experimental design and data analysis methods should be assessed for their appropriateness, adequacy, and robustness to determine the strength of the data, statistical results, and subsequent study conclusions and recommendations.

5. Reporting
Study reports should present all relevant data and information that was generated during an evaluation. Reviewers should be able to replicate all analyses with the information and data that are provided in a report. Unexpected or poor results should be reported and, if possible, causes should be identified.

6. Study Conclusions and Recommendations
Study conclusions and recommendations must be consistent with collected data and statistical analysis results. Researchers should avoid drawing conclusions that are speculative or based on ambiguous results.