Flow Restoration Accounting Framework: A Stewardship Approach for Environmental Flows Around the Western U.S.

A Report for The National Fish and Wildlife Foundation

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Cover Photo: Hot Creek, California

Photo Above: Spring Creek, Oregon

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Table of Contents

Table of Figures

Table of Tables

Terms and Definitions

Abandonment – A term in the Prior Appropriation Doctrine referring to when a water right has intentionally or voluntarily not been beneficially used within a set term of years determined specifically by each state's water laws (generally 5-10 years depending upon location) and is also referred to as forfeiture of water rights.

Base Flow – Streamflow contributed solely from groundwater inputs in the absence of significant precipitation, run-off events, or supplemental flow releases from storage; base flows provide adequate habitat to support diverse, native aquatic communities and maintain groundwater levels to support riparian vegetation (NRC, 2005).

Beneficial Use – All water rights must apply and utilize water for a recognized state beneficial use, which generally benefits the appropriator and people of the state or society and is based upon economic and efficient use of the resource.

Change of Use Process – A regulatory process administered by a state water agency to determine a request for change of a water right "beneficial use".

Compliance Status Code – A color-based coding system to track the contractual compliance of active water transactions in the FRAF.

Connectivity – Maintaining sufficient flow to provide physical, chemical, and biological continuity in a stream system throughout the hydrologic cycle or a critical portion of the hydrologic cycle.

Conveyance Efficiency Improvement – Refers to enhancing irrigation infrastructure conveyance systems efficiencies by improving or replacing existing diversions, pumps, pipes, ditches or scheduling to better conserve water.

Discharge – A rate of streamflow or volume of water which passes a specified location over a specific time period, typically measured in cubic feet per second or cubic meters per second.

Diversion – A physical structure where water is removed from its source, via surface water diversion, dam, well or pump.

Diversion Reduction Agreement (or Non-Diversion Agreement) – A legal civil agreement between two parties, with one of those parties being a legal water right holder who agrees "not to divert" a specified or reduced portion of the full water right flow or volume legally allowed over a specified period within the water right defined period of use.

Ecological Flow Objective – An identified ecological intention or goal of a streamflow restoration project specified by the sponsoring organization or practitioner, attempting to mitigate anthropogenic streamflow alterations or impairments upon the hydrologic, biologic, connectivity, water quality or geomorphic condition.

Environmental Flows (or Environmental Water) – The quantity, timing, and quality of water flows required to sustain freshwater ecosystems.

Environmental Flow Prescription – A specified quantity, timing and quality of environmental flow required to sustain freshwater ecosystems, determined by professional methods such as geomorphic surveys, hydrologic analysis, habitat surveys, water quality thresholds, hydrologic monitoring, or biological monitoring.

Ephemeral – A stream or stream reach that flows briefly in direct response to precipitation in the immediate vicinity and whose channel is always above the local groundwater level.

Flow Deficit – The volume of water needed to achieve the targeted or desired instream flow volume. This is the difference between the targeted or desired instream flow volume and the current streamflow.

Flow Depletion – The net reduction in streamflow due to developed water uses through a stream reach. This is the difference between the natural streamflow and the current streamflow.

Flow Regime – The combination of magnitude, duration, timing, frequency, and rate of change that yields flow patterns for a river that have direct impacts on maintaining ecological functions and natural processes (Poff *et al.*, 1997; Poff and Zimmerman, 2010).

Flow Target Prescription – A prescribed or targeted streamflow stage or flow rate recommendation that characterizes a specific streamflow condition intended to achieve a desired ecological outcome or response.

Forbearance Agreement – A legal civil agreement between two parties, with one of those parties being a legal water right holder, who agrees "to forgo" the diversion of water associated with a legal/valid water right for a full season.

Groundwater Level – The elevation of or depth to groundwater. Sometimes referred to as groundwater table.

Hydrograph – A graphical representation of the rate of flow past a single location through time.

Hydrologic Unit Code – A Hydrologic Unit Code is a unique numbering code from 2 to 12 digits, which has been applied to all waterways and bodies by the USGS (and later the EPA) to map the hierarchy of waterways and basins within the U.S. in the Watershed Boundary Dataset (WBD).

Hybrid Doctrine – A legal water rights doctrine developed in the western U.S., which incorporates elements of the prior appropriation and riparian rights doctrines.

Instream Flow – The amount of water in a stream to adequately provide for uses within a stream channel for riverine or ecological purposes.

Intermittent – A stream where portions flow continuously only at certain times of the year (i.e., seasonal). At low flow there may be dry segments alternating with flowing segments. The stream bed is, at times, above the local groundwater level.

Irrigation Infrastructure Agreements – Water management agreements focused on irrigation infrastructure and water management enhancements for instream flow benefit, such as a point of diversion change, diversion efficiency (e.g., automated headgates, POD consolidation), delivery efficiency (e.g., timing / scheduling), transmission efficiency (e.g., ditch lining or piping), storage release timing change, source switch, or on-farm irrigation efficiency (e.g., flood to sprinkler).

Natural Flow Regime – A streamflow pattern under completely unregulated conditions or unaltered by anthropogenic use, expressed in quantity, timing and variability, over a timescale of hours, days, seasons, years, decades and longer.

On-Farm Efficiency Improvements – Refers to improving physical irrigation water infrastructure efficiencies at the farm level or on the farm. Examples include converting a flood irrigation system to sprinkler or drip irrigation system.

Overbank Flow – An infrequent, high flow event that overtops riverbanks. Overbank flows can restructure the channel and floodplain, recharge groundwater tables, deliver nutrients to riparian vegetation, and connect the channel with floodplain habitats that provide additional food for aquatic organisms (NRC, 2005).

Percent of Flow – A hydrologic analysis method which categorizes the natural flow regime of a system into varying categories, such as subsistence flows, base flows, pulse flows, or overbank flows. Categorization is based on the percentage of natural flows in order to better prescribe instream flows needs and thresholds or manage anthropogenic withdrawals from a stream.

Perennial – A stream that flows year-round and for which base flow is generally maintained by groundwater discharge to the stream bed due to the groundwater level adjacent to the stream typically being equal to or higher than the elevation of the streambed.

Period of Ecological Significance – The time frame during which streamflow is a limiting factor for the health and survival of the targeted species and/or ecological function of the stream reach. The period of ecological significance can vary be unique for each stream reach and targeted species/ecological function.

Place of Use – An element of a water right which describes the legal area where the diverted water will be applied or utilized for its beneficial use.

Point of Diversion – An element of a water right which describes the legal location for where water will be diverted from the stream.

Point of Diversion Change (or Source Switch) – Changing the legal point of diversion from its historical source of a water to a new source, such surface water to groundwater, or other legally and physically available sources (e.g., storage or other surface sources).

Point of Diversion Consolidation – A legal and physical change to diversion locations of multiple water rights to reduce the number of unique diversion points that impact the targeted stream reach.

Prior Appropriation Doctrine – A legal water rights doctrine developed in the western U.S., which specifies that the first person to use a quantity of water for a recognized beneficial use (e.g., irrigation, industrial or domestic) may continue to use that quantity of water for that purpose, and subsequent water users may use available water if it does not harm the existing (i.e., senior) users' water rights or use.

Programmatic Approach – A long-term, strategic approach of inter-related activities/projects aimed at achieving large-scale impacts. Also referred to as "programmatic scale" or "programmatic level."

Protected Stream Reach – A defined stream reach determined by a state water agency when legally protecting water rights for instream flow purposes, which are administered and protected from junior and/or other water users to enhance flows within the stream reach.

Pulse Flows – Short-duration, high flows within the stream channels. These occur naturally during or immediately following a storm event and can be mimicked using storage releases. These flows typically flush fine sediment deposits and waste products, restore normal water quality following prolonged low flows, and provide longitudinal connectivity for species movement along the river (NRC, 2005).

Quantity, Quality, Space, and Time – A quantitative restoration approach that considers flow in terms of the quantity, quality, space (location), and time (duration) for stream on a reach-by-reach basis.

Reach Level – A level of analysis where the focus is on a single stream reach.

Reconciled Condition – A stream system condition where ecosystem functions co-exist with other competing demands. The system is not at a fully restored state due to the severity of the impairment, ongoing human impacts, climate change, or other factors.

Riparian Rights Doctrine – A property and water right doctrine which grants the lands adjacent to waterways legal access and use of available surface waters within that system equally whether utilized or not.

Source Switch – See **Point of Diversion Change**.

Storage Release – Refers to the timing and flow rate of releases from storage associated with a water right.

Stream Ecosystem Function – The processes within the natural flow regime paradigm (Poff *et al.*, 1997), where the integrity of a stream system depends upon maintaining the natural system dynamics that are critical for dependent aquatic and riparian species, in-channel and floodplain interactions, and other system processes.

Streamflow Time-Series – The series of paired flow and date/time data points.

Subsistence Flow – The minimum streamflow needed during critical drought periods to maintain tolerable water quality conditions and to provide minimal aquatic habitat space for the survival of aquatic organisms, riparian vegetation, and ecosystem function (NRC, 2005).

Targeted Stream Reach – An identified stream reach which experiences flow-limited conditions targeted or designated for improvement through water transactions or other instream flow enhancement projects.

Tributary Reconnect – When, as a result of a water transactions, the longitudinal connectivity of streams and river networks is re-established.

Water Management Agreement – A civil contract or agreement with a water right holder, typically providing an incentive to not divert all or a portion of their water right for a specified period.

Water Right Acquisition – A voluntary sale and purchase of a water right. For environmental flow purposes, when legally permitted, water right acquisition allows for the change in the historic use of the water right to a recognized instream use for enhancement of the aquatic system on a permanent basis.

Water Right Leasing – Utilizing available state water law to change an existing water right beneficial use, either temporarily or permanently, to a recognized "instream use" for enhancement of the aquatic systems, generally associated with being "protected" from other water diversion by the prior appropriations doctrine.

Water Right Reliability (or Water Rights Security) – The level of security and protectability of a water right managed within the administration of water rights by the prior appropriations doctrine seniority system.

Water Transaction – A water transaction acquires water for instream uses through a willing seller-buyer agreement (or set of related agreements). The agreement details a change in a water use and/or water right leading to legal or de facto protection of additional water in a waterway or water body (Malloch, 2005).

List of Acronyms and Abbreviations

BPA – Bonneville Power Administration

BOR – United States Bureau of Reclamation

CBMP – Chesapeake Bay Monitoring Program

CBWTP – Columbia Basin Water Transactions Program

CEFF – California Environmental Flow Framework

CFS – Cubic Feet per Second

CSC – Compliance Status Code

CWA – Clean Water Act

EFO – Ecological Flow Objective

ELOHA – Ecological Limits of Hydrological Alteration

EPA – United States Environmental Protection Agency

ESA – Endangered Species Act

ESRI – Environmental Systems Research Institute

FRAF – Flow Restoration Accounting Framework

GIS – Geographic Information Systems

HUC – Hydrologic Unit Code

IDFG – Idaho Department of Fish and Game

IDWR – Idaho Department of Water Resources

IFC – Instream Flow Council

IFIM – Instream Flow Incremental Methodology

IHA – Indicators of Hydrologic Alteration

IMW – Intensively Monitored Watershed

KBMP – Klamath Basin Monitoring Program

NEPA – National Environmental Policy Act

NFWF – National Fish and Wildlife Foundation

NGO – Non-Governmental Organization

NOAA – National Oceanic and Atmospheric Administration

PITTag – Passive Integrated Transponders Tag

PNAMP – Pacific Northwest Aquatic Monitoring Partnership

POF – Percent of Flow

POU – Place of Use

POD – Point of Diversion

POES – Period of Ecological Significance

PRRIP – Platte River Recovery Implementation Program

QQST – Quality Quantity Space and Time

SWRCB – State Water Resources Control Board

TNC – The Nature Conservancy

USFS – United States Forest Service

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

WBD – Watershed Boundary Dataset

WDFW – Washington Department of Fish and Wildlife

WWT – Washington Water Trust

W3T – Water Temperature Transactions Tool

Executive Summary

The Flow Restoration Accounting Framework (FRAF) is a streamflow monitoring stewardship approach designed to identify, quantify, and track environmental instream flows necessary to restore and maintain the ecological integrity of streams and associated ecosystem services. The original FRAF concept for managing environmental flow assets was developed in 2015 for the Bonneville Power Administration's (BPA) Columbia Basin Water Transactions Program (CBWTP), the largest freshwater restoration program in the United States. The National Fish and Wildlife Foundation (NFWF), administrators of the CBWTP, recognized that environmental flow restoration around the U.S. continues to expand in geography, complexity, and cost. To support this need, NFWF envisioned a FRAF document that was readily disseminated to watershed groups and non-governmental organizations focused on environmental flow restoration, water resource management, and aquatic species protection.

This report builds on the original FRAF concept and ongoing work completed under the CBWTP to address salmon, steelhead and other native fish populations that have been impacted by the Columbia River power system. The states, working in collaboration with BPA were early adopters of legal mechanisms designed to address flow-related fishery needs, and CBWTP has leveraged these efforts through non-governmental organizations and state agencies. This current FRAF report draws from the tools and experiences developed by the CBWTP and their partners, presenting a defined approached to monitoring, quantifying and tracking instream flows, and ongoing stewardship that will assist communities, water managers, and restoration organizations as they develop flow restoration projects.

The approach presented herein extends activities typical to most water transactions by incorporating two inter-related tasks: 1) designing stream monitoring and quantification strategies and 2) implementing a monitoring and tracking program. Both tasks are premised on a clearly identified ecological flow objective and period of ecological significance. An ecological flow objective is an identified ecological intention or outcome of a flow restoration project to mitigate anthropogenic flow alterations or impairments as they impact stream hydrology, biology, connectivity, water quality, and geomorphology. The period of ecological significance refers to the timeframe during which streamflow is a limiting factor for targeted species and/or ecological functions and is unique for each stream reach. Thus, the design of a flow restoration project depends on the identification of flow targets (based on the ecological flow objective during the period of ecological significance) and the associated flow deficit leading to impairment (the additional amount of flow needed instream to meet a flow target).

Once identified, monitoring and tracking of flow restoration projects within the FRAF is carried out through a series of four nested tier categories that include contractual compliance (Tier 1), flow accounting (Tier 2), aquatic habitat response (Tier 3), and ecological function (Tier 4). These tiers represent the four possible stages that a water transaction can progress through a stream restoration process. The monitoring and tracking requirements increase with each tier level; Tier 1 is the most basic and focuses on contractual matters, Tier 2 addresses specific hydrologic metrics, and Tiers 3 and 4 are more complex and include other, non-hydrologic parameters (such as habitat or fish population) as needed.

The FRAF is designed to be applied at an individual water transaction or stream reach level, or as part of a programmatic approach. In a programmatic application, the FRAF incorporates multiple water transactions and their respective stream reaches within a state, sub-basin, or watershed to assess and track broader programmatic-level ecological benefits (e.g., fish re-distribution throughout a region or watershed). The flow restoration practitioner implements monitoring strategies to quantify, and thus track, each project's hydrologic outcomes. Hydrological information is compiled annually in a FRAF workbook template by flow restoration managers. The FRAF workbook templates provide a uniform and flexible approach to streamflow restoration monitoring and tracking that encompasses the complexities and unique attributes of individual systems. The monitoring and tracking elements provide resource managers with a mechanism to explicitly quantify restoration outcomes, adapt restoration efforts, allocate resources, and clearly communicate project information to partners and stakeholders.

The final step of the FRAF approach addresses responsibilities of ongoing stewardship activities and adaptive management integration. Ongoing stewardship concentrates on implementation management, which requires that flow practitioners ensure the water transaction is being conducted as intended for the duration of the agreement (i.e., the volume/rate and timing of the transaction is being met). Adaptive management integration requires the flow restoration practitioner conduct an end of season assessment each year to determine transaction performance in terms of the project objective. This assessment is used to identify achievements and assess if changes to the current instream flow management activities are required. In this manner, adaptive management also provides information on the need for future water transactions. Both ongoing stewardship and adaptive management have a multi-year element, occurring over the life of the project.

Through systematic tracking and accounting activities, the FRAF assists restoration organizations by maximizing instream asset benefits, improving flow management, efficiently using available resources, and improving the pace of environmental flow restoration and success.

1. Introduction

The Flow Restoration Accounting Framework (FRAF) is a streamflow monitoring stewardship approach designed to identify, quantify, and track environmental instream flows necessary to restore and maintain the ecological integrity of streams and associated ecosystem services. The FRAF concept was initially developed in 2015 to support the Bonneville Power Administration's (BPA) Columbia Basin Water Transactions Program (CBWTP), as administered by the National Fish and Wildlife Foundation (NFWF) (McCoy and Holmes, 2015). Through the successful implementation of the FRAF within the CBWTP, NFWF recognized the value in further developing this stewardship approach and associated tools, and the need to expand and share the FRAF with other flow restoration conservation partners in the western U.S. This is part of a larger recognition by NFWF of the importance of flow enhancement as a strategy for conserving and restoring freshwater ecosystems.

The FRAF is designed to provide hydrologic monitoring tools, guidance, and assistance to flow restoration practitioners and conservation organizations working to improve instream flow conditions around the western U.S. The FRAF stewardship approach focuses on augmenting instream flow through the implementation of voluntary water transactions or other related irrigation changes to meet an ecological objective, whether it is a hydrology, geomorphology, biology, or water quality-based objective, and includes tools to identify hydrologic impairments, develop flow restoration strategies, track project implementation, and quantify and analyze project effectiveness over the life of the project or set of projects. Designed to be flexible, the FRAF also provides a standardized system for tracking a discrete water transaction project's hydrology information and data management to assist with guiding stewardship to maximize the ecological potential of each project.

Instream flow stewardship is the careful and responsible management of instream flows through a targeted or protected stream reach. While stewardship should be considered the last step in the life cycle of a water transaction project, it is the most critical step. Without adequate stewardship, there are no guarantees that the instream water rights will be managed properly. Stewardship requires that flow restoration practitioners invest in on-the-ground oversight, time, resources, and funding to ensure that the transaction is implemented properly, communicated effectively, and that the outcomes be evaluated consistently with the project objective. Flow restoration projects and associated water transactions are typically multi-year events, requiring long-term strategic investments in a basin to balance instream ecological benefits with other uses of water. The FRAF stewardship approach presented herein provides a systematic guide for flow restoration practitioners, while retaining flexibility to accommodate a wide range of varying water transaction project types, funding availability, and protectability frameworks.

This document is divided into three main sections: Environmental Flows and Flow Restoration (Section 2), Flow Restoration Planning and Implementation (Section 3), and FRAF Supported Water Transaction Example (Section 4).

- Section 2 provides background information on the key elements of an environmental flow regime and prescription, as well as a brief introduction to the key elements of the flow restoration process.

- Section 3 presents the major features of a flow restoration program and a detailed description of the FRAF stewardship approach.

- Section 4 presents a detailed example of a FRAF supported water transaction project.

The report concludes with a summary of the FRAF stewardship approach and citations.

ORIGINS OF THE FRAF

Due to historical and current water resources management practices that have detrimentally impacted freshwater ecosystems in the western U.S., the interest in and need for flow restoration and conservation planning has been growing. NFWF and its partners aim to provide flow restoration practitioners with structured guidance and innovative ideas for instream flow stewardship and tracking project implementation and outcomes, developed from lessons learned from the CBWTP, and other supported instream flow conservation programs.

The CBWTP is part of BPA's mitigation for the impacts of Federal hydroelectric dams located on the Columbia River system upon Endangered Species Act (ESA) listed fish species throughout the greater Columbia Basin in Oregon, Washington, Idaho, and Montana. The CBWTP is the largest instream flow restoration program in the United States, seeking to balance existing land and water uses with instream flow needs. The program focuses on improving instream flow and habitat conditions for target fish species, such as Chinook salmon, sockeye salmon, steelhead, bull trout and other species, through voluntary ***water transactions*** that increase streamflow or improve the timing of flows to benefit targeted ESA listed species and their associated aquatic habitat.

The original FRAF stewardship approach was developed as part of the CBWTP between 2011 and 2014 and created a standardized system for tracking the implementation and compliance of each water transaction to assess effectiveness in terms contractual agreements, over-arching ecological flow objectives for individual transaction, as well as the programmatic objectives of the CBWTP. While the CBWTP FRAF stewardship approach was specifically designed to meet the needs and requirements of the CBWTP program, NFWF identified the benefits of further developing and expanding the FRAF stewardship approach to be applicable to a wider range of geographies and conservation entities. This new version of the FRAF stewardship approach retains the primary features of the original FRAF but removes those elements that are specific to the CBWTP. The methodology is designed so that new flow restoration projects will easily incorporate the FRAF stewardship approach, while entities with an existing water transaction projects can likewise add the FRAF approach to their projects to support their instream flow stewardship responsibilities.

FRAF OVERVIEW

The FRAF stewardship approach monitors and tracks water transactions in a quantitative manner, ranging from basic contractual elements to ecological response over decades. This approach extends activities typical to most water transactions, incorporating two inter-related tasks: 1) designing stream monitoring and quantification strategies and 2) implementing a monitoring and tracking program. Both tasks are premised on a clearly identified ***ecological flow objective*** (EFO) and ***period of ecological significance*** (POES). An ecological flow objective is an identified ecological intention or outcome of a streamflow restoration project to improve upon streamflow alterations or impairments based upon the hydrology, water quality, geomorphology, and/or ecology conditions due to anthropogenic impacts. The period of ecological significance refers to the timeframe during which streamflow is a limiting factor for targeted species and/or ecological functions and is unique for each stream reach.

Monitoring and tracking of flow restoration projects within the FRAF stewardship approach is carried out through a series of four nested tier categories (Tennant, 1976; Poff *et al*., 1997) that include contractual compliance (Tier 1), flow accounting (Tier 2), aquatic habitat response (Tier 3), and ecological function (Tier 4) (Figure 8). These tiers represent the four possible stages that a water transaction can progress through within a stream restoration process. The monitoring and tracking requirements increase with each tier level; Tier 1 is the most basic, while Tiers 3 and 4 are more complex and includes other, non-hydrologic, parameters (such as habitat or fish population) as needed.

The FRAF stewardship approach is designed to be applied at an individual water transaction or stream reach level, or as part of a ***programmatic approach***, where multiple water transactions and their respective stream reaches within a state, sub-basin or watershed could be incorporated to assess and track broader programmatic-level ecological benefits (e.g., fish re-distribution throughout a region or watershed).

The FRAF provides a uniform and flexible approach to streamflow restoration that encompasses the complexities and unique attributes of individual systems. The monitoring and tracking elements provide resource managers a mechanism to explicitly quantify restoration outcomes, adapt restoration efforts, allocate resources, and clearly communicate project information with partners and stakeholders. The FRAF is designed as a stewardship guidance document for flow restoration practitioners and relies on a lengthy history of water transaction expertise, literature, and experience. The field continues to evolve, and the reader is encouraged to adaptably evolve these concepts, ideas, and approaches with other information (e.g., CCEF[1], ELOHA[2], IHA[3],

[1] California Environmental Flows Framework: https://ceff.sf.ucdavis.edu/
[2] Ecological Limits of Hydrologic Alteration: https://www.conservationgateway.org/
[3] Indicators of Hydrologic Alteration: https://www.conservationgateway.org/

PNAMP[4]) to develop water transactions that improve ecological monitoring for streams throughout the western U.S.

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[4] Pacific Northwest Aquatic Monitoring Partnership: https://www.pnamp.org/

2. Environmental Flows and Flow Restoration

The range of water demands in the western U.S. has often resulted in reduced streamflow, which can have detrimental impacts on freshwater ecosystems. Water resource management is further complicated by each western state's unique legal framework and legally recognized water uses and demands. In general, existing water right systems were not originally designed for protecting ***environmental water*** uses; however, since the late 1990s, states have begun to officially recognize the beneficial uses of environmental water for fisheries, aquatic species and stream ecosystems. Water resource managers must familiarize themselves with the respective state water laws, statutes and agency rules that will impact their project and then apply those legal frameworks as they seek to develop flow restoration programs designed to enhance instream flow.

The process of increasing instream flows through water transactions aimed at restoring aquatic systems in the western U.S. has only been practiced for a few decades. Early water transactions were often narrowly focused on adding flow to severely depleted streams (Kendy *et al.*, 2018) and, in certain cases, were set as simple minimum flow requirements. More recently, water transactions have been designed to address a wider range of ecological considerations (Yarnell *et al.*, 2020; Poff and Zimmerman, 2010; Poff *et al.*, 2010; Richter *et al.*, 1996).

Environmental flows are defined by the quantity, timing, and quality of water required to sustain freshwater ecosystems (Willis *et al.*, 2013; WWF, 2012). In certain cases, where streams are highly degraded or chronically dewatered, simply adding water can provide remarkable benefits. However, in many cases, a carefully designed and implemented flow regime is needed to achieve the desired benefits. Specifically, flow restoration practitioners should define and quantify the flow regimes and biological needs to support their ecological flow objectives during the periods of ecological significance, identify and secure the necessary water transactions, and develop and implement a flow restoration process. Each of these steps are briefly discussed below.

Environmental Flow Regimes

Environmental flow prescriptions should aim to retain, restore, and sustain ecosystem processes over a range of intra- and inter-annual flow conditions (Annear *et al.,* 2004). Research, field studies, and implementation of stream restoration strategies that have been developed and adopted over the last several decades offer insights into critical elements of river systems and their functions. The Instream Flow Council has developed a holistic model for riverine processes, wherein ***flow regime*** is the dominant variable in determining river function and form (Poff *et al.*, 1997; Annear *et al.*, 2004). A flow regime has five components:

- Magnitude of discharge is expressed as the volume of water passing a given location per a unit of time,
- Duration is an amount of time associated with a specific magnitude or flow condition,
- Timing is the period of time that a flow condition occurs,
- Frequency is how often a certain flow magnitude occurs over a specific time period, and
- Rate of change relates how quickly flow changes from one condition to another.

The combination of these five components yields flow patterns for a river or stream that have direct impacts on maintaining ecological functions and natural processes (Poff *et al.*, 1997; Poff and Zimmerman, 2010). The Instream Flow Council's holistic model of riverine system ecological functions/natural processes (e.g., hydrology, geomorphology biology, water quality, and connectivity) and the associated impacts on flow components is shown in Figure 1 (Annear *et al*., 2004; Karr, 1991). When assessing a flow impaired stream system for potential prescriptions, flow restoration practitioners should consider the impacted ecological functions and associated flow components.

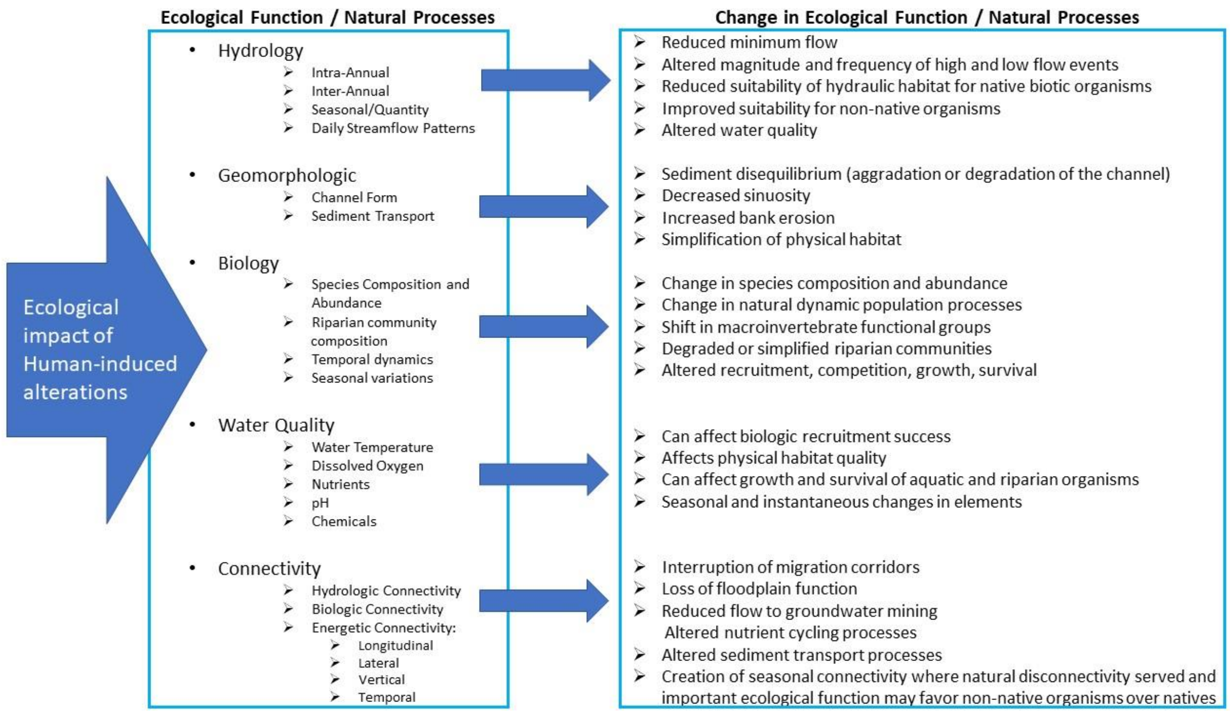


Figure 1. Ecological impact of human-induced alterations of streamflow on hydrology, geomorphology, biology, water quality and connectivity and how they relate to flow components (adapted from Annear *et al.* (2004)).

When a single water transaction for flow restoration purposes is insufficient in magnitude or duration to fully restore (i.e., achieve full ecological function) the impaired stream reach or system, multiple water transactions or a water transaction in combination with other restoration actions may be needed. Even with multiple water transactions or restoration actions, streams that have been heavily altered may not achieve full ecological function due to the severity of the impairment, ongoing human impacts, climate change, or other factors. However, such streams may reach a ***reconciled condition***, where ecosystem functions co-exist with other competing demands, at an acceptable level. The reconciled state is identified and defined during the restoration planning and implementation period with a goal of achieving a sustainable, but reduced, level of ecosystem function (Willis *et al*., 2013).

Flow restoration practitioner strategies and actions should include both an incremental approach and long-term strategy for assessing and characterizing the five key riverine components (hydrology, biology, geomorphology, water quality and connectivity) of the target stream. An incremental approach requires development of watershed-specific plan that includes streamflow restoration strategies for each targeted stream system. These strategies should include interim milestones to achieve environmental flow objectives and assess the outcomes associated with the implemented restoration actions. A long-term (e.g., decadal) temporal strategy is typically necessary because many environmental flow objectives require multiple years to achieve. Also, water transaction project development, implementation, and effectiveness monitoring are usually a multi-year process, integrating adaptive management and lessons learned, to best address restoration strategy changes and system needs when identified.

FLOW RESTORATION ACTIONS

The FRAF stewardship approach focuses on tracking hydrologic changes resulting from various types of water transactions and water management actions (e.g., irrigation operation changes) designed to increase streamflow. A water transaction is a method of acquiring water for instream flows through a willing seller-buyer agreement (or set of related agreements). Within the western U.S., this approach is necessary because of the ***prior appropriation*** and ***hybrid*** doctrines that govern water rights, coupled with the fact the most streams managed by these doctrines are over-appropriated – i.e., there are more water rights claims on the stream than can be met with available water. Over-appropriation is the reason why legal water diversions will lead to significant streamflow reductions, including the dewatering of streams. Therefore, to direct available water for restoration purposes, acquisition of existing water rights provides the most effective legal approach with the existing regulatory process.

Streamflow conservation strategies to protect or improve ***stream ecosystem function*** will utilize various legal approaches. Legal authority to protect or enhance streamflow initially occurred through state authorized and funded water programs, which allowed fish and wildlife agencies to file for very junior water right claims to protect existing streamflow conditions or establish minimum flows for specific streams. For example, in 1973 the Colorado state legislature authorized the Colorado Water Conservation Board to begin filing instream rights. In the same year, Montana, through the 1973 Water Use Act, also allowed the state water right system to protect minimum instream flows. Other states began adopting legislation enabling the protection of instream rights much earlier (e.g., Oregon adopted the Minimum Perennial Streamflow Act in 1955 to begin setting minimum flows and authorizing Oregon State Game Commission, a predecessor to Oregon Department of Fish and Wildlife, to begin review of other instream needs). However, these efforts largely lacked the ability to restore streams that were already experiencing dewatered conditions, and have been seen as inefficient and ineffective for "restoration" purposes due to the limitations associated with being a junior water right holder in an over-appropriated system. Owing to these and other state agency limitations, additional legal and statutory approaches beginning in the late 1980's designed to allow private entities to conduct limited water right leasing has been embraced by most western U.S. states. These more recent instream flow laws rely on specific legislation, statutes, and rules regarding water rights for environmental purposes and, since their adoption, many conservation organizations have engaged in streamflow restoration around the western U.S. Thus, the FRAF's primary focus herein is on private water transactions between conservation entities and private water rights holders. These water transactions are typically conducted using 1) private water right leasing or acquisition, 2) water management agreements, and/or 3) irrigation infrastructure agreements. While all three of these water transaction approaches will provide ways to protect, restore and enhance flow conditions within a targeted stream or watershed, the requirements and key features differ and are presented below.

Private Water Right Leasing or Acquisition

Private water right leasing utilizes state water law to change an existing water right beneficial use, typically for irrigation, to an instream use, either temporarily (lease) or, in some instances, permanently; however, it should be noted that not all states allow permanent dedications of water rights for instream use. In the states that do allow permanent instream dedications, ***water right acquisition*** has also emerged as an option. Acquisition allows flow restoration entities to purchase water rights outright and then change the historical use of the water right to a recognized instream use for enhancement of the aquatic systems. Early environmental flow activities by non-governmental organizations (NGOs) and smaller groups of stakeholders first began using private water rights leasing to enhance dewatered streams in the mid-1990s. Oregon, the first state to address leasing by agencies and private entities, passed legislation in 1987 (SB140, the Instream Water Use Act) to allow more tools and options to protect and restore instream flow around the state.

When a water right is leased for instream flow purposes, the water right is retained by the original owner or water user. Conversely, a water right acquisition occurs when an entity purchases the water right in its entirety from the original owner, then transfers that water right to an instream use. Both temporary and permanent water transfers utilize the ***change of use process*** to convert the original beneficial use to an instream use. The primary benefit of water right leasing or acquisition is that the priority date associated with the water right is preserved. If a senior water right can be leased or acquired, downstream junior water right users may be required to allow a portion of the leased or acquired water to remain instream through historically dewatered stream reaches past their junior points of diversion. Herein lies the strength of the leasing mechanism, as water will be protected past junior irrigation diversions once the new water right use is approved by the state water agency. The details of how a private water right lease or acquisition is implemented depends upon the state-specific laws and statutes governing water rights and the original beneficial use; however, this is the most powerful and typically most expensive water right instream flow restoration technique as the state change of use processes are general long and more rigorous.

Water Management Agreements

Water management agreements for environmental flow purposes use civil contracts to utilize water rights to enhance instream flow conditions in a targeted stream reach (i.e., there is no legal change to the water right). Private entities and organizations, and, in some instances, state and regional agencies, enter into a civil contract with a water right holder that provides financial or other incentives to change how water rights and/or infrastructure is managed for instream benefit. These agreements generally require water users to not divert all or a portion of the water right for a specified period, thus keeping the flow instream. When developing and implementing a water management agreement, considerable effort is required to characterize water right and legal issues (e.g., ***abandonment***), operations, flow management, ecosystem conditions, and other factors on the targeted stream reach.

A water management agreement does not result in a legal change in the water right, thus legal costs are typically less than when implementing a lease or acquisition. However, this means that the water remaining instream is not protected from diversion by any downstream junior water right, and there are increased challenges associated with flow monitoring and ensuring water remains instream. Despite the general lack of regulatory protections associated with water management agreements, these agreements have proven to be an effective means of protecting water through a targeted stream reach when they are well-defined and the circumstances in the target reach are suited for this approach. Benefits from using a water management agreement include significantly reducing the time required to develop the water transaction, improved financial efficiency for funders and practitioners, and increased flexibility for water users and water right holders. Water management agreements can also be used between conservation groups and water right holders when attempting pilot water transaction projects or testing locally developed flow restoration strategies, as they only require limited time and resources commitments. An additional benefit of a water management agreement is that it can be flexible in terms of the timing and volume of the water transaction (i.e., the water transaction may only need a portion of the full water right volume or may only be needed for part of an irrigation season).

Irrigation Infrastructure Agreements

Irrigation infrastructure agreements are perhaps the most utilized method for improving instream flows and are made between all types of flow restoration entities (e.g., NGOs, tribes and state and federal agencies) and water rights holders. Most irrigation infrastructure agreements require changing some components of the historical water right associated with the infrastructure. Flow restoration entities often rely on irrigation infrastructure agreements for improving instream flows because as they provide additional instream flows while also improving the irrigation system without having to retire irrigated acreages or reduce agricultural production.

Irrigation infrastructure agreement methods to improve instream flows include, but are not limited to, ***point of diversion changes*** (i.e., moving diversion further downstream), ***source switches*** (i.e., switching surface water use to groundwater), ***point of diversion consolidation*** (i.e., combining multiple points of diversion to a more efficient diversion location), ***storage releases*** (i.e., changing timing of flow releases from storage), ***conveyance efficiency improvements*** (i.e., piping or lining ditches) and ***on-farm efficiency improvements*** (i.e., converting from flood irrigation to sprinkler or drip systems) (Aylward, 2013).

Flow Restoration Planning and Implementation Process

Implementing a water transaction as part of a flow restoration project for a targeted stream reach requires activities that range from organizing the appropriate information, to developing objectives and targets, to setting up monitoring programs, to tracking and reporting results. Flow restoration planning processes are wide ranging and there is no single approach that will fit all stream systems and flow restoration projects. A generalized multi-step approach is briefly described below to provide further guidance. The steps, depicted in Figure 2, are shown in serial order, but elements of each step can occur coincident with other steps and iteration will occur as program (or individual project) refinements are made in light of new information, data, input from stakeholders, etc. The primary purpose of this brief overview is to highlight how the FRAF stewardship approach will be integrated into a flow restoration planning process. The reader is encouraged to review other sources for more information on the flow restoration planning process; an overview is provided below.

- Flow restoration plan development: In the initial step of implementing a flow restoration project, the practitioner specifies the targeted project area, develops background information, identifies participants, gathers hydrologic information, and develops a plan. Recommended components include sub tasks below that should ideally be developed early in the planning process.
    - Establishing ***ecological flow objectives*** (EFO): Early in the process, key biological, hydrologic, water quality, geomorphology and/or connectivity functions of the targeted project area are used to develop the ecological flow objective (or objectives) for riverine system functions that will be measured to determine project success and effectiveness.
    - Determine ***period of ecological significance*** (POES): After establishing ecological flow objectives, the next step is to identify a specific period (or periods) when streamflow is a limiting factor. Determining the period of ecological significance and ecological flow objectives may require multiple iterations to refine each to ensure they are representative, realistic, and compatible.
- Streamflow assessment: This step includes a general streamflow assessment to determine current (pre-project) stream-discharge conditions, irrigation infrastructure locations, diversion amounts and timing, water regulation, and stream reach flow rates, volumes and timing within the targeted stream reach. Once this information is collected and assessed, flow restoration practitioners should develop two key sub-steps as part of the streamflow assessment:
    - Establish ***flow targets***: Flow targets should be based on identified EFO, the POES, and data collected from the assessment of current streamflow conditions. Flow targets are designed to create measurable goals as criteria to quantify and evaluate the effectiveness of a flow restoration project (Beecher, 1990). Overall, flow targets should be realistic and achievable, and when possible, built with consensus among stakeholders. Flow targets should be interim and once achieved and biological response noted, be revisited, and changed.
    - Determine ***flow deficits***: A flow deficit is the amount of flow being utilized/diverted for out of stream water use or lost due to natural processes that results in streamflow

falling below established flow targets. In practice, a flow deficit is the difference between the established flow target and the current streamflow and will vary with time. This deficit is then used to determine the target water transaction volume.

- Flow transactions: The flow practitioner should also perform a ***water rights reliability*** assessment to determine which water rights would provide the most benefit as part of a water transaction project. This includes assessing irrigation point of diversion (PODs) and places of use (POU) associated with the water rights that impact flow in the targeted stream reach. Flow restoration practitioners should develop a list that prioritizes which water rights should be pursued as potential water transaction, and an initial outreach strategy should be developed.
- Design stream monitoring and quantification strategies: The FRAF stewardship approach requires designing a monitoring program to specifically capture hydrologic changes related to the water transaction(s), and their effectiveness in addressing the EFO during the POES. Initial steps might require collection of the necessary hydrologic data and information to adequately track and characterize the targeted stream reach. Thus, restoration project managers must consider available resources and identify cost efficient monitoring priorities. Data collected during this step will be used to identify current conditions (pre-project) as well as conditions after the transaction is implemented (post-project).
- Monitoring, tracking, and reporting: The FRAF stewardship approach focuses on monitoring, tracking, and reporting associated with ongoing management of instream water transactions. The flow restoration practitioner implements monitoring strategies to quantify, and thus track, each project's hydrologic outcomes. The hydrological information is compiled annually in a FRAF workbook template by flow restoration managers, and should be reported to funders, partners and stakeholders as needed.
- Ongoing stewardship: The final step of the FRAF stewardship approach is the responsibilities of ongoing stewardship and adaptive management integration. Within the context of the FRAF, there are two types of stewardship. The first type is current implementation management which requires that the flow practitioners ensure that the water transaction is being conducted as intended (i.e., the volume/rate and timing of the transaction is being met). The second type of stewardship involves adaptive management and requires the flow restoration practitioner to conduct an end of season assessment to determine how the transaction performed in terms of the project objectives and identify what changes, if any, are needed for current instream flow management and future water transactions.

  This component also has a multi-year element, where the flow restoration practitioner assesses how well the project is performing in terms of the EFO. This second approach to stewardship is an ongoing process and must be continued to provide updated and accurate management. If the ecological benefits are not being realized, then an assessment of the potential causes is needed to identify necessary changes to the management of instream flow.

Figure 2. Overview of flow restoration planning process, denoting the key steps associated with the FRAF stewardship approach (highlighted in green).

The multi-step flow restoration planning and implementation process is meant to aid the flow restoration practitioner in developing, implementing, and managing restoration projects to maximize the ecological benefits of a water transaction. The FRAF stewardship approach should be integrated into an existing flow restoration process or it can be incorporated as new projects are being developed. Key considerations to include when utilizing the FRAF stewardship approach are covered in subsequent sections below.

3. Flow Restoration Accounting Framework

The Flow Restoration Accounting Framework stewardship approach is designed to guide the flow restoration practitioner through project planning, implementation, and ongoing instream water right stewardship and management. The FRAF stewardship approach relies on many components found in a typical flow restoration planning process, with several key additions that are necessary for successful implementation of the FRAF. FRAF specific activities of the flow restoration planning and implementation process (Figure 2, green) are presented herein for each stage of the process. A simplified version of Figure 2 is included with each major step in the planning process.

Flow Restoration Plan Development

Typical flow restoration planning activities include establishing goals, developing strategies, outreach and stakeholder participation, system characterization, monitoring, and project implementation. Two activities specific to the FRAF in the flow restoration plan development include establishing an ecological flow objective and determining the period of ecological significance. Each of these activities will be discussed in more detail below.

Establish Ecological Flow Objective (EFO)

A key FRAF stewardship approach sub-task in the flow restoration plan development step is the articulation of a clear environmental flow objective (EFO). Environmental flows have a range of intended outcomes designed to enhance flow regime conditions and riverine components (hydrology, geomorphologic, biology, water quality and connectivity). To achieve instream benefits, establishment of a clear EFO for the project or program is important. Ecological flow objectives for water transactions are developed considering the riverine conditions for the targeted stream reach, as well as the degree to which flow alteration and flow regime deficit has occurred. A project may have one or more EFOs (multiple objectives should be equally important (i.e., co-equal) or they could prioritize the EFOs to encompass and target improved riverine system function. Flow restoration practitioners should develop a specific EFO for their water transaction, including specific metrics to quantify water transaction outcomes. If a project includes multiple objectives, these will be prioritized to focus resources on the most beneficial outcomes, while tracking other, lower priority outcomes. For example, if the principal ecological objective of a project is to increase streamflow and connectivity, a secondary objective could also include water temperature improvements. Example EFOs that will be employed in the FRAF planning process are provided in Table 1.

Table 1. Example ecological flow objectives, riverine conditions, descriptions, and possible metrics.

Ecological Flow Objective	Ecological Function	Description	Metrics
Increase over-summering Habitat	Hydrology	Improve seasonal base flows and low-flow hydrologic conditions typically by 10 percent or more of mean daily flows	Increased stream depth (10 to 20 percent), increased stream habitat area (10 to 20 percent)
	Water Quality	Improve water temperature conditions and dissolved oxygen for ecosystem function or specific life-stage(s) of aquatic species	Reduced daily mean (1ºF) and maximum daily water temperature (>1ºF) during transaction period Dissolved oxygen concentration >5 mg/L
	Biology	In addition to adding fish habitat (identified above), enhance macroinvertebrate production	Compare macroinvertebrate assemblage and abundance relative to unimpaired streams
Improve over-wintering habitat	Hydrology	Improve winter stream conditions for ecological function or specific life-stage(s) of aquatic species	Provide minimum flows to ensure sufficient pool depth, improve thermal refugia and/or passage (riffle depth) between winter habitats
Connectivity	Hydrology	Reconnect a stream tributary by increasing magnitude or duration of flow	Hydrologic function as measured by minimum passage depths and increased access to stream reaches (miles)
	Water Quality (ancillary*)	Provide access to cold water reaches	Presence absence of species utilizing cold water stream reaches upstream of transaction
	Biology	Improve aquatic species passage/migration and timing	Presence absence of species in reconnected stream reaches
Water Quality Enhancement	Hydrology	Change source of diversion water from spring (cold) to stream (warm)	Confirm water delivery and remaining flow in stream consistent with agreement
	Water Quality	Reduce instream temperatures by adding cold spring water	Confirm water temperatures decreased by 2ºF at historic diversion point and reductions of 1ºF persist for 0.25 miles downstream
Subsistence Flows	Hydrology	Diffuse or near immeasurable instream flow enhancement typically contributing less than 10 percent of mean daily flow	Provide minimal flows; generally, less than 10 percent of the mean daily flows

* This effect is termed “ancillary” because the transaction occurs at a different location (e.g., where the connectivity conditions exist) than where the benefit is realized (e.g., potentially miles downstream).

When assessing opportunities for restoration of altered and regulated flow regimes, all riverine components should be considered (Annear *et al*., 2004). In certain cases, the concept of a reconciled condition should be employed, wherein the actions needed to meet the EFOs can be achieved while balancing other water resources uses (Rosenzweig, 2003). A reconciled condition includes key attributes of a stream system that allows ecological function to occur, albeit at a lower level than the “pre-development” state (Hobbs and Norton, 1996). Water transactions on some stream systems will be consistent with reconciled conditions, utilizing a fraction of unimpaired flow to achieve ecological benefits in streams that support other critical, beneficial uses.

An example is provided in Figure 3, where the metric used to determine efficacy of the project is the percent of pre-development condition. Pre-development conditions exhibits a range of natural variability around some average conditions (mean), akin to a “dynamic” equilibrium. This variation is an integral and important characteristic of the natural system (Pulliam, 1988; Sousa, 1984). The subsequent impairment period results in a decline in overall system function, including suppression of the system variability. The impaired conditions lead to factors that do not support desired ecological objectives. The recovery period starts with the initiation of rehabilitation, e.g., flow restoration. Through time, the system reaches a reconciled condition that is some fraction of the pre-development condition, but with the necessary attributes to support the biological objectives (Hobbs and Norton, 1996), while also supporting other water uses.

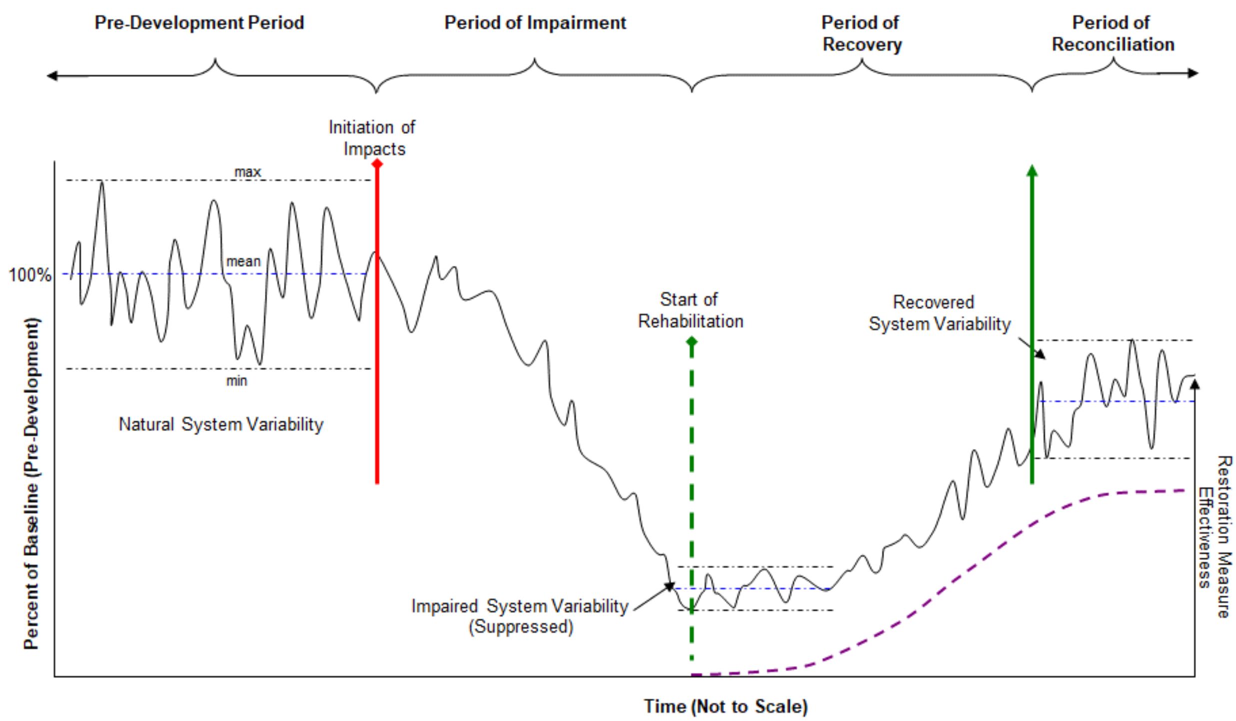


Figure 3. Temporal conceptualization of a system transitioning from a pre-development state, through an impaired condition, and into recovery with implementation of restorative measures (e.g., water transaction). Initiation of impacts depicted by red vertical line and start of rehabilitation with dashed green vertical line. Restorative measures depicted by the dashed purple line. Beginning of the period of reconciliation depicted by a solid green line.

Setting well-defined and unambiguous EFOs will also help in communicating expected and realized outcomes to stakeholders and project funders. This step may be revisited and refined after considering subsequent phases of the FRAF, including determining the POES, assessing streamflows, and establishing flow targets.

DETERMINE PERIOD OF ECOLOGICAL SIGNIFICANCE (POES)

A second key sub-task in the flow restoration plan development step of the FRAF is the determination of the period of ecological significance (POES). The POES is unique for each stream reach and refers to the time frame or duration when streamflow is a limiting factor for the identified EFO. For example, to address the timing and availability of flows to improve a specific fish population, both the fish life-stage flow needs, and general aquatic condition would be determined for the stream system. It is also possible that multiple fish species of interest, with varying flow needs, may be present in the same stream reach at the same time. The POES (and EFO) should take this into account.

Preliminary determination of the POES will come from scientific literature, agency reports, information from local watershed groups, and other sources. This determination should be refined through interviews with resource managers, agency personnel, and stakeholders that are familiar with the specific project area and species of interest. Generally, the POES requires characterizing the streamflow regime through the targeted stream reach or reaches. Dividing a stream reach or watershed into multiple stream reaches is typically necessary for longer or more complex stream systems. Natural features and human-made structures and features are often logical locations to divide stream reaches into sub-reaches. Natural features include confluences with tributaries; abrupt change in channel gradient, form, or substrate; groundwater accretion; and similar features. Human-made structures and features include dams (permanent and seasonal), diversion structures, bridges and other river works that modify the channel form and function, point and diffuse (non-point) return flows and drains, and discharges. Finally, describing and quantifying (if possible) the degree to which the streamflow regime has been altered due to water right administration/stream regulation is necessary. This includes quantifying the streamflow regime in terms of timing, location, and reliability through each stream reach during the targeted period of interest. When considering ecological flow objectives for a targeted fish species, understanding the timing of their presence and habitat-use within the stream is critical to specifying the timing of flow needs.

Assessing the streamflow for its water quantity, water quality, location (e.g., stream reach) and duration (time), and how that relates to a specific ecological flow objective should be considered when determining the POES (McCoy and Holmes, 2015). Willis *et al.* (2013) presents a quantitative restoration approach that considers flow needs in terms of quantity, quality, space (location) and time (duration) for streams on a reach-by-reach basis (termed ***QQST***). This approach is useful because it can be applied to multiple ecological flow objectives (e.g., co-equal goals) and can be used to convey information regarding trade-offs between restoration activities and other water uses (operations) to water transaction participants, stakeholders, policy makers, and others involved in the process.

Quantity, Quality, Space, Time (QQST) Example

An example of QQST to identify the POES using a simplified coho salmon life-stage history distribution (periodicity) and a typical seasonal irrigation diversion schedule is shown in Figure 4. The coho salmon life stage periodicity includes adult migration, spawning and egg incubation, juvenile rearing and outmigration, and summer rearing in space (river mile on y-axis) and time (x-axis). Instream flow needs are assumed to be constraints on these space-time graphics. Coho salmon migration and spawning requires sufficient flows to provide migratory passage from the river mouth to the upper portions of the system. Spawning and egg incubation occur in reaches where there are gravels and other suitable conditions. Juvenile rearing and outmigration, like spawning, requires sufficient conditions for fish to move from upstream reaches to the mouth of the river. Finally, summer rearing, for this example, is assumed to occur in reaches where spring inflows provide necessary flows and cool summer rearing habitats. Overlaying the coho salmon life stage and seasonal irrigation diversion graphics illustrates where in space and time there are potential flow constraints. Examining the overlapping period when both irrigation diversion and coho salmon are present indicates that the POES is different in space and time for two life stages: (a) juvenile rearing and outmigration and (b) summer rearing. Juvenile rearing and outmigration POES occur in April and May and extends throughout the 40-mile reach for April and May. Summer rearing POES extends from June through September but is limited to the upper river where spring inflows provide cool over-summer habitats. QQST not only helps identify the POES, but also illustrates where instream flow needs, and water resources demands are and are not in conflict. Focusing on locations and times where there are competing uses allows for the development of priority actions that would make the most efficient use of available resources to develop water transactions.

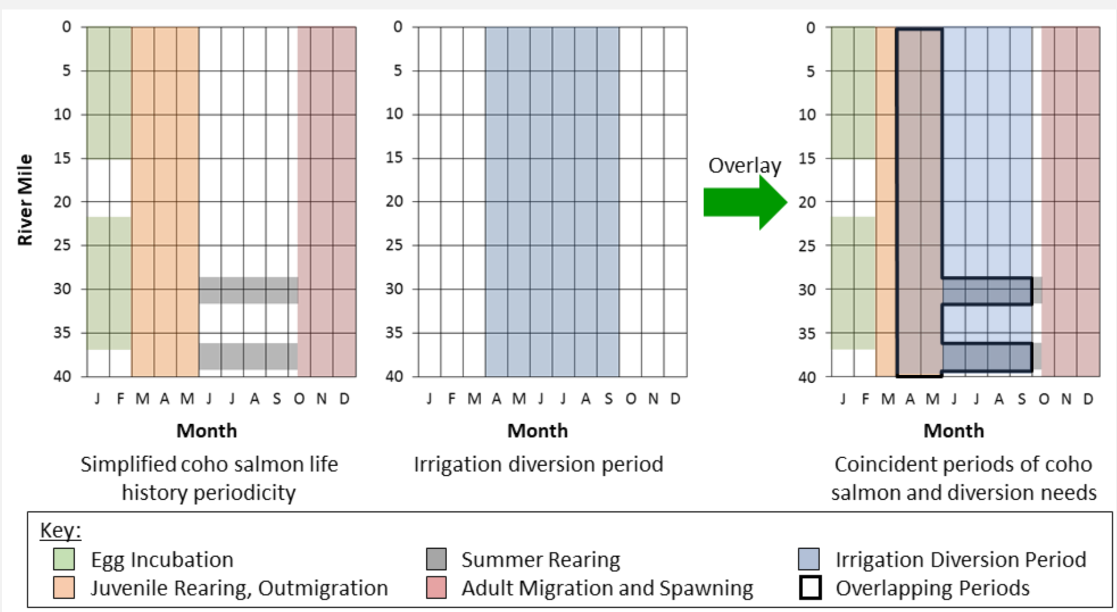
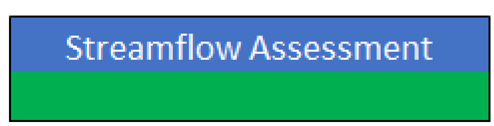


Figure 4. Determining POES using a quantity, quality, space, time (QQST) example based on a simplified coho salmon life-history periodicity (left), irrigation diversion period (center), and the combined space-time graphic showing the overlap of coho salmon and diversion needs (right).

Streamflow Assessment



Streamflow assessment defines current (pre-project) stream-discharge conditions, irrigation infrastructure locations, diversion amounts, water right administration/regulation, and streamflow rates, volumes, and timing, within the targeted stream reach. Two activities specific to the FRAF stewardship approach in streamflow assessment step include establishing flow targets and determining flow deficits. Each of these activities is described below.

Flow Targets

Within the streamflow assessment step, the FRAF stewardship approach calls for the specification of flow targets. Flow targets are designed to create measurable goals as criteria to quantify and evaluate the effectiveness of the water transaction (Beecher, 1990). In some cases, stream reaches may already have specified flow target established by an agency or other watershed stakeholders. If the targeted stream reach does not have an established flow target, then a flow target should be identified. Ideally these targets should be based on the streamflow assessment information, the EFOs, and the POES. Flow targets may encompass multiple EFOs and will vary spatially and temporally. Overall, flow targets should be realistic and achievable and, when possible, attempt to build consensus among stakeholders and restoration practitioners.

Flow targets should be prescribed for specific stream reach(es) as a desired flow rate or discharge (e.g., cubic feet per second, ft^3/sec) for a specific period, established by an accepted method and/or technique. Methodologies to establish flow targets range from simple (e.g., professional judgement) to complex (e.g., holistic water planning methods). Some example methodologies are presented in Yarnell *et al.* (2019), Poff *et al.* (2010), Richter *et al.* (1996, 1997, 1998), Stalnaker *et al*. (1995), Bovee (1982), and Tennant (1976).

Key Flow Definitions

Flow definitions that might assist practitioners include ***base flows***, ***subsistence flows***, ***pulse flows***, and ***overbank flows***. NRC (2005) defines these flows as follows:

- ***Base flow*** is streamflow contributed solely from groundwater inputs in the absence of significant precipitation, run-off events, or supplemental flow releases from storage; base flows provide adequate habitat to support diverse, native aquatic communities and maintain groundwater levels to support riparian vegetation.
- ***Subsistence flows*** are the minimum streamflow needed during critical drought periods to maintain tolerable water quality conditions and to provide minimal aquatic habitat space for the survival of aquatic organisms, riparian vegetation, and ecosystem function.
- ***Pulse flows*** are short-duration, high flows that flush fine sediment deposits and waste products, restore water quality, and provide longitudinal connectivity (e.g., passage) for species movement along the river.
- ***Overbank flows*** are infrequent, high flow events that overtop riverbanks. Such flows can restructure the channel and floodplain, recharge groundwater tables, deliver nutrients to riparian vegetation, and connect the channel with floodplain habitats that provide additional food for aquatic organisms.

Flow targets relating flow regime alteration and ecological response may use surrogates to assess system response (Jowett, 1997). For example, a flow stage can be used as a surrogate for passage, while enumerating fish observed passing a location would be a direct measure. Target flows designed to address EFOs, such as minimum flows, passage flows, and suitable habitat, may occur in different magnitudes at different locations and at different times. As such, no single flow target will likely address environmental flow needed throughout the entire season or year (Linnansaari *et al.*, 2013). However, for the purposes of the FRAF stewardship approach, flow targets during the POES should be established to enable the flow practitioner to identify potentially beneficial water transaction opportunities and to quantify the effectiveness of the transactions once implemented. Flow targets will be used by conservation organization as one of the primary metrics to guide their flow strategies, project implementation, and stewardship. Specification of flow targets also allows for benchmark testing of water transactions over multiple years to assess the effectiveness of meeting multi-year project objectives (e.g., adult fish population improvements or year around connectivity).

Flow Deficits

A second key sub-task within the streamflow assessment step is the determination of the ***flow deficit***, a principal driver of water transactions, in the targeted stream reach. A flow deficit is the amount of flow that is being utilized, diverted for out of stream water use, or lost due to natural processes that results in the streamflow falling below some identified ecological threshold for some period of time. The threshold is based on the EFO during the POES.

A flow deficit, as defined herein, is different than flow depletion. ***Flow depletion*** is the net reduction of flow associated with developed uses through a stream reach (e.g., diversion) and may or may not result in a flow deficit. An example of a flow deficit and depletion are shown in Figure 5, where the upper line represents flow if there were no diversions or losses (i.e., natural flow) and the measured flow is the observed instream flow downstream of diversion in the targeted stream reach. In the example, the depletion and deficit are not the same because the targeted flow volume is less than the total flow in the creek without diversions.

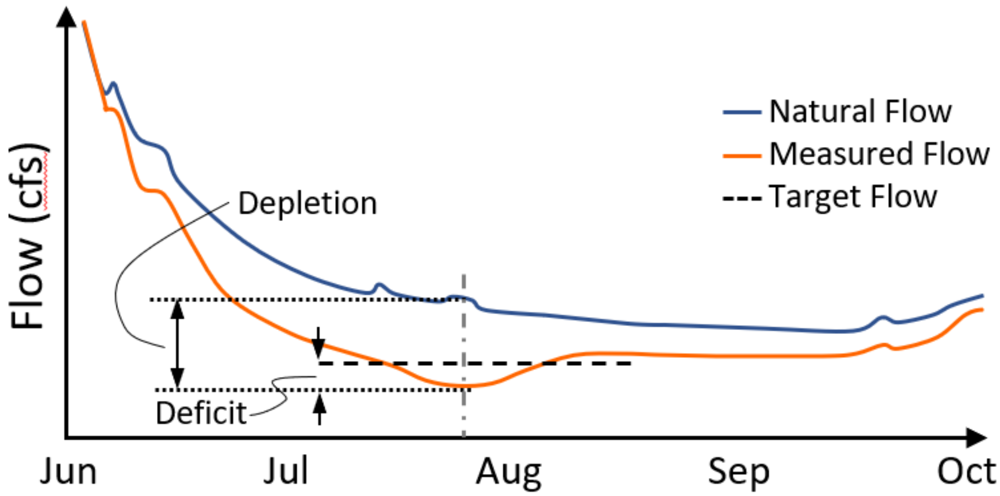


Figure 5. Example of stream reach flow deficit and depletion resulting from seasonal stream diversions.

Using hydrologic data to determine both flow deficit and depletion provides insight into the extent of hydrologic alteration to a stream reach. Identifying the magnitude, duration, and timing of a flow deficit is necessary to quantify the water transaction needed to restore and maintain instream conditions to meet the stated EFO during the POES.

Hydrologic alteration and flow regime deficits occur on both regulated and unregulated streams. Flow-limited or dewatered conditions are commonly due to anthropogenic impacts that include diversion and/or river regulation (e.g., reservoir operation), but natural conditions, such as severe drought, will also lead to flow regime deficits. The frequency of flow deficit can be a chronic or perennial issue on an over-appropriated stream system. On other streams, dewatering may occur intermittently, exacerbated by hydroclimatic variability (i.e., drought) and seasonal stream water use demands. Recent studies have also identified that climate change is extending the duration, modifying the timing, and increasing the frequency of low flow periods around the western U.S.

General guidance on determining flow deficits can be derived from methods such as the Tennant Method (Tennant, 1976), Range of Variability Approach (Richter *et al*., 1996), R2Cross (Espegren, 1996), and Wetted-Perimeter (Nelson, 1984). Flow deficits are generally site-specific and should be established for specific project locations, magnitude, duration, and timing in targeted stream reaches. This condition defines the baseline or existing stream status and represents the pre-project or reference condition[5]. Ultimately, the reference condition will be used to evaluate the water transaction efficacy by comparing pre-transaction conditions to conditions once the transaction has been implemented.

Flow Transactions

Flow Transactions

The target or ideal flow transaction volume, coupled with the water rights reliability assessment, are used to develop and implement water transactions. A ***water rights reliability*** assessment is used to determine which water rights would provide the most benefit as part of a water transaction project. Recall, water transactions are implemented using a variety of means, including private water right leasing or acquisition, water management agreements, or irrigation infrastructure agreements. There are no FRAF-specific elements in this stage.

Design Stream Monitoring and Quantification Strategies

Design Stream Monitoring and Quantification Strategies

The first major step of the FRAF stewardship approach is to design the stream monitoring and quantification strategies to capture the data necessary to assess the efficacy of the project. The approach should be developed based on known or planned water transactions or other flow restoration actions, while maintaining enough flexibility to incorporate potential future projects[6], if necessary. The FRAF stewardship approach is principally focused on flow changes in the targeted stream reach, so a key parameter to monitor is streamflow. The monitoring approach should also incorporate other parameters based on the EFO, such as habitat, fish populations, and water quality. The second major step of the FRAF stewardship approach is to select the quantification strategies that will be used to evaluate the efficacy of the project and to inform ongoing stewardship, tracking and reporting duties. These two steps are developed concurrently and will be adjusted over time (e.g., additional elements will be added to the monitoring approach or new strategies may be added).

Both elements should be developed so that they will be applied to stream reaches with existing water transactions or built into planned flow restoration actions prior to implementation. The FRAF stewardship approach provides a suite of hydrologic metrics to assist flow restoration practitioners with understanding the short-term (e.g., changes in streamflow at the time of implementation) and longer-term (e.g., hydrologic effectiveness in terms of the EFO) impacts of the project. The primary focus of this step is to design a stream monitoring approach that will capture and quantify the implemented flow restoration action, as well as capture changes to stream reach conditions that may be used to assess the effectiveness of these actions.

The FRAF stewardship approach is different from most other stream monitoring programs by focusing almost exclusively on hydrological data specifically designed to track project implementation and effectiveness of enhanced stream-discharge to achieve ecological outcomes.

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[5] Reference condition is the "pre-treatment" or "pre-project" hydrologic condition used as a benchmark to evaluate future restoration actions.

[6] The term "project" is used to refer to water transactions and other flow restoration actions (e.g., point of diversion changes, source switches, point of diversion consolidation).

Water transactions are typically conducted and monitored at either a reach-scale or watershed-scale, depending on the scope of the project, participants, the EFO, and POES.[7] Stream-discharge or flow monitoring of water transactions allows for tracking of project implementation and effectiveness through quantification of key stream features.

The first step in developing a stream monitoring approach and selecting quantification strategies is to determine the level of monitoring that is needed. To facilitate this, the FRAF stewardship approach includes specific monitoring recommendations for each of the four tier categories. Using the recommended metrics (detailed below), the flow practitioner will assign a water transaction project to one of the tiers and then develop a monitoring plan based on the needs of that tier.

FRAF Tier Categories and Project Placement

To assist the flow restoration practitioner in determining the appropriate level of monitoring, the FRAF stewardship approach has four overarching questions:

1. Does the project meet the stated contractual obligations?
2. Does the project provide instream flows at the magnitude, location, duration, and timing as designed?
3. Does the project enhance aquatic habitat as designed?
4. Does the project enhance the ecological objectives as designed?

These questions should be carefully considered by flow restoration practitioner, and detailed responses to each should be documented as the monitoring program is developed and revised throughout the project period. Such questions will also serve as a basis for post-project audit, to verify if initially defined project goals were met, identify lessons learned, better understand decision making to inform adaptive management actions, and chart subsequent steps for restoration actions. The FRAF stewardship approach helps to answer those questions after the project is implemented as part of a long-term stewardship approach to flow enhancement.

The answers to the four questions also help the flow restoration practitioner determine in which of the FRAF tier categories the project should be initially placed. The four tier categories have different monitoring and quantification strategies requirements. The tier categories are:

- *Tier 1: Contractual Compliance*: Tier 1 projects are tracked to ensure that the legal terms of the contract between the project sponsors and water user are fulfilled and accurately represented. All projects are included within Tier 1. Each type of project (e.g., lease, purchase, water management agreement, irrigation infrastructure agreements, etc.) has specified monitoring criteria.
- *Tier 2: Flow Accounting (Hydrology)*: Tier 2 projects are tracked to account for flow added to the targeted stream reach from the POD downstream throughout the target reach

[7] While most water transactions occur at a local level (e.g., reach- or watershed-scale), there have been instances of larger environmental flow programs which have targeted and concentrated numerous water transactions under a single program. In these cases, the flow and biological monitoring of the water transactions' effects have occurred at sub-basin or basin-scale (e.g., Columbia Basin Water Transactions Program).

before and after the project is implemented. In addition to verifying project implementation, monitoring will be used to assess project objectives and track progress towards flow goals and/or targets.

- *Tier 3: Aquatic Habitat Response*: Tier 3 projects track changes in flow-related limiting factors by accounting for aquatic habitat metrics along a specified section of the target reach during the POES. An effectiveness monitoring and accounting strategy is required for all projects placed within this tier.
- *Tier 4: Ecological Function*: Tier 4 projects integrate transactions and flow-specific monitoring data gathered in Tiers 1, 2, and 3 to assess status and trends as they relate to aquatic ecosystem function or biological conditions (e.g., fish population dynamics) for specific aquatic species of interest. Tier 4 projects will also include more targeted and intensive local and basin-scale monitoring efforts to address ecological flow objectives or species population responses, where applicable.

The FRAF questions, four tiers, and associated monitoring and project tracking information are summarized in Figure 6.

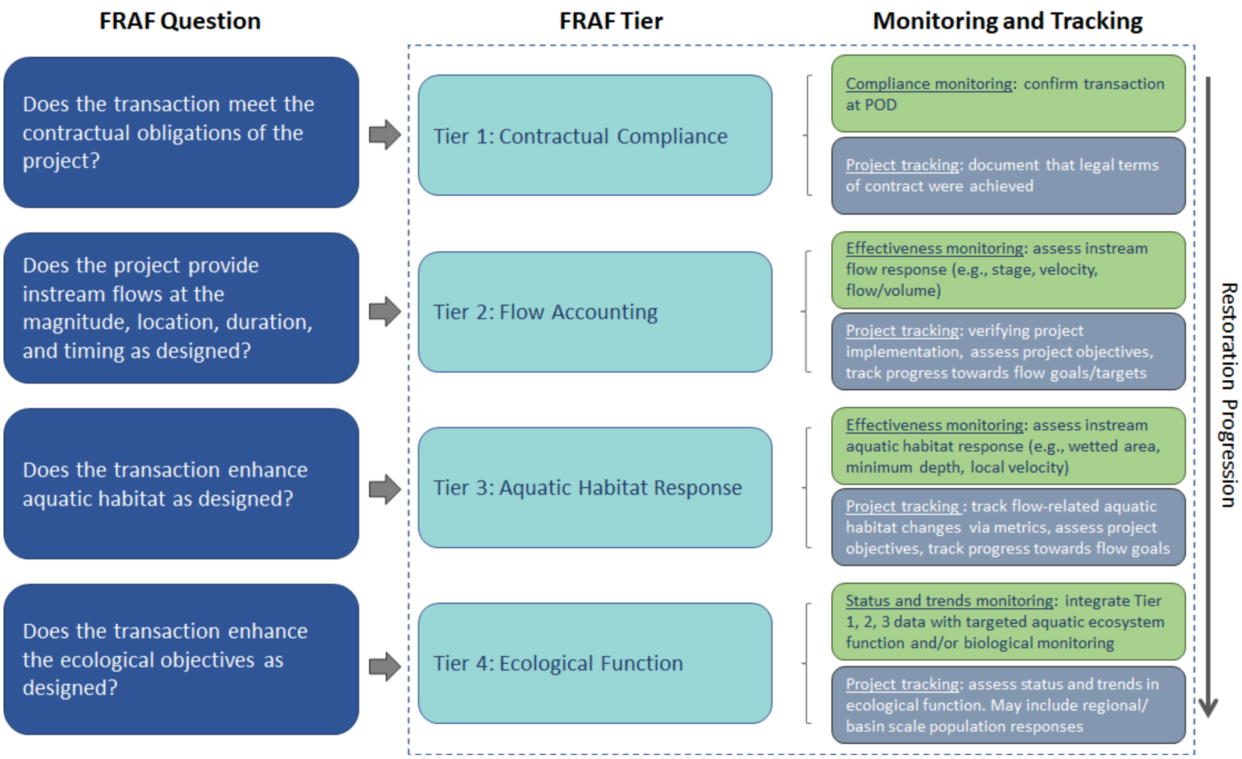

Figure 6. FRAF overarching questions and four tier FRAF structure with general monitoring and project (transaction) tracking elements.

Not all projects progress from Tier 1 to Tier 4 at the same rate, some projects do not reach the higher tiers, and some projects are not designed to progress through all four tiers. The general trend is that the number of projects within each tier diminishes with subsequent tiers. As a project progresses from lower to higher tier levels, quantification of causal linkages between the project and outcomes shifts from largely direct to more indirect measures (Figure 7). For example, in Tiers 1 and 2, measures of response are directly related to contractual compliance and directly measurable hydrologic parameters (e.g., streamflow or stage). In Tiers 3 and 4 hydrologic parameters are used to track project performance and are used as surrogates to indirectly assess aquatic habitat and ecological function response. Additionally, flow restoration practitioners are encouraged to monitor additional types of data (i.e., non-hydrologic data) for Tier 3 and 4 level projects. These data will support assessment of predetermined habitat and/or biological parameters (e.g., fish distribution, connectivity) to further support whether hydrologic changes related to flow restoration activities are functioning as expected. This is particularly critical for Tier 4 projects, where tracking should occur over years or decades and other conditions may affect system response (e.g., climate change). Regardless of the tier, ongoing stewardship is critical to ensure projects are maintained and monitoring and tracking continue as intended.

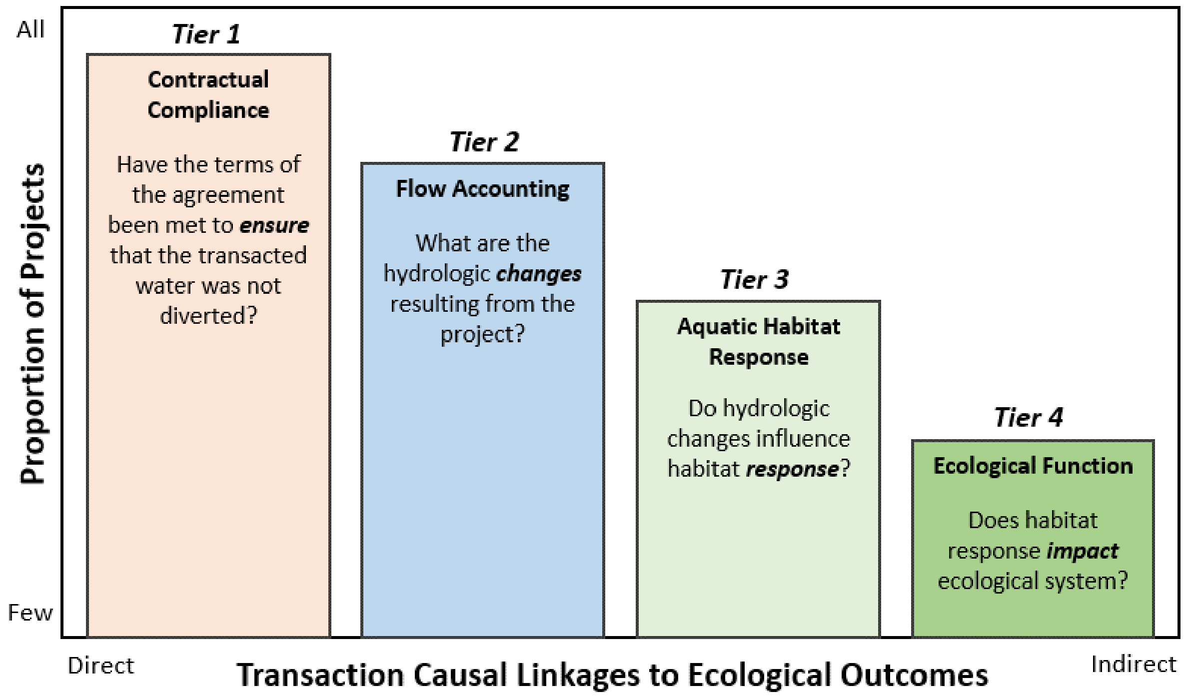

Figure 7. FRAF stewardship approach four-tiered monitoring framework.

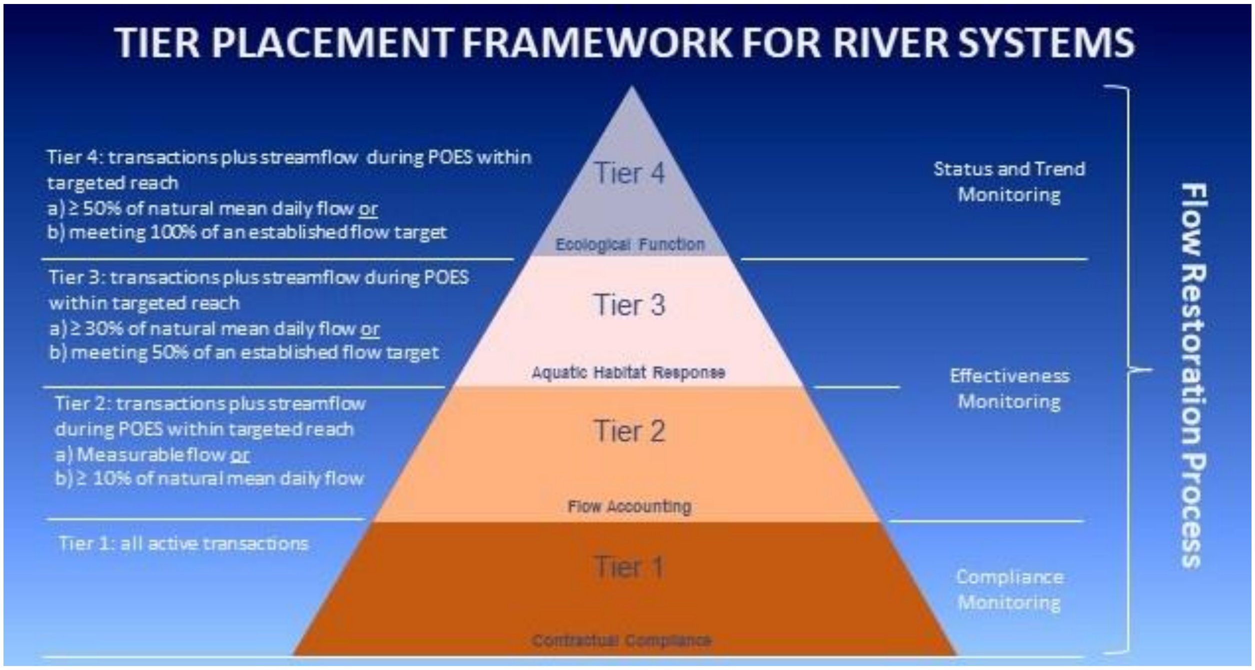

Figure 8. The FRAF tier framework classification system, structure, and monitoring approach.

When developing projects, flow restoration practitioners may consider a range of factors as they pertain to the FRAF tiers. Potentially important factors include level of investment, anticipated project flow magnitude or discharge response, scale of focus, tier selection criteria, monitoring requirements, and the dynamic nature of aquatic systems. These same factors are applied when a programmatic approach is employed. Six factors are outlined below, and others may be identified by the practitioner as important to their specific transaction.

1. *Tier Selection Criteria* – Water transactions and other flow restoration actions on the stream reaches are sorted into tiers according to well-defined selection criteria (Figure 8). All projects are included in Tier 1, with progressively fewer projects falling into the subsequent tiers due to more stringent qualifying requirements. Specifically, a stream reach flow regime is based on the transacted water plus streamflow during POES that is based on the following thresholds:
    - *Tier 1*
        - No criteria: all water transactions are included in Tier 1
    - *Tier 2*
        - measurable <u>or</u>
        - ≥ 10% of natural mean daily flow
    - *Tier 3*
        - ≥ 30% of natural mean daily flow <u>or</u>
        - meeting 50% of an established flow target
    - *Tier 4*
        - ≥ 50% of natural mean daily flow <u>or</u>
        - meeting 100% of an established flow target

These hydrologic thresholds are the primary driver used in determining a project monitoring tier placement and flow metrics.

Percentages of mean natural daily flow were derived from Tennant (1976). The Tennant method assumes that a proportion of the mean average daily flow (in cfs) would maintain suitable depths and water velocities for fish in various conditions. Determination of natural flow should be based on gages located upstream of flow diversions, unimpaired estimates[8], special studies, or other techniques. For example, the California Environmental Flows Framework[9] provides unimpaired reference hydrographs that represent seasonal stream conditions without impairments from anthropogenic land use or upstream diversions or storage for nine stream classes (e.g., representing snowmelt, rainfall, flashy ephemeral rainfall hydrographs) in the state. The TNC Conservation Gateway[10] also provides several options and associated guidance for estimating streamflow.

For Tier 2, the established flow target is replaced with a low flow criterion (i.e., greater than 1 cfs or, at a minimum, a measurable flow). This threshold is useful for:

- streams that exhibit severe depletion or dewatering,
- stream reaches where flows are naturally low and small additions will provide benefits to instream conditions, or
- encouraging small water transactions for parties that, in aggregate, will have instream benefits.

2. *Level of Investment: Monitoring* – Tier 1 projects require the least amount of monitoring effort, followed by Tier 2. Tier 3 and Tier 4 projects generally require the highest level of expertise, time, coordination, and resource investment. When developing a FRAF supported project, flow restoration practitioners should focus on Tier 1 and Tier 2 monitoring requirements. When extending monitoring efforts for Tier 3 and Tier 4 projects, flow restoration practitioners should leverage or partner with agencies and appropriate organizations to increase available expertise, financial resources, and institutional capacity. Tier 4 level monitoring typically relies on funding from federal and state agencies, with other stakeholders, such as tribes, non-governmental organizations, and universities, assisting in aspects of data collection and implementation. These efforts generally require many years and/or decades to determine ecological impact (Roni *et al*., 2018).

3. *Project Magnitude or Discharge Response* – The FRAF utilizes prescribed flow targets to assess the anticipated magnitude or discharge response for Tier 2 through Tier 4 projects (Tier 1 is strictly contractual compliance). All projects beyond Tier 1 (i.e., Tiers 2, 3, and 4) will require instream hydrologic monitoring and reporting. If multiple projects (i.e.,

[8] Federal and state agencies often provide unimpaired flow estimates as part of water resources management activities, studies, and water supply analyses.
[9] California Environmental Flows Framework: https://ceff.sf.ucdavis.edu/
[10] The Nature Conservancy Conservation Gateway: https://www.conservationgateway.org/

multiple participants) are implemented upon the same stream reach, all projects would progress through the tiers jointly as flow volumes are accumulated instream during the POES. Finally, annual assessments of project tier placements are necessary. At the end of each monitoring season (or when the projects are completed), the flow data should be analyzed to assess whether the project was correctly categorized and to determine if re-categorization into a different tier level (either higher or lower) is warranted before the project is implemented in the subsequent year. These annual reviews also occur when new projects are added to the existing projects along a targted stream reach to determine if the additional flow volumes results in a tier change.

4. *Scale of Focus* – Tiers 1, 2, and 3 are focused on individual projects at reach and/or local sub-watershed scale or on multiple projects on a single reach. Tier 4 focuses on ecosystem function at multiple scales concurrently (e.g., reach, local sub-watershed scale, watershed, basin, or some combination thereof) including biological and/or a targeted species population response.

5. *Monitoring Requirements: Responsibility* – The flow restoration practitioner or organization should be responsible for all areas of Tiers 1 and 2 monitoring and reporting. This work may be done entirely within their organizational capacity or by working strategically with other partners that have on the ground expertise and capacity to provide support if resources are limited. For Tiers 3 and 4, flow restoration practitioners should aim to partner with appropriate entities or larger agencies (e.g., state or federal agencies) to lead and manage monitoring actions.

6. *Dynamic Nature of Aquatic Systems* – Monitoring indicators should be selected so that data is collected at a frequency that will adequately capture change in aquatic system responses to flow alteration. For example, Tier 2 projects gather multiple data points over the course of each season to reflect short-term changes in flow. Data gathered for Tier 3 projects will contribute to an understanding of longer-term physical habitat changes, and typically require a minimum of five-years of data collection. Tier 4 projects generally require ten to twenty years of monitoring (Roni *et al.*, 2018).

After the flow restoration practitioner has determined the tier placement for the project, a monitoring approach and quantification strategies will be developed based on the monitoring requirements of the selected tier.

TIER 1: PROJECT COMPLIANCE MONITORING

Regardless of the tier placement, all projects are subject the monitoring requirements of Tier 1, which ensures that the legal terms of the contract between project sponsors and water-user are fulfilled and accurately represented. Thus, all projects are included within Tier 1 or, at a minimum, have a Tier 1 component even if they are categorized as Tier 2, 3, or 4. Each project is defined by type (e.g., lease, purchase, split-season, minimum-flow agreements) and has specified monitoring and reporting criteria that are consistent with that project type.

Because Tier 1 monitoring is focused on contractual compliance of the project, Tier 1 projects are typically verified annually by monitoring the water right point of diversion (POD) and/or place of use (POU) to ensure water right holder diverted less water per the historical right and use consistent with the project type. Instream flow monitoring is not typically necessary to ensure contractual compliance in Tier 1 projects, and may only account for a small percentage of flow instream (i.e., changes to instream flow due to Tier 1 project may be immeasurable).[11] Thus recommendations for Tier 1 compliance monitoring would be field inspections at the POU or POD and photo-point monitoring or the utilization of aerial imagery or other remotely sensed information to ensure the water rights were not diverted at their associated POD or applied to their historical POU.

The FRAF stewardship approach requires annual tracking of project compliance and encourages the use of the most efficient and effective techniques based on an organization's available resources. Photo-point monitoring is an inexpensive technique that should be implemented to document the water transaction. On the ground photos and annual site visits are the preferred form of photo-point monitoring, but remotely sensed imagery, whether digital aerial photos, satellite imagery, or drone imagery (Figure 9), are all suitable forms of photo-point monitoring to track annual compliance for Tier 1 projects, especially at remote (i.e., hard to access) project sites.[12]

Figure 9. Digital aerial photo illustrating fallowed field associated an instream water transaction. The dry field is used as visual confirmation that the irrigator did not divert their water right (or fraction thereof) and was in contractual compliance with the terms of the Tier 1 water transaction.

A principle photo-point monitoring recommendation is that flow restoration practitioners obtain site visit and field monitoring photos using a smart phone equipped with an inexpensive photo application that allows for the inclusion of field notes with the image. Recommended field notes include project name, stream name, description, geographic coordinates (latitude and longitude), bearing, elevation, date/time, and any other relevant information desirable by the flow restoration practitioner. Photos may then be emailed along with the metadata, and input into mapping software (e.g., Google Earth or ESRI's ArcGIS software). Collected photos may be archived into one dataset which is ultimately composed of multiple photos spanning the life of the project.

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[11] Instream flow gaging is required to verify the implementation of a water transaction or stream response for Tier 2, 3, and 4 projects, where water transactions volumes are measurable with flow meters and gages and contribute notably to the percent of flow (POF) of the stream reach.
[12] If site visits are infeasible, water transaction participants should assess what remotely sensed imagery is available given the organization's GIS capabilities.

This archive may be readily shared during project reporting. If the photo capture software does not include the ability to add metadata, then detailed documentation is needed to ensure that relevant project and site condition information is retained with each photo.

TIER 2: FLOW ACCOUNTING MONITORING

Flow monitoring for Tier 2 projects is designed to achieve two primary objectives: 1) tracking or verification of project implementation; and 2) quantifying and documenting flow change at the reach-scale. Monitoring and tracking information are used, along with the associated water rights or water management action to evaluate the transaction and to assess the efficacy of a project mechanism(s) used to create the enhanced stream condition.

Tier 2 projects have:

- The transacted water flow rate is measurable (quantifiable) instream, or
- The cumulative transacted flows are equal to or greater than 10 percent of natural mean daily flows within the targeted reach during the POES.

Tier 2 monitoring requires compliance verification, same as Tier 1, but adds flow monitoring from the POD through the target reach before and during the project term, and POES, whenever possible. In addition to verifying project implementation, monitoring of Tier 2 projects will be used to assess project objectives that address the key limiting factors of flow for identified and targeted species, through analysis of quantifiable hydrologic metrics.

To meet FRAF Tier 2 monitoring requirements, stream-discharge should be monitored at the project POD whenever possible; however, in some situations, flow monitoring may occur in downstream reaches, if no active diversions or loss occur between the POD and the monitoring site. Existing United States Geological Survey (USGS) stream gages or similar long-term gaging sites should be used when available (assuming these devices detect the project flow response accurately). Using an existing gaging station with a long-term gaging record, provides additional value for evaluating project effectiveness. If conditions do not allow a measurement location at the POD (e.g., access issues, safety concerns, multiple PODs within a reach participating in instream flow projects, potential stage shifts, or surface flow is immeasurable with a flow-meter or extreme low flow condition exist), flows should be measured at a downstream location within the targeted stream reach to quantify the flow magnitude changes and spatial distribution and duration of added flows throughout entire POES. Ultimately, there are two conditions and considerations for hydrologic data collected under Tier 2:

- The transacted water flow rate is measurable instream during POES; or,
- If instream flow response is expected to be non-point (e.g., diffuse along the targeted stream-reach) but measurable, quantification of the project impacts along the targeted stream-reach may be measured as:
    - Changes in instream flow at multiple locations along the targeted stream-reach,
    - Change in stream geometric metrics (e.g., pool stage, wetted area, and/or volume),

- Changes to identified critical low-flow stream-reach location (e.g., stream mouth or location of surface flow disconnections, critical riffle depth), or

- Changes to groundwater levels using well monitoring along the targeted reach(es) to measure adjacent groundwater levels as they relate to stream surface connectivity.

All hydrologic measurements and quantification, whether using wadeable spot stream-discharge measurements or a continuous stage logger instrument, should follow all applicable USGS water measurement protocols as described in Rantz *et al.* (1982b) and Olsen and Norris (2007), whenever possible. Modification of these protocols should be noted and archived for tracking and evaluation purposes. All data should be collected and reported for depth/stage and distance, velocity, discharge/flow rate, and volume as listed in Table 2.

Table 2. Measurements, units, and resolution for FRAF Tier 2 monitoring.

Measurement	Unit	Resolution
Depth/Stage	Feet (ft)	0.1 or 0.01
Distance (width or longitudinal)	Feet (ft)	0.1
Velocity	Feet per second (fps)	0.1 or 0.01
Discharge/flow rate	Cubic feet per second (cfs)	0.1
Discharge/flow rate	Gallons per minute (gpm)[1]	0.1
Volume	Acre-feet (af)	0.1

[1] Discharge/flow rate measured in gpm for subsistence flows (low flows, e.g., << 1.0 cfs)

Projects may be tracked by various hydrologic metrics based on percent of flow, flow targets, and connectivity. Richter *et al.* (1996) recommend over 30 Indicators of Hydrologic Alteration (IHA), many utilized within the FRAF; however, only a subset of these is generally suitable for assessing specific ecological flow objectives.

Whichever EFO (see Table 1) is the primary basis of the project, monitoring design and metric selection should be determined and established in advance of implementing a flow restoration project. Secondary flow objectives, such as water temperature or other water quality parameters[13], should also be monitored and tracked when possible for Tier 2 projects. Considering both the primary and secondary EFOs are important when designing a monitoring program because more than one ecological response is likely to occur as a result of projects in a flow limited streams undergoing substantial flow restoration (Poff *et al*., 1997).

The types of flow metrics that may be developed and applied to a project are dependent on factors already discussed; several key factors are:

[13] To attain water quality conditions at the top of the reach, sampling can occur immediately upstream of the POD. Selection of the subsequent monitoring locations should take distance downstream into consideration because water quality conditions can change in response to conditions external to the water transaction (e.g., meteorology).

- Ecological flow objective: identification of the primary and secondary objectives associated with the proposed water transaction.
- Frequency of data collection: determination whether to collect continuous time-series data with an automated system or collect manual spot flow measurements. The latter option precludes development of most flow assessment metrics because of the relatively sparse data set associated with spot measurements.
- Flow monitoring location: selection of the appropriate location(s) to monitor flow. This should be at the POD for all measurable surface flows or within the targeted stream-reach when diffuse gains are expected from the project (e.g., drought condition responses, groundwater well leasing, subsistence flow conditions).
- Period of record: determination of the period when flow monitoring should occur. This period should always encompass the period of use of the water rights and transaction, but at a minimum should cover the POES. Having year-round gaging may be ideal for certain project objectives, however, monitoring expenses, resources, and snow/ice or flooding conditions may make this infeasible or even unnecessary.

Hydrologic monitoring of Tier 2 (and Tiers 3 and 4) water transaction streams should have a continuous ***streamflow time-series*** to fully evaluate the transaction and assess both intra and inter-annual conditions. Practitioners are encouraged to use existing stream gages, such as USGS gages, whenever possible. As mentioned previously, data from established gages may allow for more in-depth hydrologic analysis and metric development, if a sufficiently long period of record exists. Recommended hydrologic metrics that may be applied to analyze and evaluate water transactions and flow regime impacts for various ecological flow objectives are shown in Table 3 (Richter *et al*., 2012). Additional flow related metrics and guidance are presented by CEFF[14], PNAMP[15], TNC Conservation Gateway[16], as well as other sources.

[14] California Environmental Flow Framework: https://ceff.sf.ucdavis.edu/
[15] Pacific Northwest Aquatic Monitoring Partnership: https://www.pnamp.org/
[16] The Nature Conservancy Conservation Gateway: https://www.conservationgateway.org/

Table 3. Tier 2 ecological flow objectives with associated flow (hydrology) and other metrics.

Ecological Flow Objective	Flow Regime Characteristic	Variable	Metric
Over-summering and Connectivity	Magnitude, duration	Monthly mean (discharge)	Monthly mean daily average (April-October)
	Magnitude, duration	Monthly median of daily averages (discharge)	Monthly Median of Daily Mean Discharge (April-October)
	Magnitude, duration	30-day minimum (discharge)	Minimum 30-day moving average over annual record
	Magnitude, duration	7-day minimum (discharge)	Minimum 7-day moving average over annual record
Connectivity	Magnitude, duration, timing	Surface water flow	Number of days zero flow per month or season; flows < specified flow rate
Water quality enhancement and Connectivity[1]	Not applicable		
Subsistence Flows and Connectivity	duration, timing	Days of disconnection / zero flow	Number of days/year of zero flow
	Magnitude, duration, timing	Residual pool volume, depth or area	Monthly average volume, depth or area; lowest pool volume of summer, season or project-term
	Magnitude, duration	Biological changes[2]	Riparian vegetation distribution and composition; fish passage/migration
Over-wintering	Magnitude, duration	Water Temperature	Number of days mean values above specified threshold
	Magnitude, duration	Monthly mean (discharge)	November-March
Channel maintenance	Magnitude, duration	Maximum 7-day mean flow (discharge)	Maximum 7-day moving average flow
	Magnitude	1-day maximum	Annual 1-day maximum of project-term

[1]Water quality is generally a Tier 3 or higher metric, but low flow conditions can adversely impact water temperature and/or dissolved oxygen and may need to be considered as part of Tier 2 project monitoring.

[2]Biological change is generally a Tier 3 or higher Tier metric but may be considered as part of Tier 2 for certain type of project monitoring.

Tier 3: Aquatic Habitat Response Monitoring

Tier 3 project monitoring is focused on aquatic habitat response and focuses on *changes* in flow-related limiting factors using aquatic habitat metrics along a specified section of the target reach during the POES. Recall, the POES is defined by the objective of the project in terms of addressing key limiting factors that are unique to the location and purpose of the project. An effectiveness monitoring and accounting strategy is required for each project placed within this tier.

Tier 3 projects have:

- The cumulative transacted flows are equal to or greater than 30 percent of natural mean daily flows within the targeted reach during the POES, or

- If transacted flows provide 50 percent or more of an established flow target within the targeted stream reach during the POES. This threshold may be less than 50 percent of mean daily flow dependent upon flow target methodology selection.

Tier 3 monitoring builds upon the flow monitoring elements from Tier 2 (and Tier 1), but also includes additional potential monitoring activities focused on aquatic habitat. In terms of instream flows, Tier 3 projects benefit a targeted reach by measurably increasing the flow in the stream during the POES. Flow restoration practitioners should aim to utilize continuous stream gaging instruments and techniques to monitor changes to instream flow due to the project if these methods were not employed in Tier 2. Additionally, expanding the continuous flow gaging sites and network may be needed to adequately capture hydrologic stream reach changes. As with Tier 2, continuous stream gaging approaches are used to track daily flows and provides an ability to assess conditions on an intra- and inter-annual time frame. Flow information will also be used to develop and/or support additional aquatic habitat metrics.

In addition to the metrics used for Tier 2 projects, potential indicators (metrics) of aquatic habitat changes for Tier 3 projects include, but are not limited to, water temperature, dissolved oxygen, critical riffle analysis, pool volume/wetted area, weighted usable area, velocity profiles, or reconnected tributaries (Table 4). These indicators and metrics may be used to compare the pre-transaction conditions to conditions following project implementation in the targeted stream-reach on an intra- and inter-annual basis.

Table 4. Tier 3 ecological flow objectives with associated flow (hydrology) and other metrics.

Ecological Flow Objective	Flow Regime Characteristic	Variable	Metric
Over-summering and Connectivity	See Tier 2 (Table 3)		
Connectivity	Magnitude, duration, timing	Full Tributary Reconnect	Surface flows connect longitudinally to next order stream with greater than or equal to 50 percent mean daily reach flow
	Magnitude, duration, timing	Partial Tributary Reconnect	Surface flows connect longitudinally to next order stream with less than 50 percent mean daily reach flow
	Magnitude, duration, timing	Critical riffle	Number of days critical riffle flow threshold for fish passage not met seasonally
	Magnitude, duration, timing	Surface water flow	Number of days zero flow per month or season; flows < specified flow rate
	Magnitude, duration, timing	Residual pool volume, area or depth	Monthly average volume, lowest pool volume of summer, season or project-term
	Duration, timing, frequency	Water temperature and dissolved oxygen	Number of days mean values below or above specified thresholds
	Timing, Distribution	Fish surveys	Number of fish observed passing by a fixed location; distribution, and life-stage presence
Water quality enhancement and Connectivity*	Duration, timing, frequency	Water temperature and dissolved oxygen	Number of days mean values below or above specified thresholds
Subsistence Flows and Connectivity	See Tier 2 (Table 3)		
Over-wintering	Magnitude, duration	Water Temperature	Number of days mean values above specified threshold
Channel maintenance	See Tier 2 (Table 3)		

Connectivity is an important metric is reconnecting tributaries that have disconnected from a downstream river (Figure 10 and Figure 11). For low flow periods, tributary reconnection occurs when surface flows are longitudinally re-connected for the entire length of the stream from the targeted stream reach to the confluence with the next order stream during the POES. The difference between a full and partial reconnect is whether there is sufficient flow depth throughout the tributary to support targeted physiochemical and biological processes:

1) Full Tributary Reconnect: Full reconnection occurs when surface flows are longitudinally re-connected at a sufficient depth for the entire length of the stream from the targeted stream reach to the confluence with the next order stream during the POES.

2) Partial Tributary Reconnect: Partial reconnection occurs when surface flows are longitudinally re-connected for the entire length of stream from the targeted stream reach

to the confluence with the next order stream during the POES, but not at sufficient depths to support all targeted ecological function (e.g., adult fish passage).

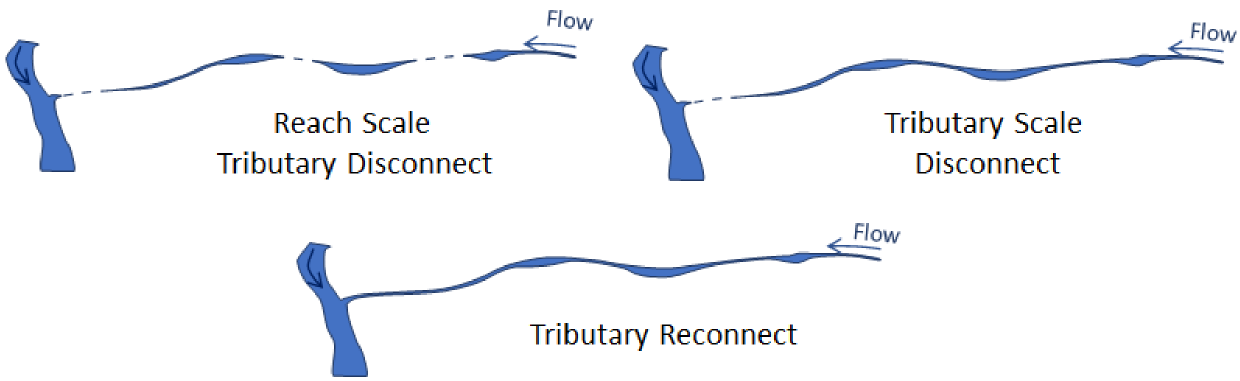


Figure 10. Example conditions of stream connectivity: (top, left) reach scale tributary disconnect (multiple disconnection locations, denoted by dash marks), (top, right) tributary disconnect (single disconnection location), and (bottom, middle) longitudinal tributary reconnect (no disconnection locations).

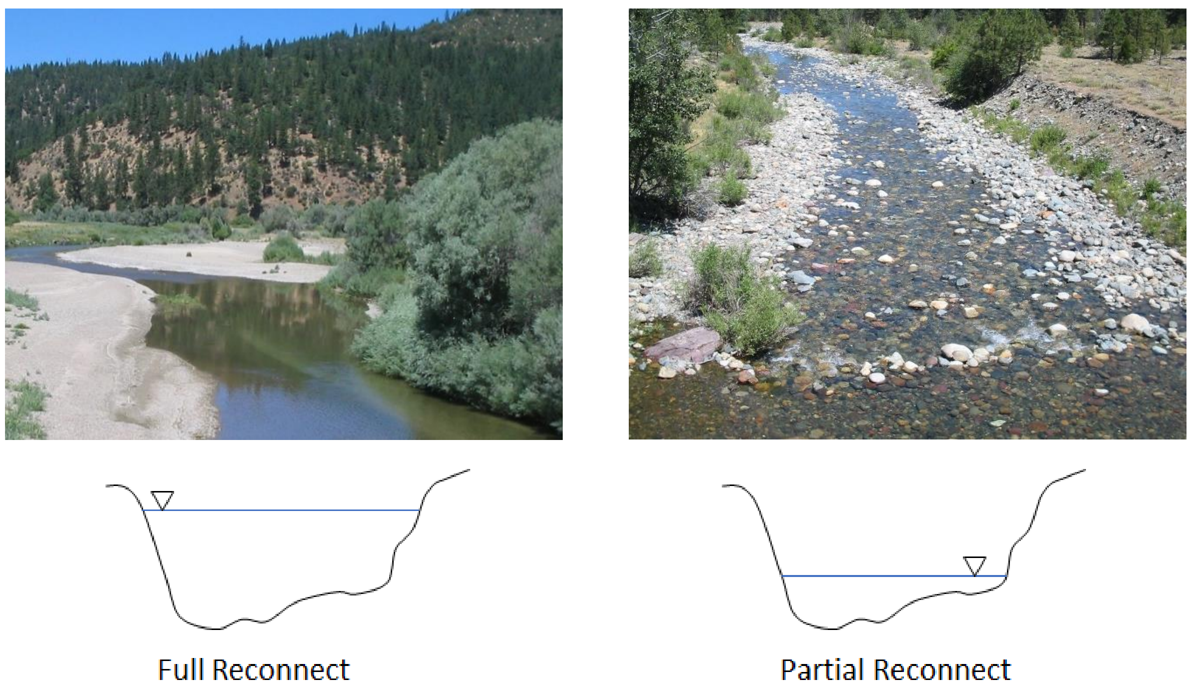


Figure 11. Examples of (left) full reconnect, where there is sufficient depth throughout the reach to support all targeted ecological function and (right) partial reconnect, where there is insufficient depth to support all targeted ecological function.

These are hydrologic tributary metrics only and may not take into account other physical barriers which may exist in the targeted stream-reach, whether related to water quality (e.g., temperatures), critical riffles, diversion dams, or other physical or water quality barrier. This approach is based entirely upon the percent of flow restored during the POES and longitudinal physical surface flow connectivity.

Field visits are necessary to effectively assess aquatic habitat response to a project. Flow restoration practitioners should visually inspect the targeted stream reach during the POES to identify other potential passage and barrier issues or locations (e.g., critical riffles, stranding of fish during low flow periods, etc.) as they relate to the aquatic species of interest and systems they are targeting to enhance.

Fish Life-Histories and Aquatic Habitat Response

For a low flow period, when streams are more vulnerable to disconnecting, juvenile rearing is often the most impacted fish life-history stages. Rearing often requires less flow than other fish life-histories and may be the most critical for survival (Thompson, 1972). A "tributary reconnect" habitat metric may be used for "programmatic approach" benchmarks and tracking. This metric requires project-scale data and can be used to assess available data in terms of a broader-scale (e.g., watershed-scale) quantified aquatic habitat impact.

If adult fish passage is an ecological flow objective, most trout species require thalweg depths of greater than 0.4 ft and velocities of less than 4 ft/sec (Thompson, 1972), while Chinook salmon require thalweg depths greater than 0.9 ft with velocities less than 8 ft/sec. Other fish species preference and specifications may be applied, and flow practitioners are recommended to review Thompson (1972) and other similar studies for details on ideal depths and flow rates for targeted fish species passage requirements.

Table 5. Minimum depth for adult and juvenile salmonid passage (source: Thompson, 1972).

Species	Minimum Passage Depth (ft)
Steelhead (adult)	0.7
Coho salmon (adult)	0.7
Chinook salmon (adult)	0.9
Trout (adult, including 1-2+ juvenile steelhead)	0.4
Juvenile salmonid (young of year)	0.3

Tier 4: Ecological Function Monitoring

Unlike Tier 1, 2, and 3 projects, which focus on the targeted stream-reaches that directly benefit from augmented flows, Tier 4 projects may assess ecological function (i.e., benefits to a targeted aquatic species) of waterways enhanced by water transactions and other flow restoration actions at both the local level and on a larger scale (e.g., watershed, basin, and/or system-scale). Projects may have impacts beyond their localized stream reaches. Along with providing hydrologic connectivity and/or maintaining a base flow for a depleted or dewatered stream reach, a project can restore aquatic ecosystem integrity and resilience through improving or maintaining aquatic species passage, enhancing water quality, improving flow regimes and hydrologic connectivity, improving habitat, and enhancing riparian plant community assemblages.

For a project to be placed in Tier 4, all cumulative restored flows in the targeted reach or region should collectively provide:

- Instream flows equal to or greater than 50 percent of the natural mean daily flow[17] within the targeted reach during the POES; or
- Transacted flows are attaining 100 percent of an established flow target instream within the targeted stream reach throughout the POES.

Achieving either of the Tier 4 projects criteria signify important changes from a pre-treatment flow condition to post-transaction flow condition. When targeted flow thresholds have been met, instream ecological and/or biological responses are expected and assumed to be quantifiable; however, in some systems, responses may take several years to develop if all limiting factors are not addressed. Tier 4 monitoring is designed to verify that the responses are either as designed or provide insight into potential causes for unexpected outcomes.

> ***Multi-Party Monitoring Efforts***
>
> Multi-party monitoring efforts or similar collaborative enterprises are often born out of necessity – a comprehensive (space and time) monitoring effort is too large, expensive, resource intensive, technically challenging, etc. to carry out by one (or even a few) entities. These programs benefit immensely from the expertise, local knowledge, and experience of their members.
>
> Examples of multi-party monitoring efforts include the Intensively Monitored Watersheds (IMW) found in the greater Columbia Basin and coordinated by the Pacific Northwest Aquatic Monitoring Partnership, a group of state and federal agencies, tribes and NGOs. Other examples include the Klamath Basin Monitoring Program (KBMP), Chesapeake Bay Monitoring Program (CBMP), or the Platte River Recovery Implementation Program (PRRIP).
>
> For more information on each program see their respective websites:
> - IMW: https://www.pnamp.org/imw/overview
> - KBMP: http://www.kbmp.net/
> - CBMP: https://www.chesapeakebay.net/
> - PRRIP: https://platteriverprogram.org/ (PRRIP).

Tier 4 projects do not require the development of a basin-scale monitoring program in their respective watershed or sub-basin. Such programs are expensive and resource intensive undertakings, generally requiring a larger, multi-party effort. While Tier 4 water transactions do not have a regulatory nexus, these efforts are typically driven by ESA and/or CWA mitigation efforts and regulatory obligations. However, utilizing ongoing monitoring activities associated with water management, water transactions, ecological studies, and other efforts, conditions can be characterized over broader landscapes and is encouraged if the opportunity exists. The FRAF workbook (discussed in more detail in section 3.5.1) and reporting approaches will be used to organize and document these data sets and outcomes, providing a means to communicate information to partners and stakeholders. Further, leveraging existing monitoring efforts will reduce costs and identify if additional monitoring is necessary. Finally, because there tends to be a strong correlation between degraded rivers and ESA or CWA requirements, restoration practitioners should be educated in these and similar regulatory topics.

[17] Note, that an established streamflow target may be less than the 50 percent of a stream's mean daily natural flow through the targeted reach, especially on larger HUC 8 sub-basin scales, where some biological objectives (e.g., adult passage/migration) may not require that magnitude of flow change to achieve desired biological outcomes. HUC 10 watersheds and HUC 12 sub-watersheds, or smaller tributary systems are more suitable for a POF response from streamflow restoration actions than the HUC 8 sub-basin, which are much larger systems.

To detect ecological or biological response in targeted species, flow restoration practitioners should anticipate monitoring requirements spanning longer periods (years to decades) that will allow assessment of long-term status and trends in aquatic ecosystems and species of interest. Observing and documenting ecological change and species status and trends at appropriate spatial and temporal scales requires a consistent and strategic focus of monitoring efforts and resources. Flow restoration practitioners are encouraged to leverage and support habitat and fish biological monitoring from other qualified parties with shared resource interests, goals, and resource management capacity and experience. This level of ecological monitoring should include state and federal agencies, tribes, academic institutions, NGOs and other natural resource restoration practitioners whenever possible. These broader stakeholder monitoring efforts are necessary to maintain long-term monitoring programs.

Tier 4 project monitoring should continue to focus on hydrologic responses and tracking project implementation as discussed for Tiers 1, 2, and 3. Flow monitoring should collect continuous stage data at targeted flow monitoring stations. Reporting should include both hydrologic and habitat indicators and metrics accrued over the lifetime of the restoration projects. In many instances, when projects are targeting a broader area (as opposed to a specific stream-reach), hydrologic response may be observed in downstream reaches (this is especially likely when there are multiple projects along the same stream reach). Flow restoration practitioners and their partners should consider expanding flow monitoring to any stream reach that appears to be experiencing hydrologic responses, including those beyond the initial reach targeted by the projects. Spot measurements can provide useful information as an initial monitoring effort, providing direct, quantitative information that will be used as a basis for continuous monitoring.

With many measurement methods and metrics that may be applied to study the interaction of hydrological, ecological, and other stream processes, the FRAF aims to constrain or, at a minimum, assist the flow restoration practitioner make efficient decisions on monitoring efforts. First, Tier 4 monitoring efforts should ensure that flow changes associated with the transaction are effectively quantified. Second, using this information, coupled with other information developed in Tiers 1 through 3, appropriate hydrologic metrics should be selected, and monitoring implemented to support these metrics and track long-term system changes. Third, document relationships between the hydrologic metrics and changes in ecological status of the system (e.g., habitat response) and species of interest (e.g., fish response). This requires monitoring to include biological conditions and other responses, along with the hydrologic data. While these ecosystem-related studies will be resource intensive, such monitoring can be collected at less frequent time scales and on larger spatial domains. For example, fish counts may occur at annual intervals, macroinvertebrate studies may be repeated at longer intervals (e.g., 5 years), and habitat and channel-type information may be updated following large flow events. By tracking hydrologic indicators that are less expensive and requires fewer resources, and relating ecosystem response data collected less frequently, system response will be quantitively assessed using the FRAF approach.

Finally, in certain basins, additional water transactions will occur over time, particularly as earlier transactions yield success, uncertainty decreases, and basin stakeholders become more confident in the process. Accommodating additional transactions within the framework may require continuous adaptive management of the selected metrics, monitoring needs, and tracking. For example, as water transaction projects demonstrate successful restoration of targeted watersheds and key species, potentially more sophisticated and expensive monitoring resources will be needed to improve the understanding of how the ecosystem responds to changes in flow. This may result in increased timing and scale of monitoring actions. With increased monitoring demand, equipment needs (such as water quality instrumentation, year-round flow gaging instruments, and biological monitoring equipment) will also increase. Monitoring aquatic species utilizes methods such as electro-shocking instruments, fish screw-traps, drone surveys, LIDAR, satellite imagery, boats, and other methods may also need to be integrated into restoration efforts as part of an adaptive management plan.

Monitoring and Modeling Tools

The flow restoration practitioners require data to define existing (pre-project) conditions, as well as conditions during and after the project has been implemented. Flow restoration practitioners should begin by identifying past data collection efforts as part of the streamflow assessment step. Past data collection efforts may have had different underlying objectives and, as such, may not fully capture information necessary for decision-makers to properly characterize current conditions and identify necessary actions to attain the EFO during the POES. Practitioners should also consider spatial and temporal scales and available monitoring methods for the parameters (e.g., flow, water temperature, habitat) and metrics of interest (e.g., critical depth, rating curves).

For monitoring of conditions while the project is being implemented, the FRAF stewardship approach is based on the methods identified by the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) Project Effectiveness Monitoring Workgroup (Hillman and O'Neal, 2009). Specifically, the PNAMP[18] provides a pathway for a general design and implementation framework, integrating lessons learned, developing new approaches, and applying adaptive management to monitoring actions.

Capacity and resource challenges associated with monitoring are a persistent concern for flow restoration practitioners. Known and anticipated resource challenges should be taken into consideration when applying the FRAF to a proposed flow restoration project. The FRAF process will be adapted to accommodate such constraints by considering the following guidelines:

- Produce structured and meaningful information for project sponsor organizations and stakeholders. Well-documented project goals, plans, and activities, transparency among parties, and clear communications reduces inefficiency that will detrimentally impact budgets and schedules.

- Work within known program resource capacity and budget constraints (e.g., available funding, staff expertise and time). Completing a modest project with measurable outcomes represents success that can readily be built upon. However, failing due to a lack of resources or adequate planning will be a setback that is not easily rectified.

[18] While the PNAMP approach was originally developed at the programmatic level (i.e., for the entire Pacific Northwest), the general approach may be adapted for use at the reach scale.

- Design monitoring and reporting programs to demonstrate seasonal, annual, and multi-year effects of flow restoration. Even a modest amount of planning can lead to an efficient means of assessing data at these multiple time scales throughout the target reach.

- Design monitoring and reporting to integrate with and complement watershed or regional monitoring efforts. Documenting results, assessments, and outcomes provides a means to communicate information to participants efficiently, share critical information to adapt program elements for improved results, and is a means to share successes and lessons learned both locally and at the broader watershed or regional scale.

The data collected as part of the project monitoring and instream flow assessments can be used to develop a range of monitoring tools to either directly assess the effectiveness of the project or to support other associated analysis. Examples monitoring tools include rating curves (stage and habitat), critical depth, direct data assessment, and modeling.

A ***rating curve*** relates a readily measured parameter (e.g., stage) to a parameter of interest that is measured less frequently (e.g., flow rate or habitat area) over a range of continuous conditions. The FRAF stewardship approach relies on two types of rating curves: a stage-discharge rating curve and a habitat rating curve (Figure 12). These two curves are used to assess changes to instream flow and habitat over the life of the project. Because rating curves are typically site specific and can change over time, such curves may need to be periodically assessed and updated over the life of the project.

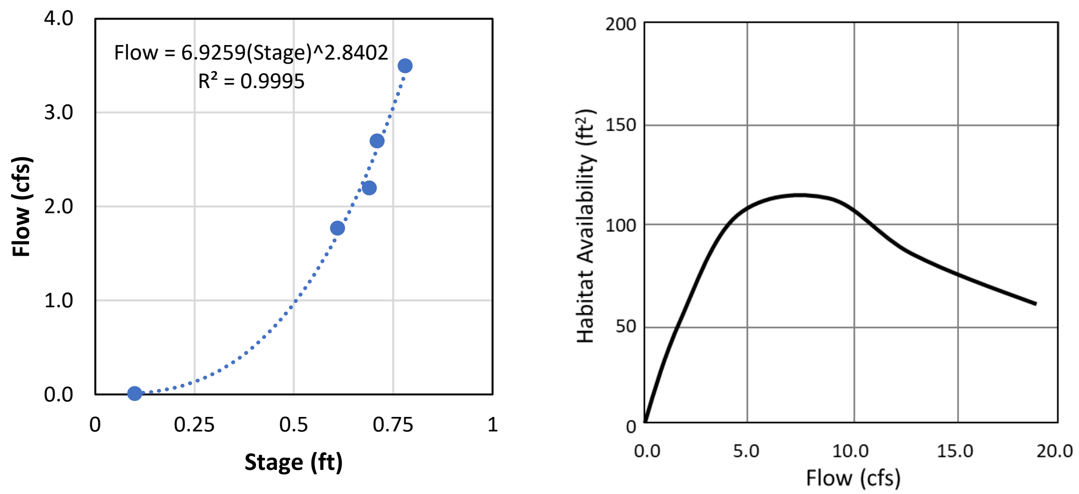


Figure 12. Example flow rating curve (left) and habitat rating curve (right).

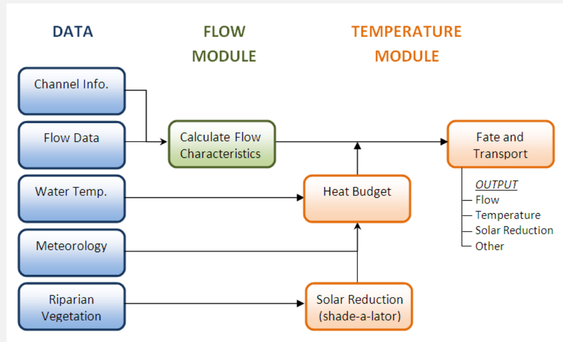
Another metric that can be used to assess restoration outcomes is ***critical depth***. Critical depth is the minimum depth of flow needed in the channel to meet the ecological flow objectives (e.g., fish passage, riffle or pool depth, connectivity). Stage monitoring within the targeted reach can be used to determine if and how often the project added sufficient water to meet critical depth.

Along with depth and flow, some additional parameters used to assess project effectiveness in meeting ecological flow objectives can be directly measured. Measurements are usually made either through the deployment of self-contained continuous monitoring loggers, site visit observations, or other similar methods, and include water temperature, other water quality parameters (e.g., dissolved oxygen) and information (e.g., fish distribution).

Project information and data can also be used to develop computer models of the targeted stream reach. Models can assist flow restoration practitioners in assessing how the system may respond to changes in one or more key parameters (e.g., flow, water temperature) prior to implementing a project. Flow models range from simple mathematical formulations to complex computer models. In addition to flow models there are water temperature, water quality, biological, and ecological models. As with flow models, these tools range from simple to complex. Simple models are often easy to use, typically inexpensive, require modest technical expertise to interpret, and are easy to explain to stakeholders and partners. However, simple models may not explain the various inter-tied relationships among processes, accommodate system complexity, or sufficiently address spatial and temporal variability. Modeling tools are not necessary to carryout projects. The decision to utilize models, while helpful, should consider available funding, resources, and expertise.

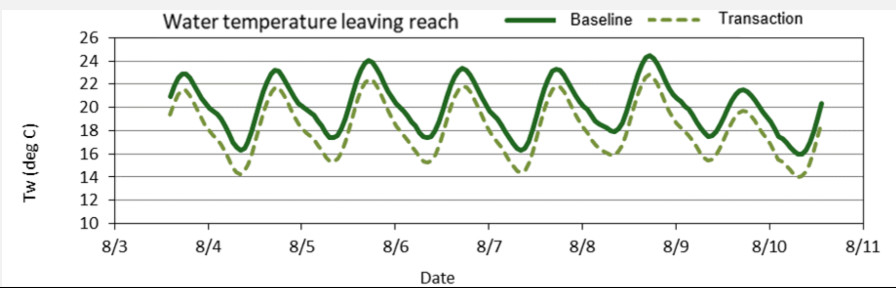
Modeling Tools Example: W3T

An example modeling tool that can assist in quantification in support of FRAF activities is the Water Temperature Transaction Tool (W3T), developed in 2013 by the National Fish and Wildlife Foundation (NFWF) with support from a Conservation Innovation Grant (CIG) from the Natural Resources Conservation Service (NRCS) (Watercourse, 2013). W3T was designed specifically for flow restoration practitioners, offering a practical tool for assessing impacts of water transactions upon water temperature conditions



The model was constructed in Microsoft® Excel®, a familiar and accessible platform. Basic data needs include channel form, daily average flow before and after transaction implementation, water temperature at the top of the study reach and for inflowing tributaries and return flows, meteorological data, and topographic and riparian shading features. The model calculates flow through the reach under steady flow conditions and hourly water temperatures for a desired 7-day period. Results illustrate the impacts of water transactions on flow, stage, wetted channel area, and water temperature. Because the model simulates hourly temperatures, biologically relevant metrics such as daily maximum and minimum temperatures or 7-day average of the daily maximum temperature can be calculated. Tabulated and graphical output on a reach-by-reach basis can readily be compared for a baseline and water transaction conditions.

Currently, W3T has been applied to dozens of streams in California, Oregon, Washington, Montana, and Idaho, assisting restoration practitioners with stream characterization, restoration action quantification, and conservation planning.



Example of W3T simulated water temperature prior to a transaction (baseline) and following a transaction.

Tracking and Reporting

Tracking and Reporting

With the stream monitoring approach designed and the quantification strategies selected, the next step in the FRAF stewardship approach is tracking and reporting. This encompasses developing both pre-transaction and post-transaction information. To assist the flow restoration practitioner, the FRAF includes guidance on specific monitoring and tracking information for each tier and presents the FRAF workbook to assist flow restoration practitioners in reporting the data and assessing outcomes associated with a project, assessing project effectiveness, and supporting ongoing stewardship.

FRAF Tracking and Reporting Workbooks

To assist flow restoration practitioners, a FRAF workbook template has been developed. Built in Microsoft® Excel®, the workbook is composed of five basic worksheets. Additional worksheets can be added by flow restoration practitioners and their partners as needed to reflect their system and water transaction program. FRAF workbooks should be updated, at a minimum, annually to assess water transaction compliance, implementation, and effectiveness of how each project is functioning and which tier placement is most appropriate for each project or set of projects. All associated project information should be updated as changes occur and prior to the start of the monitoring season. This includes information such as changes in project names, stream location, monitoring sites, targeted flow rates, targeted stream reach lengths and other associated project information. This also includes adding or removing projects, if applicable. Specific FRAF workbook pages are:

- *Read Me – Instructions*: provides general information and instructions for using the FRAF Monitoring workbook.

- *#1 – Transaction List*: contains a list of organizational projects being tracked, including a project reference number, name, description, project type (e.g., lease, minimum flow agreement), time period of transactions, assigned tier information, and other notes. This worksheet is used for all projects, regardless of their tier categorization.

- *#2 – Tier1 Compliance Summary*: used to track contractual (or project) compliance of a water transaction project. In general, all projects, regardless of their assigned tier, will need to have project compliance tracked; thus all projects listed on the *#1 – Transaction List* worksheet, should be tracked for compliance on this worksheet. More detail on this worksheet is provided in Section 0

- *#3 – Tier2 Monitoring Points*: This worksheet is used to track the information associated with each monitoring location within the targeted stream reach. Information includes reach name/description, length of targeted stream reach, number of monitoring locations, monitoring location information (latitude and longitude, river mile, etc.), and other information. More details on this worksheet are provided in Section 0.

- *Flow (Q) Template*: This flow template worksheet can be copied as needed. The flow restoration practitioners can use this worksheet to track monitored instream flows over time. Required data include information describing the monitoring site (e.g., site number, latitude and longitude, location of the monitoring site relative to the POD), associated stream and transaction number, hydrological monitoring method (e.g., continuous stage, manual), and measured daily mean flow, for the full period of record. There should be one of these worksheets for each monitoring location.

- *WR Template*: This water right (WR) template worksheet that can be copied as needed. The flow restoration practitioners can use this worksheet to track flow along the length of the monitored stream reach for a single point in time. Required data includes the stream name, river miles, and associated flow rates. There should be one of these worksheets for each targeted stream.

Upon completion of project or seasonal monitoring, hydrologic data may be stored and managed within the FRAF workbook, providing the ability to track hydrologic information in a single location that can then be used for direct metric quantification (e.g., graphs, summary statistics).

Reporting water transaction outcomes is a critical component of the FRAF approach. The FRAF workbook provides multiple ways to analyze, map and share data related to project outcomes effectively. Being built in Microsoft® Excel® allows the flow restoration practitioners to use many of the built-in graphing and statistical features when conducting direct metric quantification. These efforts, along with narrative descriptions embedded directly in the workbook, provide a single repository for all project flow data and site information, which can be used to support organizational reporting requirements. Practitioners should always review and conduct annual audits of water transaction(s) performance to determine if issues exist (or persist) in project streams. At the end of each monitoring season (and prior to the next monitoring season), the flow restoration practitioners should evaluate and adjust project tier placements and determine if increased or decreased stewardship is needed.

The FRAF workbook allows data to be easily shared with project partners and funders. The data format (time-series) allows for easy migration to geospatial databases for better visual and spatial modeling using Geographic Information Systems (GIS)[19]. Data collected within the FRAF stewardship approach has multiple spatial and temporal components, allowing for the generation of numerous geospatial data layers (if using GIS). Examples of key data and/or datasets are:

- Water transaction POD locations,
- Water transaction targeted stream reaches,
- Stream gage monitoring locations,
- Stream gage discharge and period of record, including metadata (e.g., ownership, type of gage, frequency of data collection),
- Instream target flow rates by reach or location, and
- Timing of water transaction flow rates at gaging location.

These types of data and information allow for robust spatial and temporal analyses as well as advanced evaluation of water transactions. These datasets can be imported into GIS systems, and shared in GIS dashboards, story maps, and customized models to provide additional insights. Most data collected as part of the FRAF stewardship approach can be developed into geospatial layers for integration into external models (such as W3T), allowing for customized analysis or planning. Overlaying key aquatic geospatial data, temporal information, available river habitat and other necessary datasets allows for improved planning capabilities, easier assessment of the efficacy of conservation investment, and clearer communications of results and outcomes to project partners and stakeholders. Overall, stronger tools than what are provided within the FRAF workbook alone are needed to assist practitioners with conveying this complex, dynamic work around streamflow restoration. The FRAF workbook provides an initial and useful way to store and share data among project partners, but flow restoration practitioners are encouraged to

[19] A specialist may be required to fully leverage the capabilities of using GIS for visual representation of the data.

implement a multi-disciplinary approach, using a suite of tools to convey information and assess the outcomes of the flow restoration project.

FRAF Tracking by Project Tiers

Tracking and reporting requirements vary depending on the FRAF project tier. Recall that the FRAF stewardship approach is primarily focused on the collection and use of flow data to assess the impacts of the project, and, as such, the FRAF workbook was developed to store and track flow data over time. The FRAF workbook is meant to be a "living document" and can be customized based on the needs of the flow restoration practitioner. While not developed to include other data (e.g., water temperature), the workbook can be customized to include parameters important to the project. Likewise, other data repositories can be used to store non-flow data collected as part of the monitoring program.

Tier 1 Project Compliance Tracking

The objective of Tier 1 monitoring is to demonstrate that the water right holder is in compliance with the agreement by either forgoing or reducing their diversion. For example, the flow restoration practitioner would verify that for the period of the project, there was a reduction (or elimination) in diversion per the terms of the agreement. Annual Tier 1 compliance monitoring is tracked using the FRAF workbook template or a similar reporting template. The FRAF workbook template allows organizations to track their active water transactions by assigning a color-based ***Compliance Status Code*** (CSC) of dark green, light green, yellow, red, or purple (defined below).[20]

The FRAF CSCs have been designed to encompass and capture various implementation challenges in the reporting template.[21] The CSC reporting guidelines and descriptions for individual projects are:

- Dark Green – No issues with compliance and implementation throughout the project period.
- Light Green – Non-compliance issues were identified but did not persist beyond 48-hours or there were no issues, but the project required active instream or POD management, such as placing calls for water or flow discharge monitoring to maintain compliance.
- Yellow – Non-compliance issues were identified, and non-compliance persisted beyond a 48-hour period before being resolved. This code identifies projects that were not fully implemented according to the terms of the contract.
- Red – Non-compliance issues were identified and were not or could not be resolved. This code identifies projects that were not implemented according to the terms of the contract.

[20] The FRAF's CSCs are applicable for all tiers, however some color codes may not be applicable for all projects.
[21] It is worth noting that hydroclimatic variability will have an impact upon streamflow and tracking of projects over its lifespan. At times, water rights may be reduced in terms of flow rate or available volume, but these reductions are not an indication of project non-compliance.

- Purple – No monitoring occurred. Planned monitoring did not occur due to emergency conditions, staff limitations, lack of safe conditions, or other reasons.

The FRAF CSC system can help identify projects that may have initially been considered Tier 1 projects, but due to more oversight, enforcement and/or shepherding of the water instream, a higher tier assignment may be warranted. Additionally, details such as time frame (e.g., 48 hours) for Light Green or Yellow, may be customized for periods more appropriate for specific organizational needs.

The FRAF workbook template with an example project list and CSC is shown in Figure 13. The Tier 1 compliance summary section of the FRAF workbook (*#2 – Tier1 Compliance Summary* worksheet) allows annual tracking of project compliance and implementation by allowing flow restoration practitioners to record the number of site visits, number of non-compliance instances, CSC, associated photos, and any key notes/observations for each active project.

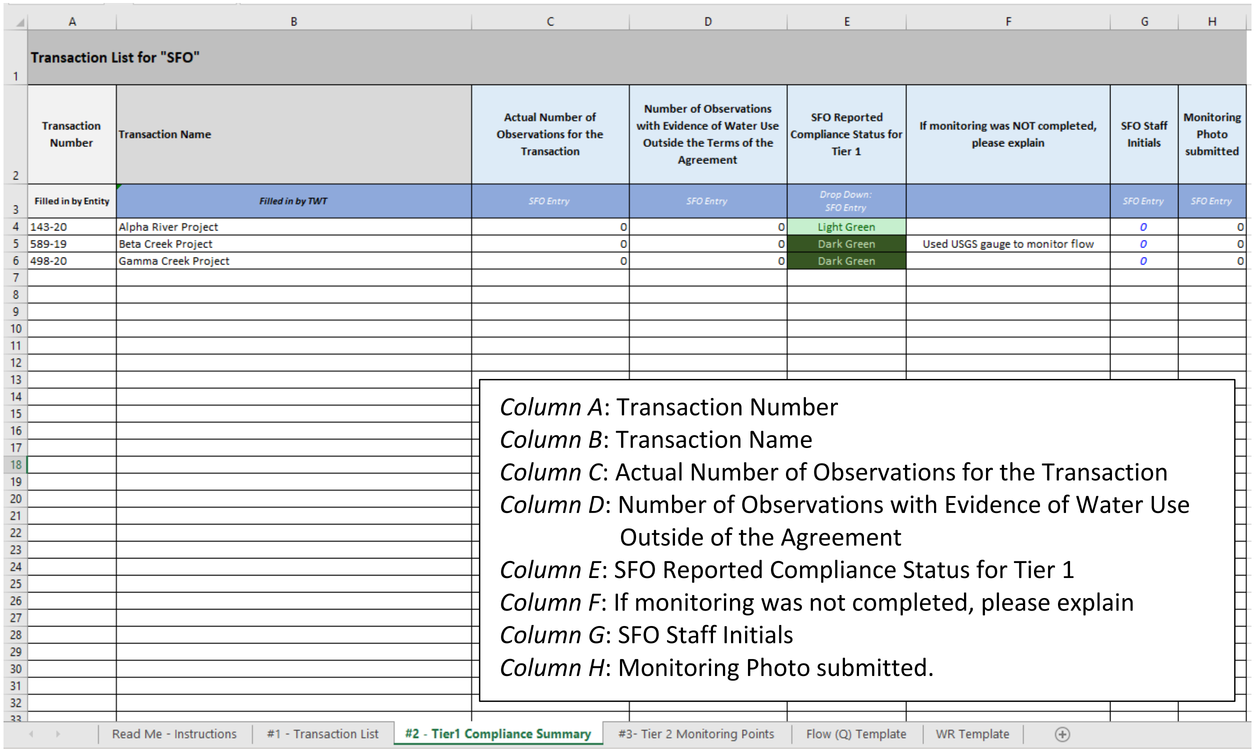


Figure 13. Example of FRAF field workbook Tier 1 compliance sheet (*#2 – Tier1 Compliance Summary* worksheet).

Tier 2: Flow Accounting Tracking

Along with the *#2 - Tier1 Compliance Summary* worksheet to track project compliance, Tier 2 projects also use the *#3 - Tier 2 Monitoring Points* worksheet to summarize the monitoring locations and attributes of each flow gaging station along the targeted stream reach. Information on this worksheet includes name and length of the targeted reach, monitoring location (latitude, longitude, and river mile) and relative location to the POD, associated transaction number, and a monitoring site description. The *Flow (Q) Template* is where daily streamflow data are stored and reported, along with legally contracted water instream flow rate at the gaging location. Much of the specific monitoring site location is echoed from the *#3 – Tier 2 Monitoring Points* worksheet, but additional information includes the gaging method (e.g., manual, staff gage). The *WR Template* is used to track the instream flow rates instream longitudinally along the targeted stream reach. Projects may have expanding or contracting instream flow rates, both temporally and spatially longitudinally along the targeted stream reach during an irrigation season, so both the *Flow (Q)* (temporal) and *WR* (longitudinal) are used to better track the intra-annual changes in flow.

Monitoring Points of Targeted Stream Reaches

Name of Protected Stream Reach	Length of Protected Reach (miles)	Monitoring Points	Transaction Number	Monitoring Location *POD -or- End of Protected Reach (EPR)*	LAT *(Decimal Degrees)*	LONG *(Decimal Degrees)*	River Mile Location (rm 0.0)	Description of Monitoring Point Location
SFO Entry	*SFO Entry*	*SFO Entry*	*SFO Entry*	*SFO Entry*	*SFO Entry*	*SFO Entry*	*SFO Entry*	*SFO Entry*
Alpha River	9.1	#1 USGS		Above POD	30.745291 N	99.171360 W	9.1	
	3.25	#2 USGS mid		Below POD	30.754757 N	99.108258 W	3.26	
	0.5	#3 USGS lower		EPR	30.749421 N	99.081769 W	1.7	
Beta Creek	3	#1 SFO Gage		POD	31.1261N	103.5251W	0.83	
Gamma River	15	#1 USGS		POD	29.1786N	97.5739W	15	
	15	#2 Lower Bridge		EPR	29.125042 N	97.508173 W	10	
	2.7	#3 USGS		POD	29.061076 N	97.407968 W	3.24	
	2.7	#4 Trib 4 Confluence		EPR	29.030661 N	97.393648 W	0.09	

Column A: Name of Protected Stream Reach
Column B: Length of Protected Reach (miles)
Column C: Monitoring Points
Column D: Transaction Number
Column E: Monitoring Location POD -or- End of Protected Reach (EPR)
Column F: LAT (Decimal Degrees)
Column G: LONG (Decimal Degrees)
Column H: River Mile Location (rm 0.0)
Column I: Description of Monitoring Point Location

Read Me - Instructions | #1 - Transaction List | #2 - Tier1 Compliance Summary | #3- Tier 2 Monitoring Points | Flow (Q) Template | WR Template

Figure 14. Example of FRAF field workbook Tier 2 monitoring sheet (*#3 – Tier2 Monitoring Points* worksheet).

In the FRAF workbook, the *Flow (Q) Template* allows project flow monitoring data to be tracked inter-annually, creating a project record through time. Flow data are summarized as mean daily flows, when possible, for all data collected continuously throughout the monitoring season. These daily data not only provide a method to assess and evaluate intra-annual and inter-annual flows, but also are used to develop and apply the appropriate hydrologic metrics for project tracking. An example of a FRAF workbook with annual hydrologic data reporting is shown in Figure 15.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	**Site Number:**	**#1 USGS**															
2	**Stream Name:**	**Alpha Creek**															
3	**Transaction Number**	**285-10, 333-11**															
4	**Latitude:**	**30.745291 N**															
5	**Longitude:**	**99.171360 W**															
6	**Gaging Method**	**Manual**															
7	**Upstream Water Diversion**	Yes															
8	**Downstream Water Diversion**	No															
9	Water Year Calendar (If your project monitors only in summer period you may delete unnecessary rows)														Provisional data		
10	**Date**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Mean**	**2019 IQ (instream flow)**
11	4/1	0.0	0.0	22.0	14.4	5.2	26.7	30.6		6.8	2.8	9.3	7.3	20.0	9.84	12.1	
12	4/2	0.0	0.0	28.1	13.5	6.4	30.8	21.0		7.3	2.2	10.2	10.1	16.2	9.68	12.2	
13	4/3	0.0	0.0	28.6	13.1	6.1	23.2	20.4		6.3	2.3	11.8	12.5	14.7	9.71	11.6	
14	4/4	0.0	0.0	15.1	12.6	6.1	20.4	20.2		5.6	2.7	13.1	12.8	14.0	10.2	10.2	
15	4/5	0.0	0.0	13.3	12.1	6.3	22.6	19.3		5.5	2.2	12.2	12.4	15.2	10.4	10.1	
16	4/6	0.0	0.0	19.7	13.7	6.0	17.7	17.8		5.5	1.9	11.7	12.1	20.4	8.8	10.5	
17	4/7	0.0	0.0	18.8	15.4	6.0	21.2	14.1		6.0	1.5	13.1	15.3	21.1	8.06	11.0	
18	4/8	0.0	0.0	21.2	17.4	6.4	18.7	16.6		8.7	1.7	13.1	15.0	21.7	8.77	11.7	
19	4/9	0.0	0.0	18.6	17.0	6.2	19.7	17.7		17.3	1.1	15.7	11.1	15.0	11.8	11.6	
20	4/10	0.0	0.0	18.8	16.2	7.2	23.8	18.1		15.4	0.1	16.6	10.6	14.8	7.47	11.8	
21	4/11	0.0	0.0	19.0	16.4	7.3	21.8	20.1		15.0	0.1	14.5	10.8	18.8	5.54	12.0	
22	4/12	0.0	0.0	20.5	17.8	7.2	17.5	20.8		13.1	0.1	14.2	11.1	17.5	5.4	11.6	
23	4/13	0.0	0.0	24.9	19.0	6.4	21.3	18.8		8.0	0.1	17.6	12.6	12.6	3.96	11.8	
24	4/14	0.0	0.0	37.2	18.3	4.8	21.6	16.9		4.8	0.1	17.5	13.2	12.8	4.66	12.3	
25	4/15	0.0	0.0	28.4	16.7	4.1	20.0	15.5		5.3	1.6	14.2	11.8	13.7	3.87	10.9	
26	4/16	0.0	0.0	23.0	15.7	5.4	21.1	14.9		4.2	5.2	12.9	11.8	15.3	4.07	10.8	
27	4/17	0.0	0.0	24.5	16.0	8.1	22.9	14.7		5.0	4.6	11.4	12.7	11.4	3.68	10.9	
28	4/18	0.0	0.0	27.1	17.3	6.5	18.2	14.6		7.7	4.3	10.3	11.8	9.7	3.29	10.6	
29	4/19	0.0	0.0	29.5	17.8	4.5	15.4	14.3		7.6	4.7	10.8	10.2	9.4	4.95	10.4	
30	4/20	0.0	0.0	29.3	17.9	3.6	11.7	14.4		8.2	5.2	13.6	9.2	10.6	6.88	10.3	
31	4/21	0.0	0.0	25.4	20.3	5.3	8.5	16.2		8.8	6.2	17.3	9.6	13.4	8.28	10.9	
32	4/22	0.0	0.0	27.7	23.8	7.0	8.4	19.2		11.4	6.0	23.0	8.9	16.1	6.09	12.6	

Figure 15. An example of a FRAF Tier 2 workbook reporting annual flow records with continuous mean daily flows at gage location (based on the *Flow (Q) Template* worksheet).

With project flow data being collected in a continuous record and stored in the FRAF workbook, flow metrics comparisons and data analysis may be applied to streamflow. A common visualization tool for viewing intra-annual and inter-annual changes in streamflow is a raster hydrograph. First applied to hydrology by Koehler (2004), raster hydrographs are pixel-based plots for identifying variations and changes in large multidimensional datasets (*waterwatch.usgs.gov*). Days of the year are placed on the x-axis, years on the y-axis, and stream-discharge is on the z-axis (color-plotted).

The key metrics (see Table 1) to be included in project reporting should be identified prior to data collection and project implementation. However, some metrics may be applied retro-actively if sufficient data (e.g., continuous time-series) are collected. Selecting (several) appropriate flow metrics for water transactions based upon the ecological flow objective, streamflow regime and basin hydrology is critical to setting up a robust and efficient stream monitoring program. Upon completion of project or seasonal monitoring, hydrologic data may be stored and managed within the FRAF workbook, providing the ability to track hydrologic information in a single location that can then be used for direct metric quantification (e.g., graphs, summary statistics). These efforts, along with narrative descriptions embedded directly in the workbook provide a single repository for all project information that can be used to support organizational reporting requirements.

Tier 3 Aquatic Habitat Response Tracking

While the FRAF workbook tracks hydrologic response data both intra-annually and inter-annually, other indicators of hydraulic alteration (IHA) parameters may also be used to assess habitat response to the water transaction (Richter *et al.*, 1996). In terms of the FRAF stewardship approach, the primary aquatic habitat response metric is connectivity. For Tier 3 reporting[22], a variety of suggested datasets, parameters, and metrics may be reported: however, stream parameters focusing on the ecological flow objective should be the primary focus of monitoring and reporting. Monitoring entities and flow restoration practitioners should begin developing adequate Tier 3 monitoring strategies and metrics and with an emphasis on maintaining a multi-year monitoring effort. Examples of datasets and information collected include:

- FRAF Monitoring Workbook with all summarized streamflow data with applied flow metrics.
- Water quality data (e.g., water temperature metrics, water temperature models, dissolved oxygen, conductivity or other relevant parameters or metrics) and information with associated flow data.
- Critical riffle analysis or other passage data information with associated flow data and information.
- Tributary reconnects resulting from water transactions maintaining longitudinal connectivity of streams and river networks tracked with appropriate IHA metrics or defining with programmatic approach metrics such as partial and full tributary reconnects.
- Geomorphology features and habitat wetted area response (pools, riffles, or runs) with associated flow data/metrics.
- Annual resident fish use surveys that conduct stream reach fish usage and distribution throughout a stream's watershed or a river network to verify inter-annual fish spawning, migration, holding and rearing usage.
- Passive Integrated Transponders Tag (PITTag) information system interrogation site data for tracking migratory fish movements with imbedded radio transponder chips which can verify migration timing and passage enhancements.

TIER 4 ECOLOGICAL FUNCTION TRACKING

Tier 4 projects should be tracked using Tiers 2 and 3 strategies and metrics; however, given the greater ecological and biological scale associated with Tier 4 projects, some adaptations of the FRAF workbook are necessary. Flow restoration practitioners will list all projects (*#1 - Transaction List*), track project/contractual compliance of all projects (*#2 - Tier1 Compliance Summary*"), identify all monitoring locations (*#3- Tier 2 Monitoring Points*) and store monitored flow data (*Flow (Q) Template* and *WR Template*).[23] Additionally, monitoring (both the hydrologic and biologic) should continue after the primary restoration efforts have concluded and the data should be analyzed at the greater river network, basin or species population scales.

[22] There are no specific worksheets for Tier 3 projects in the FRAF monitoring workbook. Flow practitioners will use the template worksheets to track compliance, monitoring locations, and flow data (spatial and temporal). Additional worksheets, to track aquatic habitat response, can be developed based on the ecologic flow objectives and needs of the monitoring entities and specific project attributes.

[23] There are no specific worksheets for Tier 4 projects in the FRAF monitoring workbook. Flow practitioners will use the template worksheets to track compliance, monitoring locations, and flow data (spatial and temporal). Additional worksheets can be developed based on the ecologic flow objectives and needs of the monitoring entities.

Unlike projects focused on a single stream-reach, Tier 4 projects tracking may require a different methodology. Tracking the various parameters, indicators, and ecosystem responses should be done with a method more akin to multi-level, multi-source data. Project managers should track various indicators and parameters at a high level using a data "dashboard" to identify general large-scale ecosystem trends in recovery or decline, while still retaining the data necessary to assess more localized or specific responses to a project. Maintaining a multi-level data approach will ultimately provide resource managers with a means to assess multiple levels of success, gauge ecosystem health, and help them effectively manage water resource conditions and their dependent systems.

Tier 4 is designed to encourage and integrate with larger regional or basin-scale monitoring efforts if or when they exist. As such, Tier 4 monitoring and reporting should build upon Tiers 2 and 3 hydrologic monitoring data, but also target relevant habitat and biological information that helps understand the ecological response to the flow restoration actions. These would vary dependent upon the project EFO and over-arching restoration goals. Methods and techniques which would further support ecological function monitoring could potentially include those listed for Tier 3, as well as, but not limited to:

- Fish redd survey data with associated flow data/metrics.
- Radio telemetry fish information with flow data/metrics.
- Targeted fish life-stage use or benefit with flow information.
- Video weir counts with flow data/metrics.
- Macro-invertebrate species composition and abundance with flow data and biological metrics.
- Fish species composition and abundance information with flow data and biological metrics.

ROLE OF REPORTING

The tracking of hydrologic data collected under the FRAF stewardship approach is designed to aid the flow restoration practitioner in meeting the reporting requirements of the project. The FRAF stewardship approach does not have specific recommendations regarding reporting because the final forms of the reporting (e.g., data sets, figures, one-page summaries, full reports) will depend on the needs of the project. Instead, the FRAF workbook is meant to be a framework for organizing the hydrological information collected as part of the project, as well as the assessments performed to determine the impacts of the projects. Given the broad range of participants that are typically involved in flow restoration planning processes, it is likely that more than one form of reporting will be needed (e.g., the reporting needs of the project manager may be different than those of the project funder).

ONGOING STEWARDSHIP

The final step in the FRAF stewardship approach is ongoing stewardship of the flow restoration program and the associated projects. Ongoing stewardship includes both short-term and long-term assessments of the impacts of the project in terms of the stated EFOs. Short-term assessment occurs during and at the conclusion of each project and/or season. The long-term assessment span multiple years. While the duration of long-term assessment is undefined in the FRAF (it is system specific), the approach assumes that through ongoing adaptive management, stewardship would undergo changes through lessons learned to match stewardship needs, available resources, and aquatic ecosystem response.

During the period when the project is active, the flow restoration practitioner is responsible for ensuring the terms of the project are met. This typically requires the practitioner to actively monitor the diversion and/or targeted stream reach. Additionally, it is within the practitioner’s interest and responsibility to be transparent with monitoring actions, results, and data, as well as communicating this information to the other stream water-users and stakeholders (such as state wildlife and water agencies). Openness and education are critical for creating trust and credibility with all stakeholders and existing restoration partners, which in turn will help create future restoration partners and supporters and improve stream access.

Restoration practitioner’s monitoring should confirm that the agreement/contract water rights were instream at the location, rate, and duration as planned. Subsequently, flow target attainment in terms of flow rate, location and duration should be determined (i.e., was the amount and timing of water transaction consistent with the EFO and POES). Once the transaction (or set of transactions) is completed, the practitioner should conduct an assessment to determine how well the projects performed and whether management adjustments are needed.

If project flow rates did not meet instream flow rates or instream flow targets, flow restoration practitioners should assess whether the water right leased was in compliance, whether it was reliable (instream throughout the term), or whether stewardship and management of water was adequate, and thus the reason flow rates were not instream. The primary reason which prevents project flow rates (and flow targets) from being achieved is typically lack of active stewardship, resulting from inadvertent diversion by other water-users and lack of actively calling instream water past active diversions. At times, and to a lesser degree, hydrologic conditions (e.g., a dry water year) will also impact projects. Likewise, biological actions (e.g., beaver constructed dams) may prevent instream flows from adequately being quantified. Ideally projects should accommodate such hydrologic variability by selecting water rights with enough seniority to not be impacted by dry year conditions; however, severe drought conditions will be a challenge to balance water uses on stream systems and alter flows beyond what has been historically experienced.

If the flow targets are fully met, the practitioner should assess if augmented flows resulted in the expected ecological benefit. If the expected benefits were not realized, then an assessment of conditions that may have prevented ecological benefits from being achieved should be completed. This will require utilizing other parameters/metrics (e.g., water temperature) to perform a broader assessment. The results from these analyses may indicate that a new streamflow assessment may be required (i.e., flow targets may need to be reassessed or revised). Recall that flow restoration projects are typically multi-year strategic investments in a basin to provide instream ecological benefits. The FRAF approach emphasizes that stewardship is an ongoing process and includes an ability to track all restoration activities from Tier 1 through the long-term responses identified in Tier 4, as appropriate.

4. FRAF Supported Water transaction Example: Kenney Creek, Idaho

The FRAF stewardship approach outlined herein provides a defined process to identify, quantify, and track environmental instream flows. These flows provide the necessary instream conditions to restore and maintain the ecological integrity of streams and associated ecosystem services through a series of tiered activities (Figure 7). An example application of the FRAF stewardship approach to Kenney Creek is included herein to illustrate how the approach is applied to a project through the various tiers.

Kenney Creek is a tributary to the Lemhi sub-basin (HUC 8) in the Salmon Basin of central Idaho (Figure 16). The creek has had extensive flow and habitat work implemented over the last two decades, targeting ESA listed steelhead, Chinook salmon, and bull trout. The analysis presented herein focuses on August, a period of chronic low flow conditions.

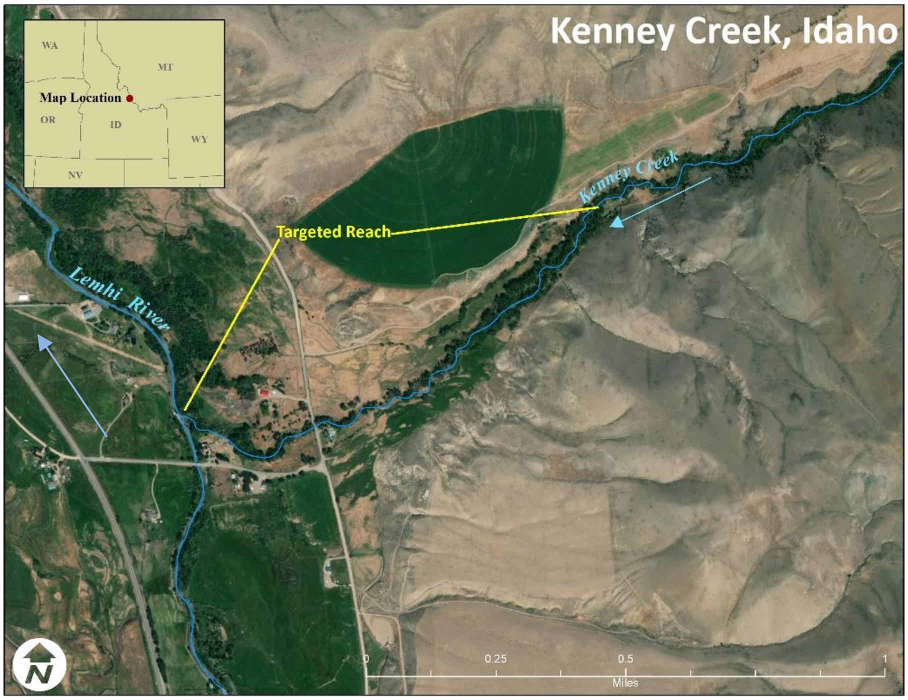


Figure 16. Kenney Creek, in the Lemhi sub-basin.

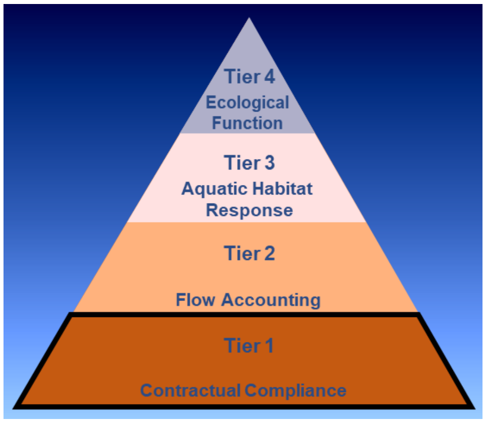
Kenney Creek minimum flows prior to flow restoration work ranged from approximately 0.6 cfs to 1.7 cfs for the month of August (median flows ranged from 0.8 cfs to 2.5 cfs), but other periods of the year occasionally faced shortfall such as early spring dewatering of the stream prior to snowmelt runoff. The lower portion of the creek was chronically dewatered in the late summer months, with surface flows regularly disconnecting from the Lemhi River. The first formal instream flow transaction on Kenney Creek was completed by the Idaho Water Resources Board (IWRB) and included a one-year lease in 2005. The lease was not renewed by the landowners the following season, and transactions did not occur in the creek for several years.

In 2010, six steelhead redds were observed in the lower reaches of Kenney Creek by Idaho Department Fish and Game (IDFG). In response to these observations, a local land trust in consultation with IDFG negotiated a conservation easement that included a water management agreement with an upstream landowner. The arrangement included a diversion reduction agreement on a portion of the upstream landowner's irrigation withdrawals, resulting in approximately 4 cfs of flow through the targeted stream reach where steelhead spawning had been observed. IDFG identified that a 4 cfs flow would avoid redd dewatering and provide passage, as well as improve over-summering conditions in the creek. Though the water management agreement provided the basis for the 4 cfs flow, the water was "unprotected," i.e., no formal instream water right was issued in this case and all or portions of the 4 cfs could be legally diverted by junior water right holders (up to their allocated right quantities) located within the targeted stream reach. To avoid this outcome, IWRB conducted a source switch agreement with these downstream junior water rights holders in 2013, allowing them to access their water from a different location. This source switch agreement not only removed the junior water rights holders' legal abilities to divert any of the 4 cfs flows provided by the earlier agreement with the upstream landowner, but also resulted in an additional 0.14 cfs in the targeted stream reach (NFWF, 2020).

Through the two flow agreements, the total instream flow rate in lower Kenney Creek increased from approximately 0.5 to 1.5 cfs to approximate 4.14 cfs, providing the necessary flows to meet the IDFG flow prescription for improved spawning and passage. Additionally, the increased flow rate reconnected Kenney Creek to the Lemhi River and provided enhanced over-summering conditions later in the year, supporting juvenile rearing and holding (Uthe *et al*., 2017). Finally, although the primary target flows were developed for steelhead, both Chinook salmon and bull trout have increasingly utilized stream reaches and associated habitat within Kenney Creek.

The activities in Kenney Creek as they apply to the four tier FRAF structure are outlined below.

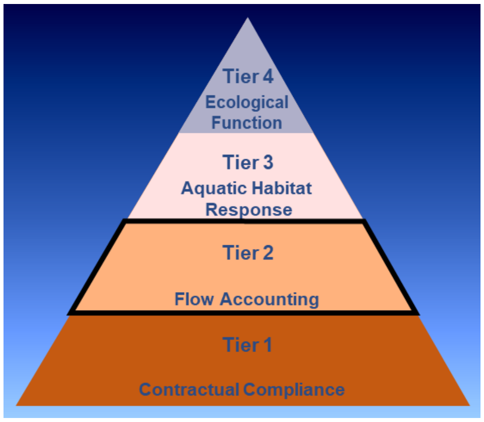
Tier 1: Contractual Compliance



Tier 1 compliance focuses on contractual obligations and typically requires annual verification to ensure the water right holder diverted less water per their historic right. The parties involved in the Kenney Creek flow transaction include a local land trust, IDFG, IWRB, and the water right holders – all whom have an active interest in the stream either through an interest in managing streamflow stewardship and/or diverting for other beneficial uses. In this case, the two agreements identified above represent the contractual requirements and project compliance is based on a stream gage on Kenney Creek.

For the Kenney Creek flow transaction project, contractual compliance was confirmed via measurable changes in the instream flow (i.e., as part of the Tier 2 monitoring efforts).

Tier 2: Flow Accounting



By 2013, the sum of all flow agreements on Kenney Creek yielded approximate 4.14 cfs of flow in the target reach. The 4 cfs flow target to meet ecological objectives in lower Kenney Creek set by IDFG met the Tier 2 criteria of being greater than 1 cfs (or measurable). The transaction was initially placed in Tier 2; however, because flow agreements that provide 100 percent of the established flow target (4 cfs), the stream meets Tier 4 status (see below). Recall, that legally the IWRB and IDWR have no ability to regulate the 4 cfs from the upper landowner because this is a private agreement between the land trust and the landowner.

Streamflow on Kenney Creek is measured in the targeted stream reach at the Idaho Power gage (#13305040), which was installed in 2004, before the flow agreements were implemented. Tracking of daily streamflows were completed using the FRAF workbook with a modified version of the *Flow (Q) Template* worksheet (Figure 17). Flow data for the April through September period from 2004 to 2019 (present) were entered into the worksheet. These data were subsequently used to develop project metrics based on the POES and include monthly mean August flows and summary statistics of monthly median, mean, maximum, and minimum flows (Table 6 and Figure 18). In addition to the charts and summary statistics that were developed within the FRAF workbook, the data was also used to generate other analysis methods (e.g., a raster hydrograph (Figure 19).

These tabular data indicate that after the transactions were initiated in 2011 and 2013, Kenney Creek August flows increased from a median flow of 1.7 cfs (2004-2010 average) to 4.0 cfs (2011-2019 average) and were typically 2 to 4 cfs higher than pre-transaction flows (Figure 18). After the 2013 agreement was implemented, summer flows in Kenney Creek typically remained above approximately 3 cfs throughout the summer months but were not always above 4 cfs (the flow target). Some of these challenges were related to climate and drought conditions in the region (Crozier, 2016). Incremental progress has been made on increasing flows in lower Kenney Creek and this remains an active, ongoing project.

The stewardship of water management agreements (including leases) is necessary for flow practitioners. Having a stream gage that will be accessed online at Kenney creek, allows managers to make actively track conditions and calls contact landowners when flows fall below agreed upon levels. Variability in hydrology, changes in demands and operations, meteorological conditions, and other factors will impact achieving target flows defined in the agreements, as evidenced by the variability in monitored flows in lower Kenny Creek. Stewardship activities in Kenney Creek have included water users becoming accustomed to managing irrigation water for both their operations and instream flows, with all partners working each year to improve and maintain the prescribed flows.

	A	B	C	O	P	Q	R	S	T
1	Site Number:	#1 - KEN							
2	Stream Name:	Kenney Creek							
3	Transaction Number	369-13							
4	Latitude:	45.0272							
5	Longitude:	-113.6539							
6	Gaging Method	QLE-Continuous							
7	Upstream Water Diversion	Yes							
8	Downstream Water Diversion	No							
9	Water Year Calendar (If your project monitors only in summer period you may delete unnecessary rows)					Provisional Data		(all contracted water instream should be totaled here with period of use)	Conservation Easement Flow Agreement
10	Date	2004	2005	2017	2018	2019	Mean	2019 IQ (instream flow)	
11	4/1		2.2	5.6	3.0	3.3	3.6	0.1	4.0
12	4/2		2.2	5.8	3.2	3.4	3.6	0.1	4.0
13	4/3		2.4	5.9	3.3	3.5	3.6	0.1	4.0
14	4/4		2.2	5.7	3.0	3.8	3.6	0.1	4.0
15	4/5		1.6	5.5	3.0	4.1	3.6	0.1	4.0
16	4/6		1.4	5.4	3.5	4.3	3.8	0.1	4.0
17	4/7		1.6	5.6	5.3	4.2	3.8	0.1	4.0
18	4/8		1.6	5.7	5.8	4.7	3.9	0.1	4.0

Figure 17. The modified *Flow (Q) Template* worksheet in the FRAF workbook with the information and data associated with the Kenney Creek water transaction.[24]

[24] The Kenney Creek project collected flow data from mid-2004 through 2019, inclusive. Columns D (water year 2006) through N (water year 2016) are hidden from view.

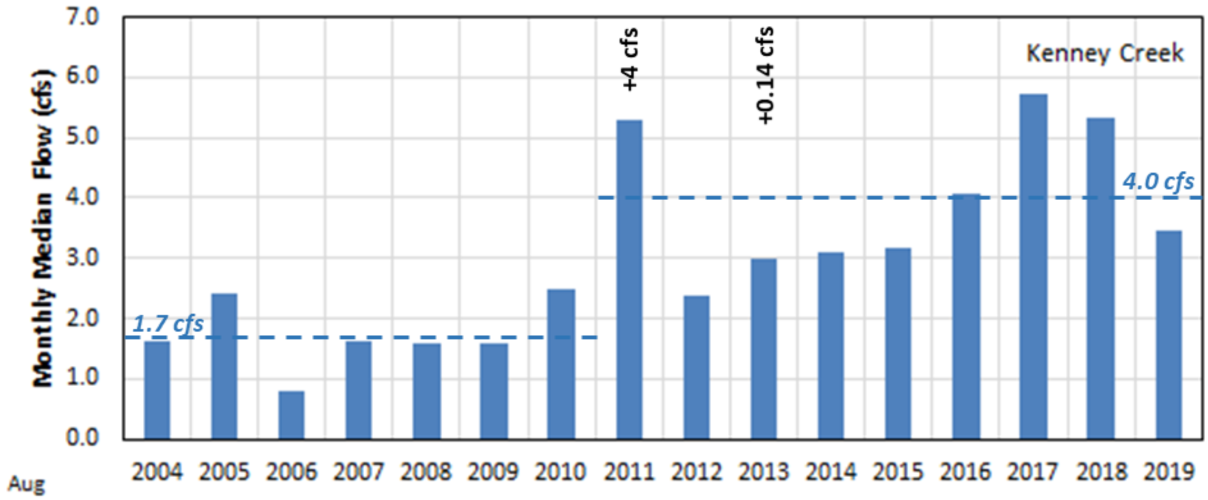


Figure 18. Kenney Creek, ID August monthly median flows from FRAF workbook. Flow transactions are shown in 2011 and 2013 (4 cfs and 0.14 cfs, respectively). Median flow for the pre-transaction period was 1.7 cfs (2004-2010), and median flows for the post-transaction period was 4.0 cfs (2011-2019).

Table 6. Example of Kenney Creek, ID August monthly flow data used for assessing "over-summering" flow objectives and project scale metrics for the project tracking.

Month	Kenny Creek - August Flow Data						
Year	Median	Avg	Max	Min	7D A Min	30D A Min	Count
2004	1.6	1.8	2.9	1.0	1.2	1.8	31
2005	2.4	2.3	2.8	1.7	1.9	2.3	31
2006	0.8	0.8	1.1	0.6	0.7	0.8	31
2007	1.6	1.6	2.0	1.2	1.2	1.6	31
2008	1.6	1.7	2.9	1.1	1.4	1.7	31
2009	1.6	1.8	3.2	0.8	1.0	1.7	31
2010	2.5	2.7	4.9	1.7	1.8	2.6	31
2011	5.3	5.5	9.3	3.4	4.0	5.3	31
2012	2.4	2.4	2.7	2.1	2.3	2.4	31
2013	3.0	3.0	3.4	2.7	2.8	2.9	31
2014	3.1	3.0	4.3	1.8	2.1	2.9	31
2015	3.2	3.2	3.9	2.7	2.8	3.2	31
2016	4.1	3.8	4.4	2.5	2.7	3.8	31
2017	5.7	5.1	6.9	2.8	3.0	5.1	31
2018	5.3	5.3	5.7	4.6	5.0	5.3	31
2019	3.5	3.5	4.5	3.0	3.3	3.5	31

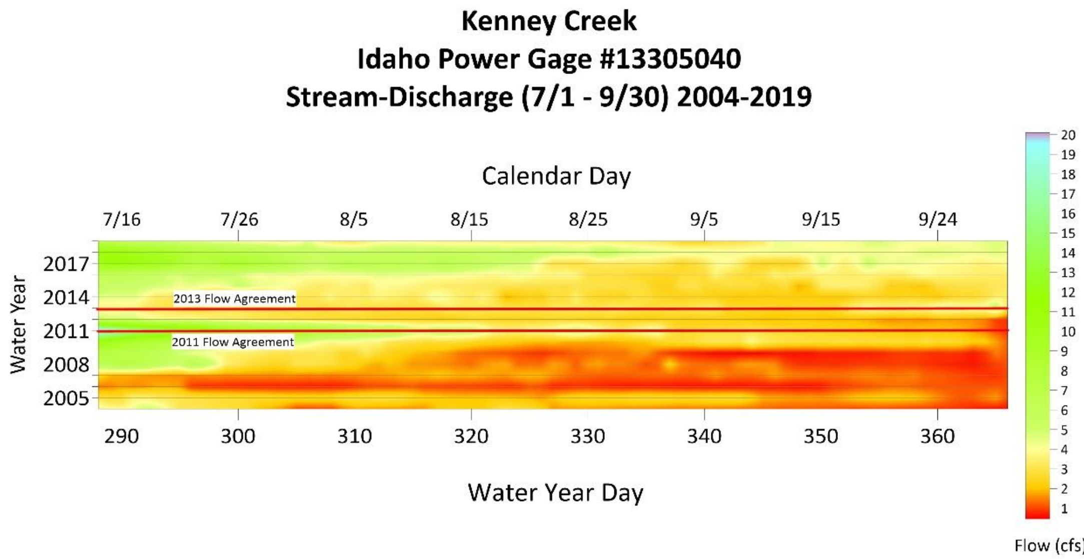
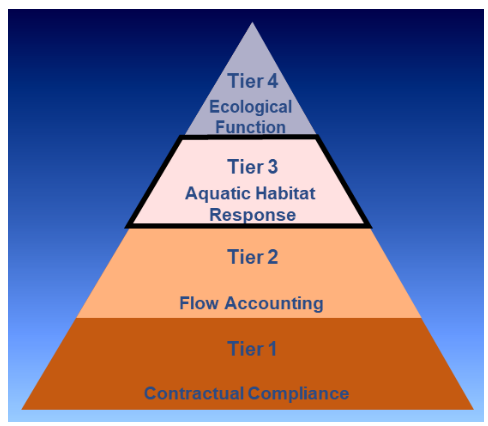


Figure 19. An example of a FRAF Tier 2 project with intra-annual and inter-annual stream-discharge data visualization employing a raster hydrograph on Kenney Creek, Idaho.

TIER 3: AQUATIC HABITAT RESPONSE



The FRAF focuses on monitoring restoration outcomes through changes in flow using hydrologic metrics; however, additional metrics will be used to assess the efficacy of a water transaction for higher tier levels. Tier 3 metrics relate increased flows from water transactions to quantifiable aquatic habitat outcomes.

The basic flow requirement for Tier 3 was met at Kenney Creek because the flow transaction provided 50 percent or more of an established flow target within the targeted stream reach during the POES. To assess aquatic habitat response, a Tier 3 metric for tributary reconnection was used. As noted in the previous section, tributary reconnection occurs when surface flows are longitudinally re-connected for the entire length of the stream from the targeted stream reach to the confluence with the next order stream during the POES. Prior to the flow transactions, Kenney Creek experienced conditions that led to intermittent dewatering or low flow passage challenges for salmonids during summer low-flow months.

In 2010, IDFG installed a PIT tag site on Kenney Creek upstream of the targeted reach to assess and track adult migration/passage from and to the Lemhi River. PIT tagging programs can help resource managers understand escapement, passage, timing, response to flow conditions, and other information unique to specific fish species needs as they move throughout watersheds. To support ongoing fisheries restoration efforts multiple species of salmonids in the Lemhi River sub-basin have been tagged, including steelhead, Chinook salmon, bull trout, and westslope cutthroat trout. These tagged fish are tracked as they pass various PIT tag sites (termed “arrays”) located throughout the sub-basin.

PIT tag data for Kenney Creek was used as a surrogate for hydrological monitoring of instream flows. The absence or presence of tagged fish upstream of the targeted reach during the low flow summer months indicates whether there was sufficient flow in the system to allow for passage. The data indicated that passage was improved through the lower system due to the two Kenney Creek flow agreements (in 2011 and 2013) (Figure 20). In 2010, prior to the agreements, almost no fish were observed in Kenney Creek. After the agreements were implemented the data demonstrated that adult fish were able to move upstream into Kenney Creek during all low flow summer months, indicating passage depth under the flow agreements provided full connectivity from the mouth of Kenney Creek through the targeted reach.

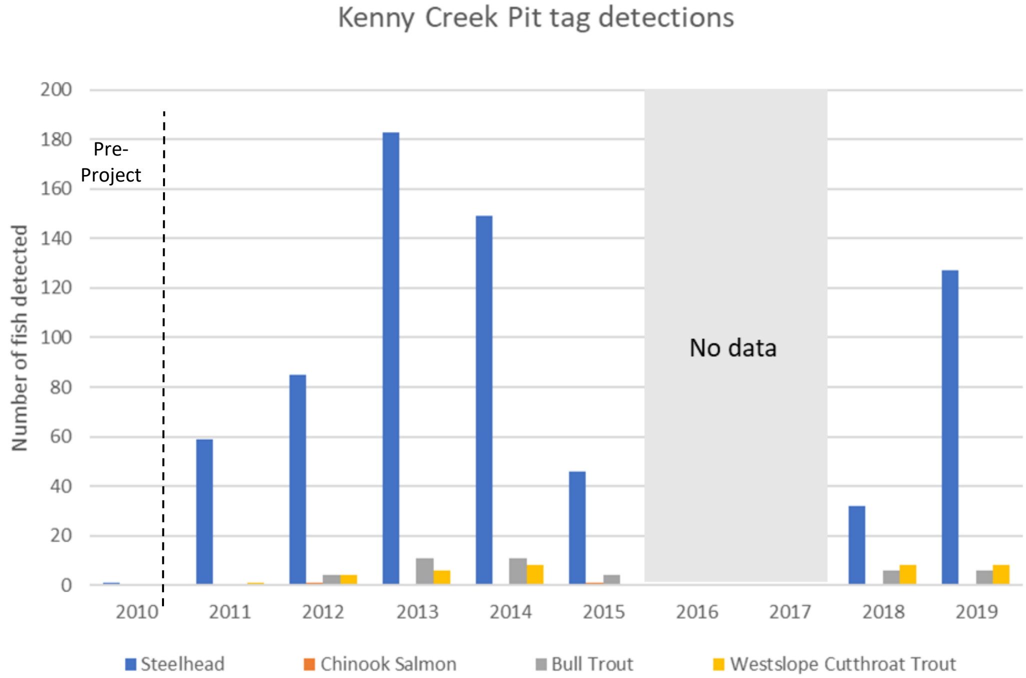
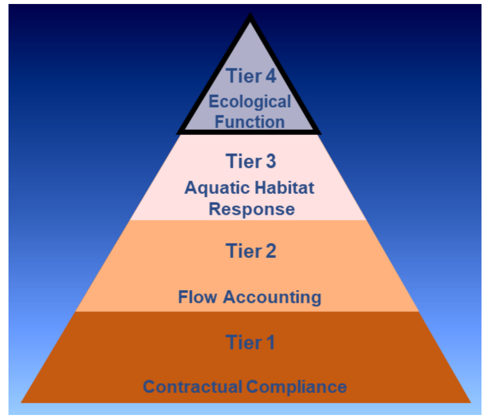


Figure 20. Annual PIT tag detections of salmonid species at the Kenney Creek PIT tag monitoring site located upstream of the targeted stream reach (www.ptagis.org), 2010-2019, no data for 2016-2017.

Broader knowledge of conditions external to the study area will also be important to determine whether system response is due to the flow restoration projects or if there are out-of-basin (i.e., external) factors that may have impacted system performance. For example, historic drought conditions in the Columbia River basin, coupled with poor ocean conditions, adversely impacted steelhead populations in 2015 (Crozier, 2016; Jacox *et al*., 2016; Faulkner *et al*., 2016). The FRAF proves particularly helpful under conditions where out-of-basin conditions adversely impact metrics used for tier assessment and project performance. Lower tier information and metrics may be used to confirm Kenney Creek flow conditions reflected the agreements in place and provide a basis for adaptive management and continued stewardship.

TIER 4: ECOLOGICAL FUNCTION



Tier 4 water transactions and the associated monitoring of ecosystem function will include larger spatial and temporal scales. Examples include anadromous fish life-stage histories that include extensive migrations, rearing, and redistribution, as well as tracking multiple year-classes over a decade or longer. Conditions beyond the region of interest for the tier will impact ecological conditions within the region of interest. In the Tier 3 example above, ocean conditions and regional drought impacted Kenney Creek steelhead populations in 2015. These conditions, and other regional challenges exist, including hatchery competition, invasive species competition, recreational and commercial fishing impacts upon escapement, migration survival, inadequate local habitat conditions, and other factors.

The flow requirement for Tier 4 was met at Kenney Creek with the 4.14 cfs flow transaction providing 100 percent of the established flow target of approximately 4 cfs within the targeted stream reach throughout the POES (see Figure 18), as well as achieving Tier 3 habitat response (e.g., use of the stream by multiple species: steelhead, Chinook salmon, bull trout, and westslope cutthroat trout).

Ecological function will be demonstrated by inter-annual fish distribution response to water transactions. Specifically, resource managers should track accessibility of restored stream reaches for specific species life-stage (e.g., spawning, holding, and rearing) and determine if historically inaccessible or unfavorable reaches become accessible and are being utilized by one or more life-stages. These reaches may be related to other streams in the sub-basin to assess distribution and movement within a larger regional scale. Also, multiple year efforts provide a basis for tracking individual year-classes through time to track the long-term restoration metrics typical of Tier 4.

A high level of collaboration among multiple partners and agencies is typically necessary to quantify Tier 4 FRAF actitivites. For tracking and understanding fish species, IDFG, NOAA fisheries, USFWS, BPA, and many other restoration partners are tracking fish migration using PIT tag sites throughout the Columbia Basin. Fish survival through hundreds of miles of the Columbia River is tracked and coupled with annual fish surveys in local watersheds such as Kenney Creek (e.g., HUC 10 and HUC 12 scale) within the Lemhi sub-basin (HUC 8). This collaborative is funded, in part, through restoration programs for specific ESA listed fish species such as steelhead, Chinook Salmon and bull trout. Many of these watersheds in the Lemhi sub-basin, such as Kenney Creek have been reconnected due to water transaction investments made by NFWF and BPA supporting IWRB, IDWR and IDFG. Studying these inter-annual fish population trends is vital for fish species targeted restoration.

Kenney Creek, ID was monitored for fish distribution by the Idaho Department of Fish and Game from 2009 through 2016 from the Lemhi River upstream to the confluence with East Fork Kenney Creek (approximately 6 miles). Juvenile steelhead distributions in this reach pre- and post-transaction are shown in Figure 21, where black triangles denote locations were fish were observed. Results from these annual fish surveys demonstrate expanding reach utilization by juvenile steelhead for rearing following the 2011 and 2013 water transactions. In 2009, there were only two locations where fish were observed in lower Kenney Creek, but after 2013 fish were observed throughout the lower reach of the creek as holding and rearing conditions improved. Analysis of flow data for passage and over-summering conditions indicates that there have not only been connectivity improvements as a result of this project, but also additional steelhead spawning, extensive upstream utilization for juvenile rearing, and increased fish abundance throughout the system (Uthe *et al.*, 2017). FRAF activities on Kenney Creek illustrates how flow data, along with other metrics may be used to assess the ecological outcome of water transactions in the context of the stated EFO.

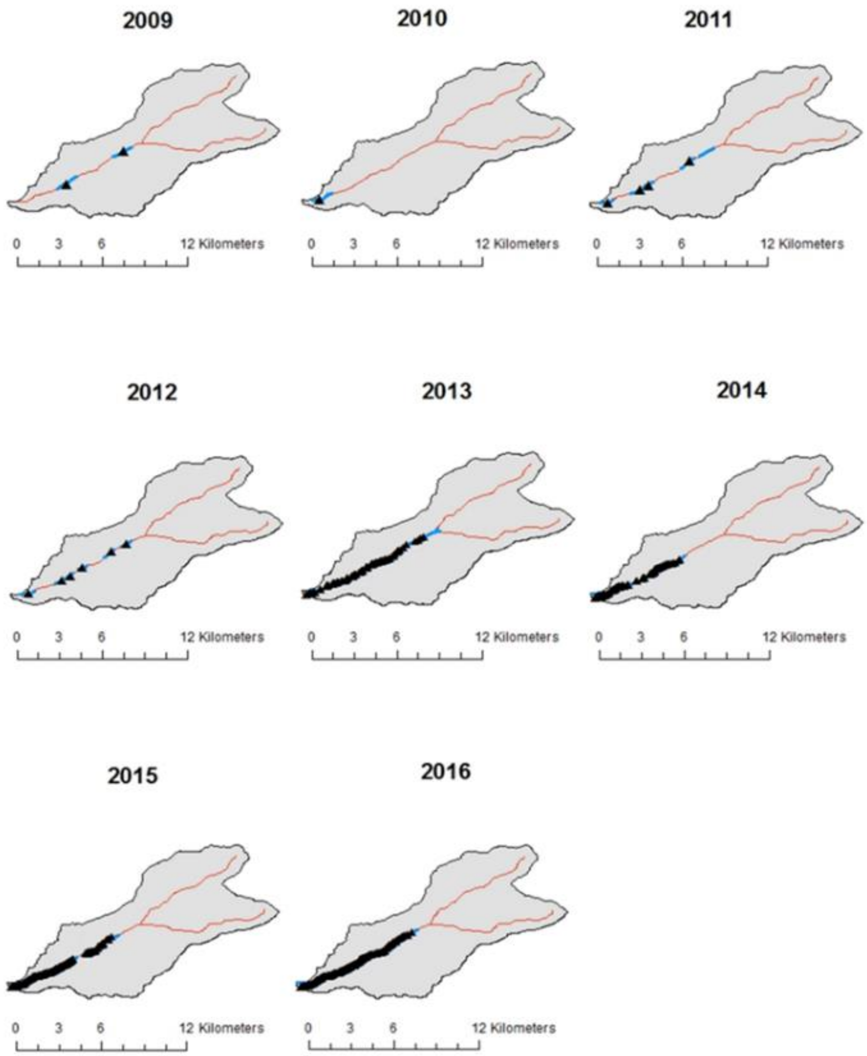


Figure 21. Idaho Department of Fish and Game fish juvenile fish surveys on Kenney Creek, located in the Lemhi sub-basin of Idaho. Juvenile steelhead fish survey reaches are marked in blue, non-surveyed reaches in red, locations where fish were observed are denoted with a black triangle (source: IDFG and IWRB).

IDFG has undertaken a restoration and species management approach for Chinook salmon similar to the effort for steelhead. This approach will track status and trends and improve understanding of population dynamics. Annual fish surveys have not detected any spawning Chinook salmon in Kenney Creek as of 2016; however, juvenile Chinook salmon have been observe accessing and utilizing lower reaches of Kenny Creek for rearing habitat, further suggesting conditions are improving there (Uthe *et al.*, 2017).

Kenney Creek FRAF monitoring and tracking for all tiers continues to provide ongoing assistance with instream stewardship to continue to strive for optimal biological effectiveness. Monitoring should continue to expand and adapt to further understand and quantify existing and other identified key ecosystem parameters. Examples include identify passage barriers in the upper system (e.g., above East Fork Kenney Creek), quantify water temperature in the lower reaches, inventory substrate conditions, catalog riparian conditions, and assess available physical habitat. The Tier 4 activities associated with fish and biological monitoring, as noted above, should extend beyond Kenney Creek to improve characterization of targeted species and local watershed ecosystem function and flow restoration effectiveness at the sub-basin scale and, as feasible, the larger regional scale.

5. Closing

The Flow Restoration Accounting Framework is a stewardship approach designed to identify, monitor, quantify, and track environmental instream flows to maintain the ecological integrity of streams and associated ecosystem services. The FRAF approach is designed to provide guidance to flow restoration practitioners and conservation organizations working to improve instream flow conditions throughout the western U.S. The approach encompasses all potential ecological flow objectives, whether focused on hydrology, geomorphology, biology, water quality, or connectivity. The FRAF may be applied to environmental flows resulting from any type of water conservation action, assuming the new flows are measurable. Potential project types include water transactions, irrigation efficiency projects, infrastructure changes and on-farm irrigation or crop shifts. Additionally, the FRAF includes tools to identify hydrologic impairments, develop flow restoration strategies, track project implementation, and quantify and analyze project effectiveness. Further guidance is provided for tracking discrete water transaction project hydrology information and data management over the entire life of the project. In sum, the FRAF is an adaptable, overarching approach that may be used as guidance for all types of hydrologic restoration projects (e.g., drought flow responses, protective flows, or restorative flows).

Flow restoration projects are fundamentally collaborative efforts, where partnerships are often a necessary element of successful projects. Combining collaboration with a multidisciplinary stewardship approach increases the prospect of producing lasting, effective, and robust outcomes. The FRAF assists organizations and individuals navigating the complex systems that are common in western water management to find balanced solutions to improve conditions in streams and waterways.

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