Instream Flow Methodology

A Review of Historical Approaches

George Guillen

2-11-09

Presented to BBEST Galveston Bay Group

Instream Flow

- **What is an Instream Flow?** An instream flow is an amount of water running in a river, usually measured by the volume moving down the channel in a specified amount of time (discharge).
- A variety of instream flows are required to maintain a healthy river.
- How much water should flow in rivers for a healthy environment?
- Instream Flow Studies and Programs – A State Experience. Some Federal Guidance early on – Bovee, Stalnaker, et al. USFWS → USGS. Salmonid Fisheries.
- Instream Flow Council – technical support

Instream Flow

- Flows – amount, frequency, duration
  - Velocity
  - Instream habitat vs. flows
- Geomorphology – sediment movement, changes in stream morphology
- Biology
  - Spawning
  - Rearing
  - Adult Habitat

Features of Water Flow

- Water quality – temperature, dissolved oxygen, suspended sediment
- Water quantity/ availability/ abundance
- Constant flow – groundwater, base flow, drought conditions
- Maintaining springs
- Flow levels – hydrology
- Channel stability

A POTENTIAL GOAL: Maintenance of the natural environment in and along the river

- Natural beauty and aesthetics
- Wildlife and riparian habitat supported along the river
- Health of tributaries
- Regeneration of the land
- Floodplain connectivity
- No impoundments/ dams/ development
- Living in harmony with the natural flow of things
- Natural ability of the river
- Freshwater inflows to bay and estuaries

Additional Goals

- Recreation Bird and wildlife viewing
- Hunting and fishing
- Swimming
- Canoeing Outdoor education
- ** Tribal/cultural purposes

Additional Goals

- Resource for humans Water source for livestock/ irrigation/ drinking water
- Economic growth and development including tourism
- Drainage Impact on land value
- Tax deduction for floodplain
- Historical value/aspects of river and tributaries How it connects us

Environmental flow approaches

The approaches developed in various countries around the world to define environmental flow allocations can be divided into four categories:

- Look-up tables **Historical Hydrology – minimum, max, little ecology**
- Desk top analysis **Historical Hydrology, hydrograph pattern, IHA**
- Functional analysis **Expert Input: Hydro & Biology; Build Block**
- Hydraulic habitat modelling **Flow-Habitat-Fish Models: e.g. PHABSIM**

Defining environmental river flow requirements – a review

Mike Acreman and Michael J Dunbar

Hydrology and Earth System Sciences, 8(5), *861–876* (2004)

Table 3. Some advantages and disadvantages of different methods and characteristics of setting environmental flows.

Method type	*Sub-type*	*Advantages*	*Disadvantages*
Look-up table	Hydrological	Cheap, rapid to use once calculated	Not site-specific. Hydrological indices not valid ecologically
	Ecological		Ecological indices need region-specificdata to be calculated
Desk top	Hydrological Hydraulic Ecological	Site specific Limited new data collection	Long time series required No explicit use ofecological data Ecological data time consuming to collect
Functional analysis		Flexible, robust, more focused on whole ecosystem	Expensive to collect all relevant data and to employ wide range of experts. Consensus of experts may not be achieved.
Habitat modelling		Replicable, predictive	Expensive to collect hydraulic and ecological data

Defining environmental river flow requirements – a review

Mike Acreman and Michael J Dunbar

Hydrology and Earth System Sciences, 8(5), *861–876* (2004)

Approaches: Another Classification

- Standard Setting Methods (desktop and field)
  - Tenant Method
  - Wetted Perimeter
- Instream Flow Incremental Method:
  - Physical Habitat Species Curve Models
    - Species and river specific
    - Species Guilds
    - Off the shelf models
- Geomorphology (desktop in part)
  - Implicit – functional flow, geomorphology, fish habitat
  - Natural Hydrograph

Table 2.1. The opposite ends of the problem-solving spectrum.

Standard-setting	Incremental
Low controversy project	High controversy project
Reconnaissance-level planning	Project-specific
Few decision variables	Many decision variables
Inexpensive	Expensive
Fast	Lengthy
Rule-of-thumb	In-depth knowledge required
Less scientifically accepted	More scientifically accepted
Not well-suited for bargaining	Designed for bargaining
Based on historical water supply	Based on fish or habitat

*** MINIMUM FLOWS USUALLY OBJECTIVE**

USGS Bovee 1995.

Tennant Method

Table 2.2. Instream flow analysis based on the Tennant method (Tennant 1976).

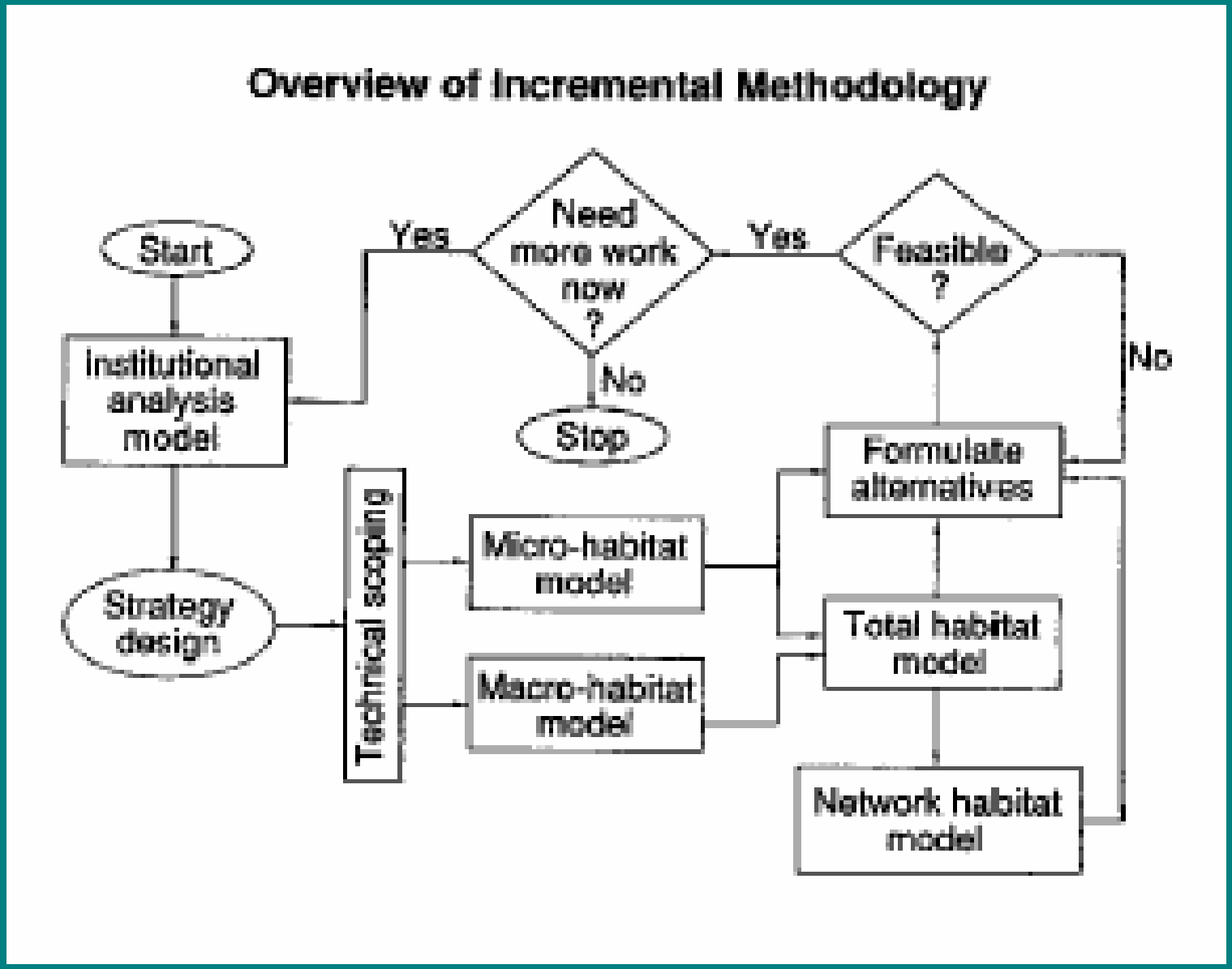
Health of habitat	Percent of mean annual flow	
	October–March	April–September
Flushing or maximum	200	200
Optimum	60–100	60–100
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair	10	30
Poor	10	10
Severe degradation	<10	<10

Based on trout streams in Montana, evaluating hydrology, habitat relationships for trout.

Used 10 years of data.

Desktop Method: Requires long term data sets of hydrology

USGS Bovee 1995.



USGS Bovee 1995.

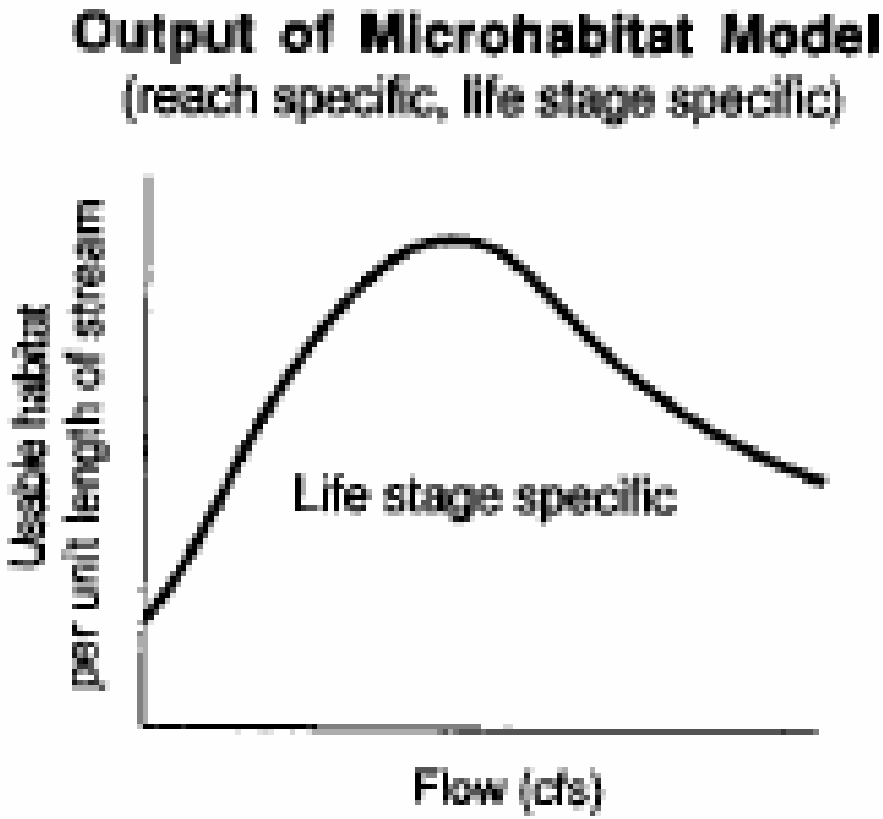


Fig. 2.2. Flow-habitat relation developed by using PHABSIM.

But first you need suitability curves!!!

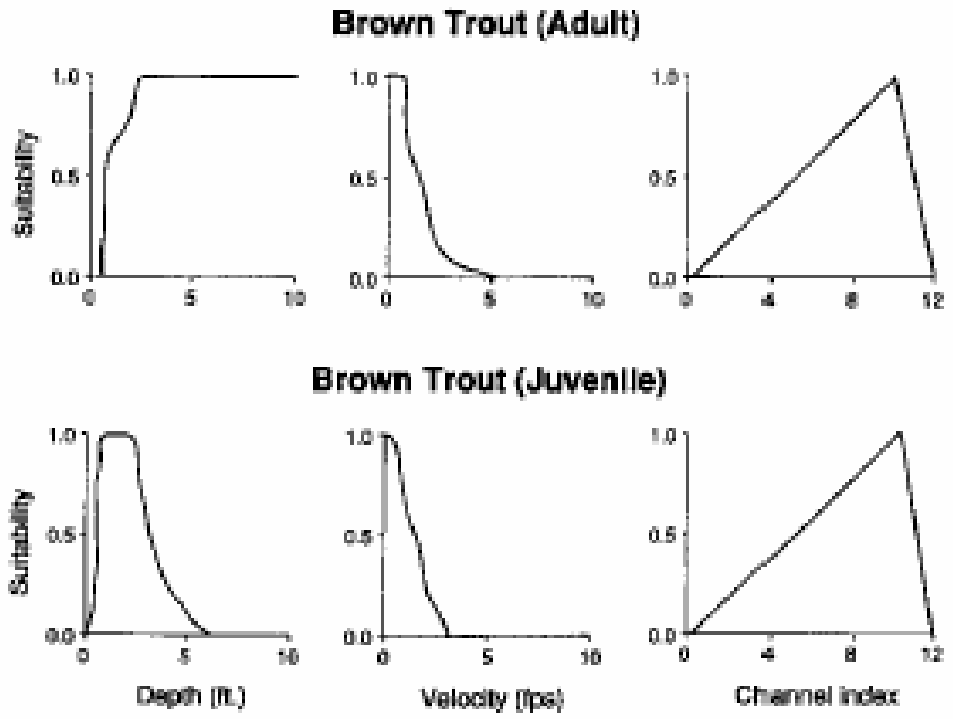


Fig. 2.3. Suitability-of-use curves for brown trout.

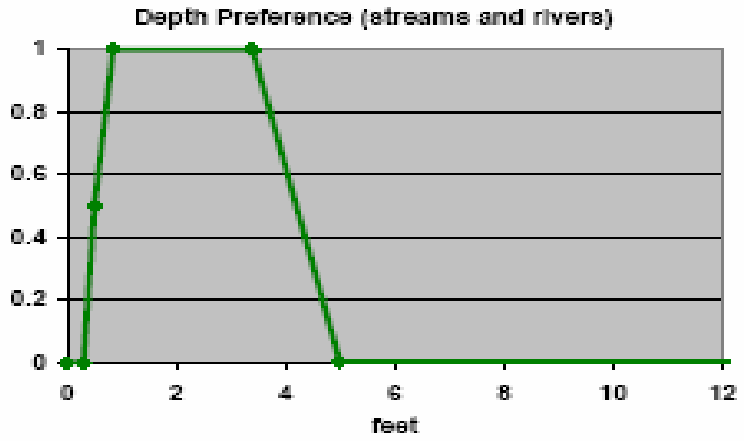
Source: Previous studies or new data
Preferred same or similar species, same river
How: snorkel surveys, use of habitat – works good in clear rivers
Turbid rivers – seining, electroshocking, acoustics – not as precise

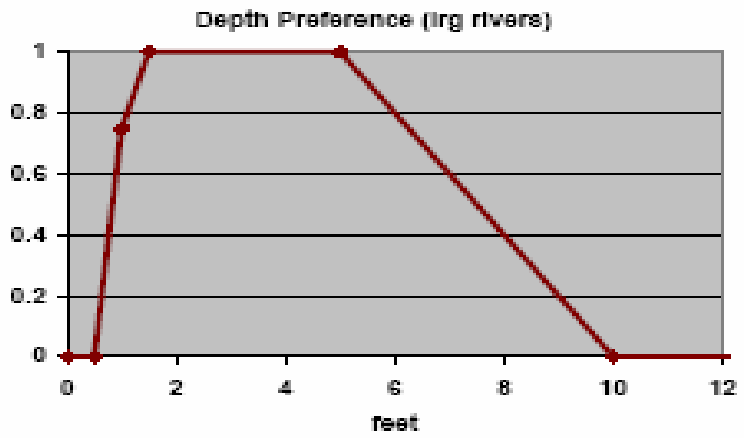
Single Species Habitat Suitability Curves (off the shelf or river specific

FIGURE 1a. Chinook Salmon (Oncorhynchus tshawytscha) Spawning Depth Preference
For all subspecies: Use streams and rivers when the mean annual flow (maf) <1,000 cfs and the large rivers when maf >1,000 cfs (2 studies, 46 redds plus Caldwell, Caldwell & Bruya 1987)

Plotted depth (feet)	Recommended depth preference	
	streams and rivers	large rivers
0.00	0.00	0.00
0.30	0.00	-
0.50	0.5	0.00
0.85	1.00	-
1.00	-	0.75
1.50	-	1.00
3.40	1.00	-
3.50	-	-
4.50	-	-
5.00	0.00	1.00
10.00	-	0.00
99	0.00	0.00

Large rivers include the Skagit and White rivers but exclude the Columbia and Snake rivers. In mainstem Columbia or Snake rivers, depth preference of 1.0 continues to the limit of light penetration (about 35 ft) (SOURCE Hanrahan???) .





INSTREAM FLOW STUDY GUIDE LINES: Technical and Habitat Suitability Issues including fish preference curves. UPDATED, April 05, 2004.Error Correction Update 2/12/2008. State of Washington.

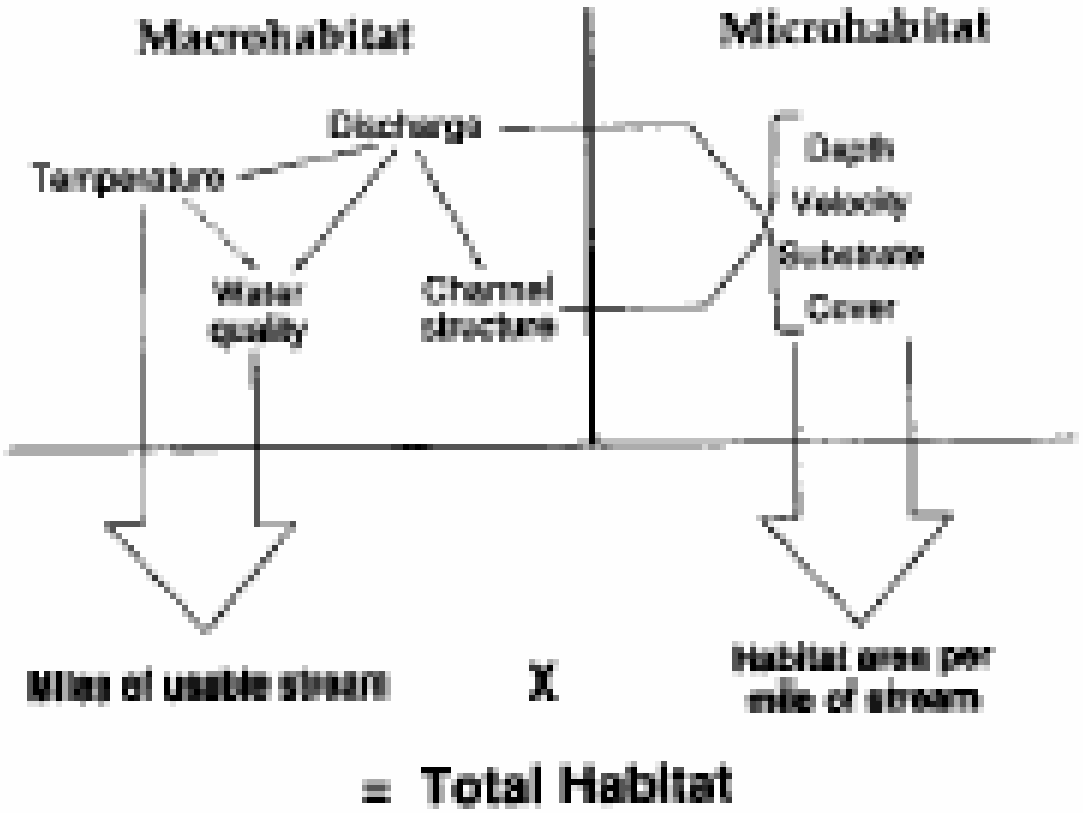
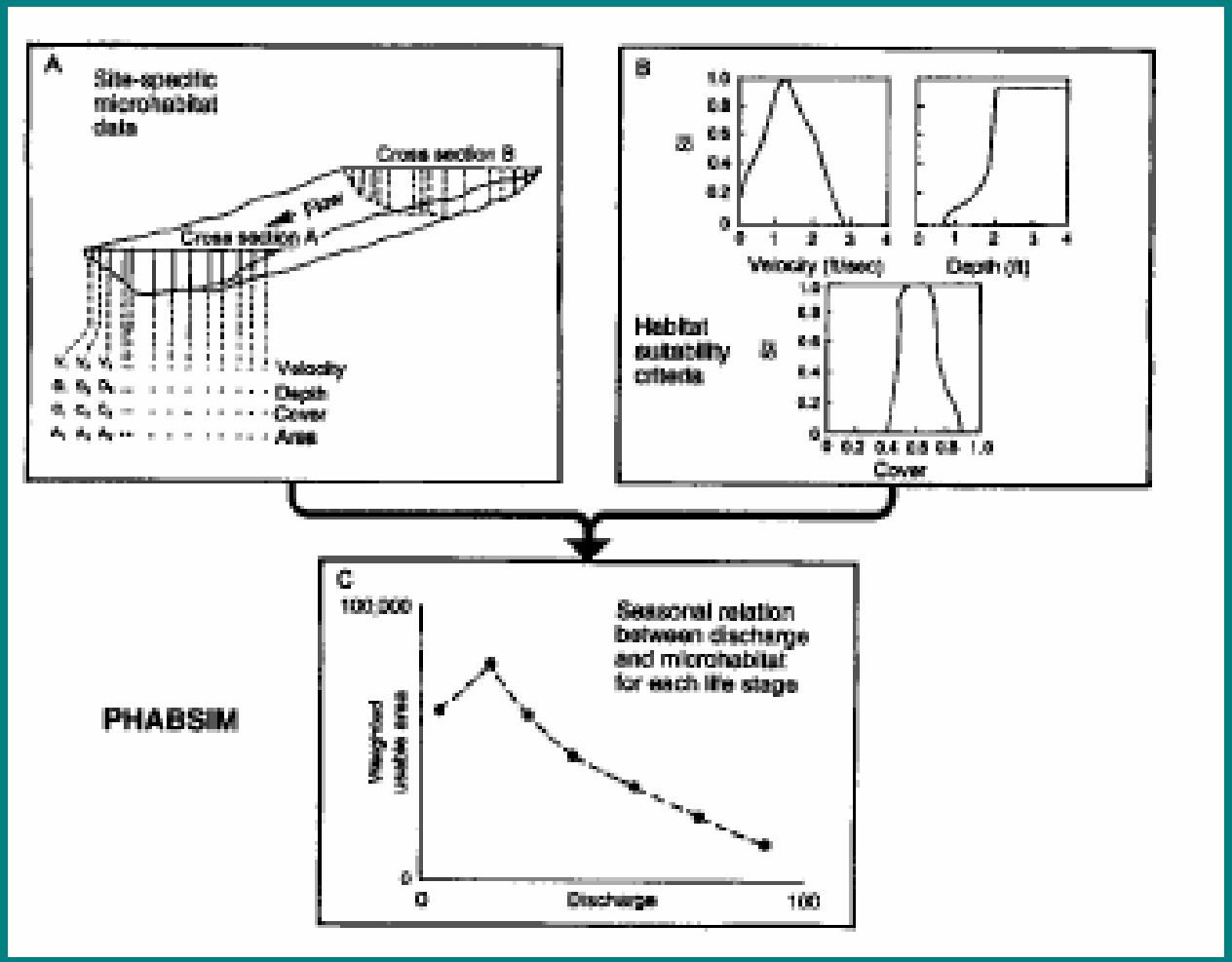


Fig. 5.2. Total habitat combines elements of macrohabitat and microhabitat.

Calculation of Habitat vs. Flow



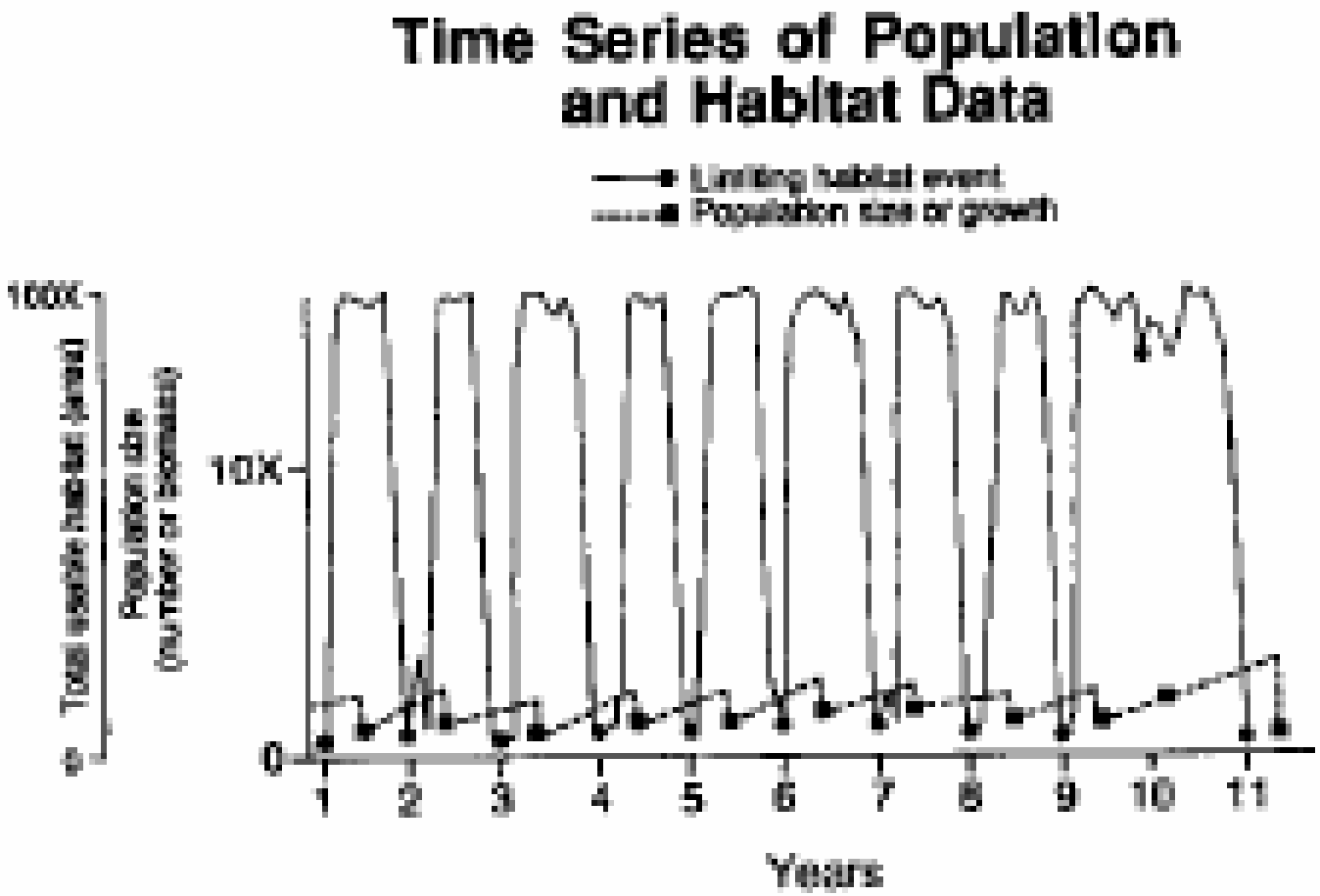


Fig. 2.4. Example fish population size related to usable habitat area using the IFIM.

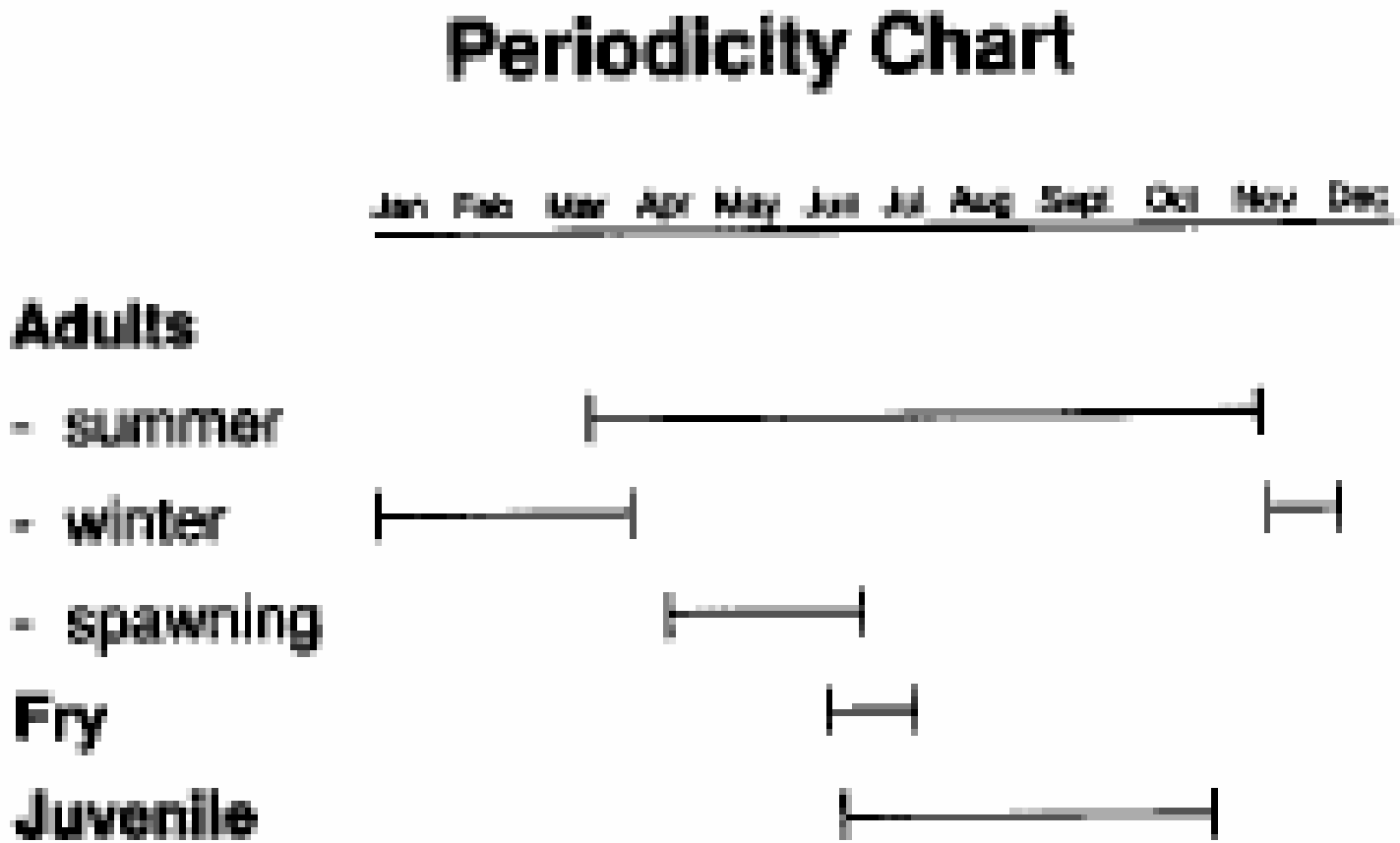
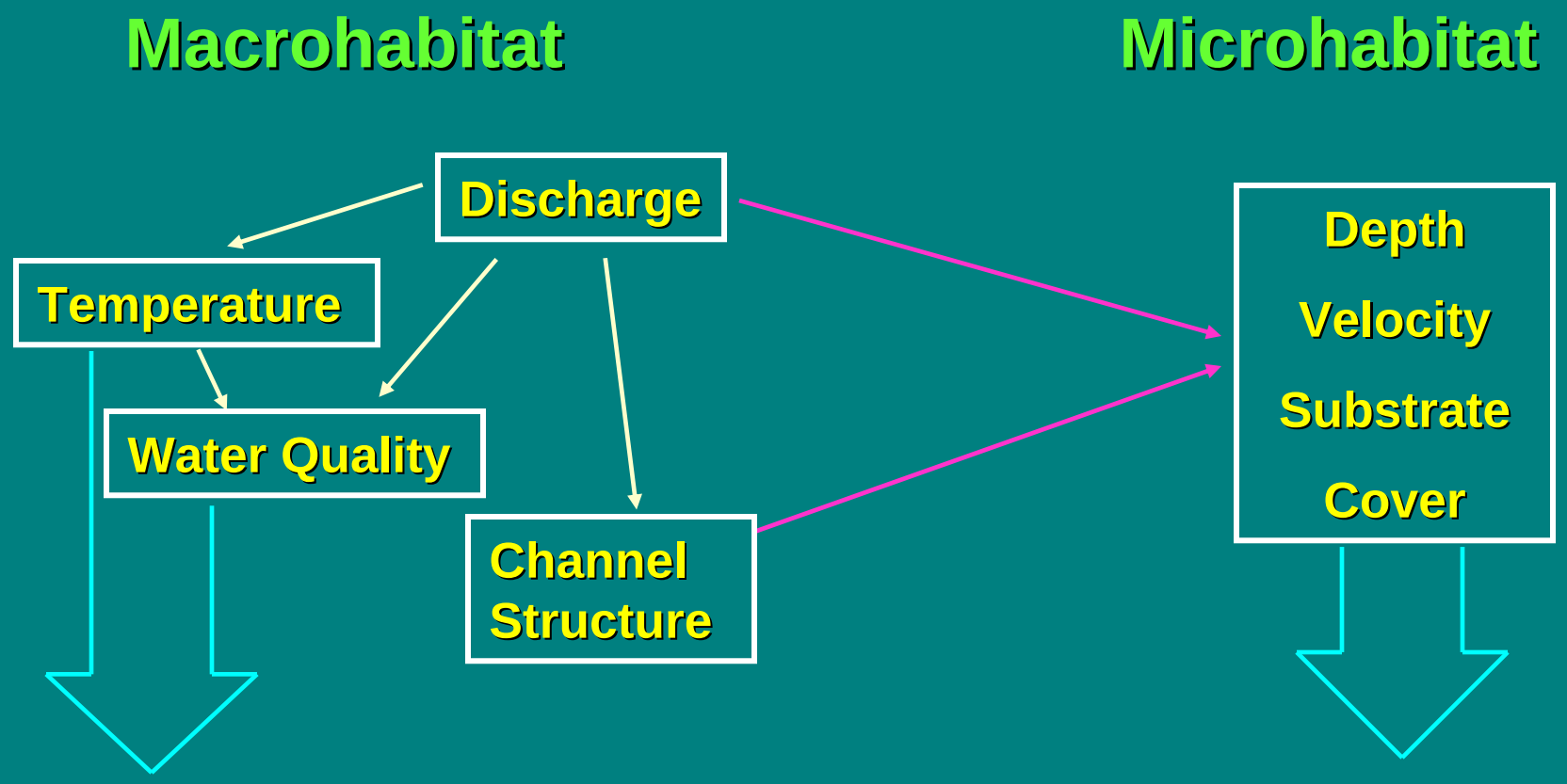


Fig. 4.1. Species periodicity chart.

PHABSIM



Kilometers of Usable Stream × Habitat area per kilometer of stream

= TOTAL HABITAT

Stalnaker et al 1995

PHABSIM

- The Physical Habitat Simulation System (PHABSIM) has been a central part of the U.S. Government's method of setting minimum stream flow requirements
- Other flavors – RHABSIM
- PHABSIM – 2D

Guild Based (e.g. Dilts et al. 2003).

Table 1. Guild-based habitat suitability criteria evaluated and the species/groups that they were selected to represent

Guild-based criteria	Represented species/group
Shallow, fast, coarse	Spawning cyprinids, adult darters, and some macroinvertebrates, including multiple mussel species
Shallow, fast	Adult cyprinids and darters inhabiting sand bed riffles
Shallow, slow, fine	Spawning centrarchids
Shallow, slow, cover	Cyprinid and catostomid young-of-year
Shallow, slow	Adult cyprinids and the young-of-year of multiple species
Deep, fast, cover	Some adult catostomids and some macroinvertebrates
Deep, fast	Adult catostomids and cyprinids
Deep, slow, cover	Adult centrarchids and other cover-dependent species
Deep, slow	Some adult centrarchids and ictalurids
Deep, stream margin, root mats	Some mussel species including dwarf wedgemussel

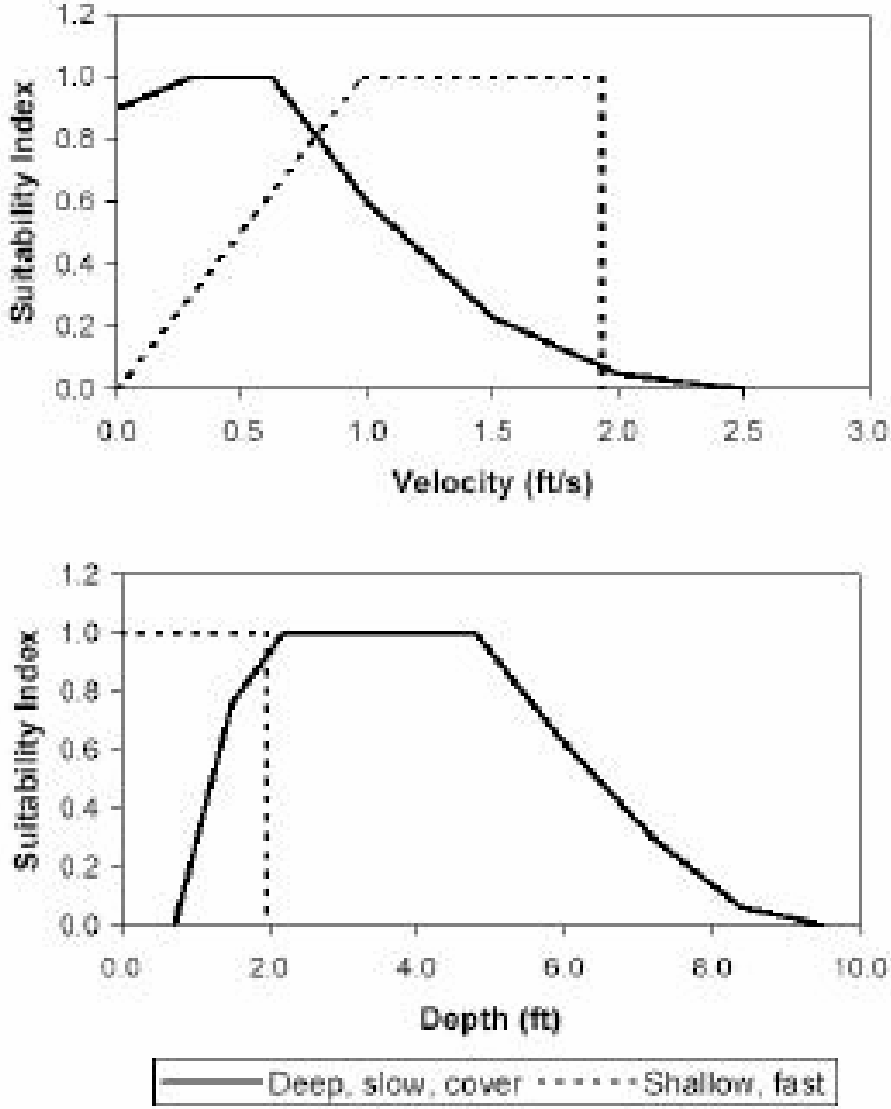


Figure 2. Example velocity and depth habitat suitability criteria developed to represent the range of habitats preferred by two differing habitat-use guilds in Swift Creek, North Carolina.

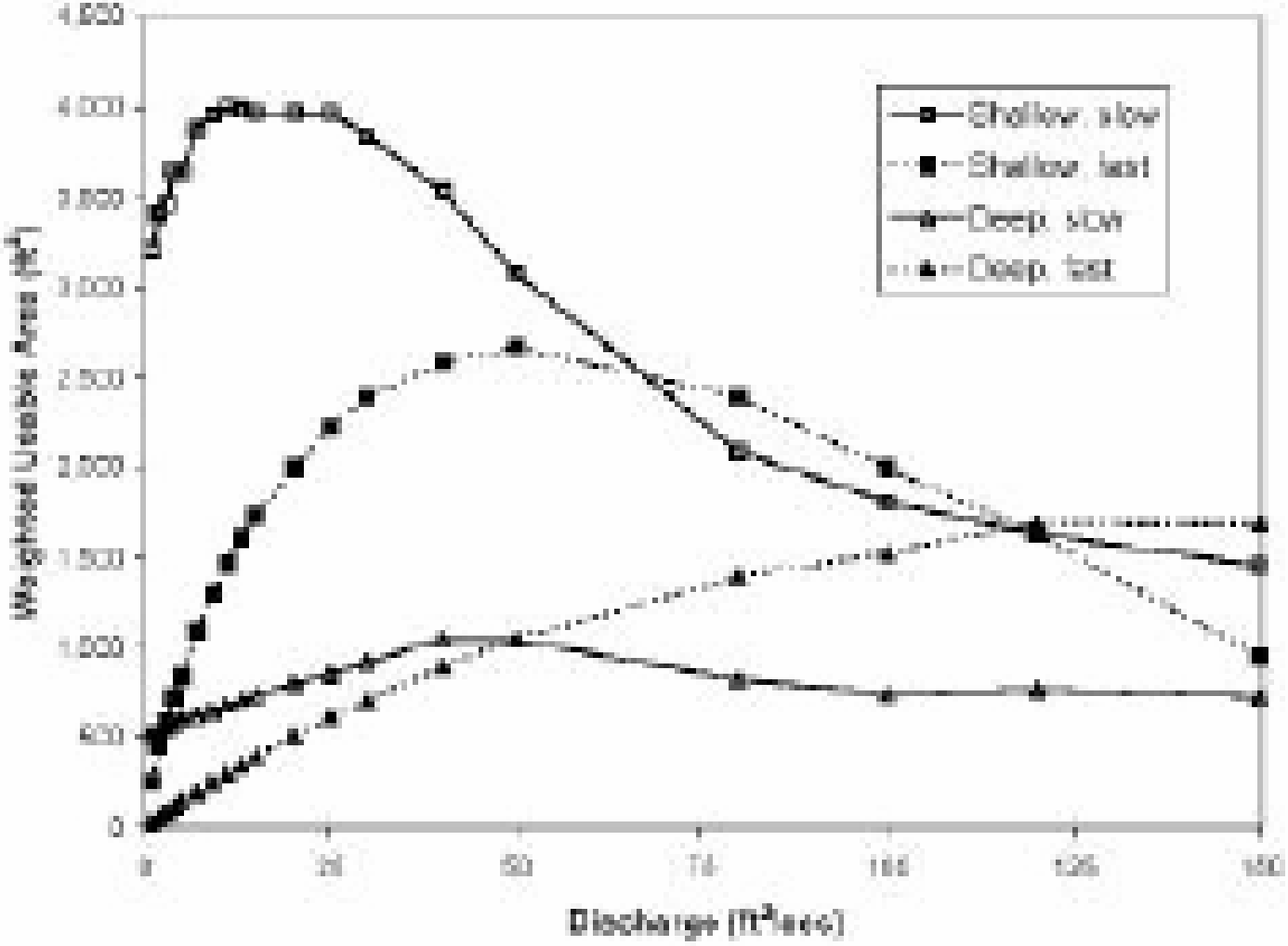


Figure 4. Example weighted usable area versus flow relationships developed for four of the habitat-use guilds evaluated in the study.

TABLE 8-2

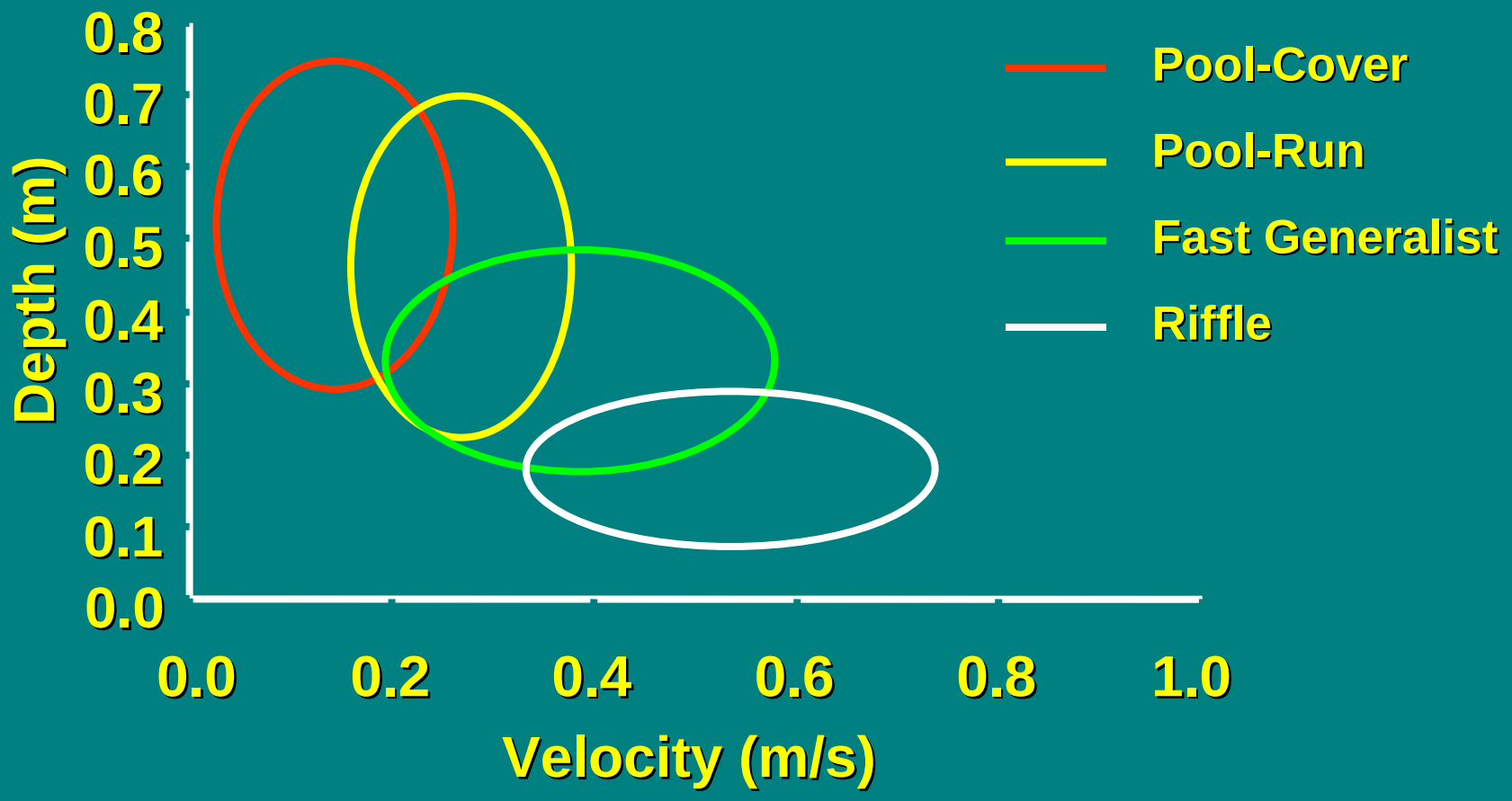
SPECIES AND HABITAT GUILD ASSIGNMENT FOR THE PEE DEE RIVER INSTREAM FLOW STUDY

Scientific Name	Common Name	Habitat Types and Guilds[1,2,3]			
		Shallow Slow	Shallow Fast	Deep Slow	Deep Fast
Petromyzontidae	**Lampreys**				
Petromyzon marinus	sea lamprey		A		
Acipenseridae	**Sturgeons**				
Acipenser oxyrinchus	Atlantic sturgeon				S
Acipenser brevirostrum	shortnose sturgeon				S
Lepisosteidae	**Gars**				
Lepisosteus osseus	longnose gar	A, J		A, J, S	
Amiidae	**Bowfin**				
Amia calva	bowfin			A, S	
Anguillidae	**Freshwater eels**				
Anguilla rostrata	American eel	J		A, J	J
Clupeidae	**Herrings**				
Dorosoma cepedianum	gizzard shad	A, J		A, J, S	
Dorosoma petenense	threadfin shad	A, J		A, J, S	
Alosa mediocris	hickory shad			J, S	
Alosa sapidissima	American shad			J	J, S
Alosa aestivalis	blueback herring			J, S	
Cyprinidae	**Carps and Minnows**				
Cyprinus carpio	common carp	J, S		A, J, S	
Notemigonus crysoleucas	golden shiner	A, J, S		A, J, S	
Hybognathus regius	Eastern silvery minnow	J, S		A, J, S	
Nocomis leptocephalus	bluehead chub		A, S		
Cyprinella analostana	satinfin shiner	A, J, S		A, J, S	
Cyprinella nivea	whitefin shiner	A, J	S	A	
Cyprinella pyrrhomelas	fiery black shiner	A, J	S	A	
Notropis altipinnis	highfin shiner	J, S		A	
Notropis amoenus	comely shiner	A, J	S	A, J	
Notropis hudsonius	spottail shiner	A, J	S	A, J	
Notropis petersoni	coastal shiner	A, J	S	A	
Notropis scepticus	sandbar shiner	A, J	S	A	
Catostomidae	**Suckers**				
Catostomus commersoni	white sucker	J	S	A, J	A
Minytrema melanops	spotted sucker	J	S	A	
Scartomyzon spp.	brassy jumprock	J	S	A	A

Tarbell and Associates 2004 – North Carolina Power plant Study

D. J. Orth, 2003

- North Fork Shenandoah Guild Structure



Riffle Guild

greenside darter	***Etheostoma blennioides***
mottled sculpin	***Cottus bairdi***
central stoneroller	***Campostoma anomalum***
bluehead chub (J)	***Nocomis leptocephalus***
river chub (Y)	***Nocomis micropogon***
longnose dace	***Rhinichthys cataractae***

Orth 2003

Images from Jenkins and Burkhead 1994

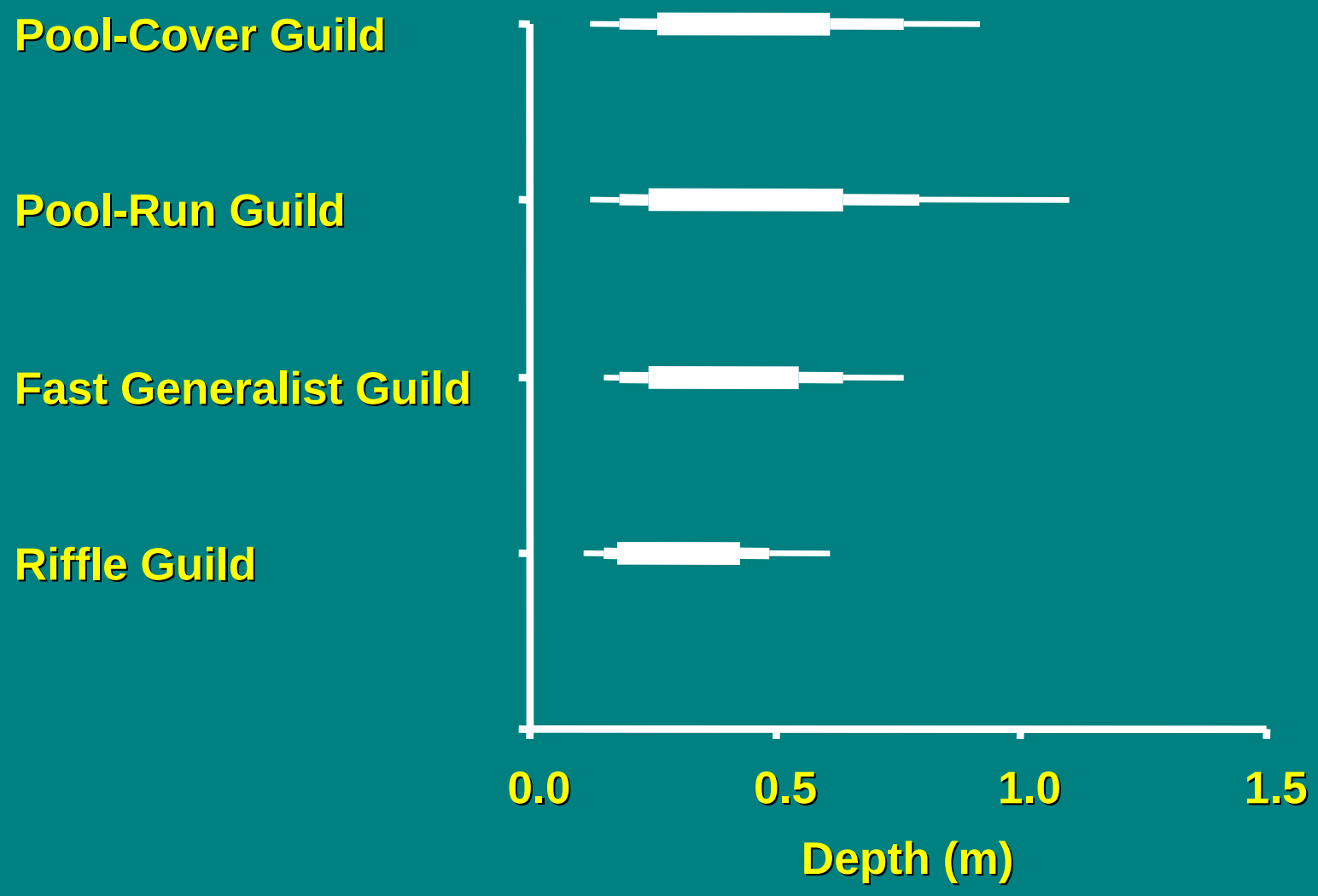
Fast generalist Guild

potomac sculpin	Cottus girardi
margined madtom	Noturus insignis
roseyface shiner	Notropis rubellus
comely shiner	Notropis amoenus
satinfin shiner (A)	Cyprinella analostana
spotfin shiner (A)	Cyprinella spiloptera
bluehead chub (A)	Nocomis leptocephalus
fallfish (J&Y)	Semotilus corporalis

Orth 2003

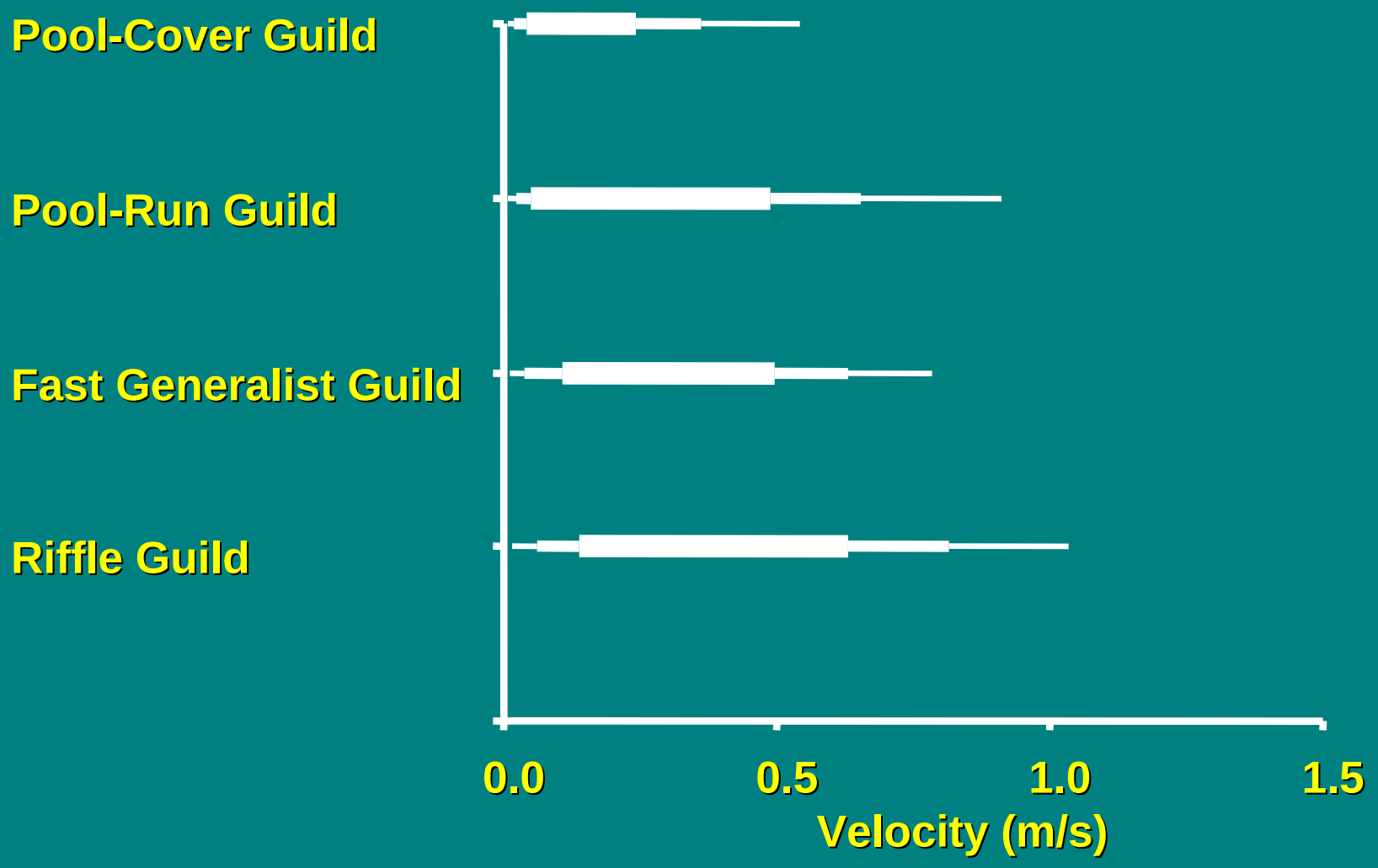
Images from Jenkins and Burkhead 1994

Guild Depth Criteria



Orth 2003

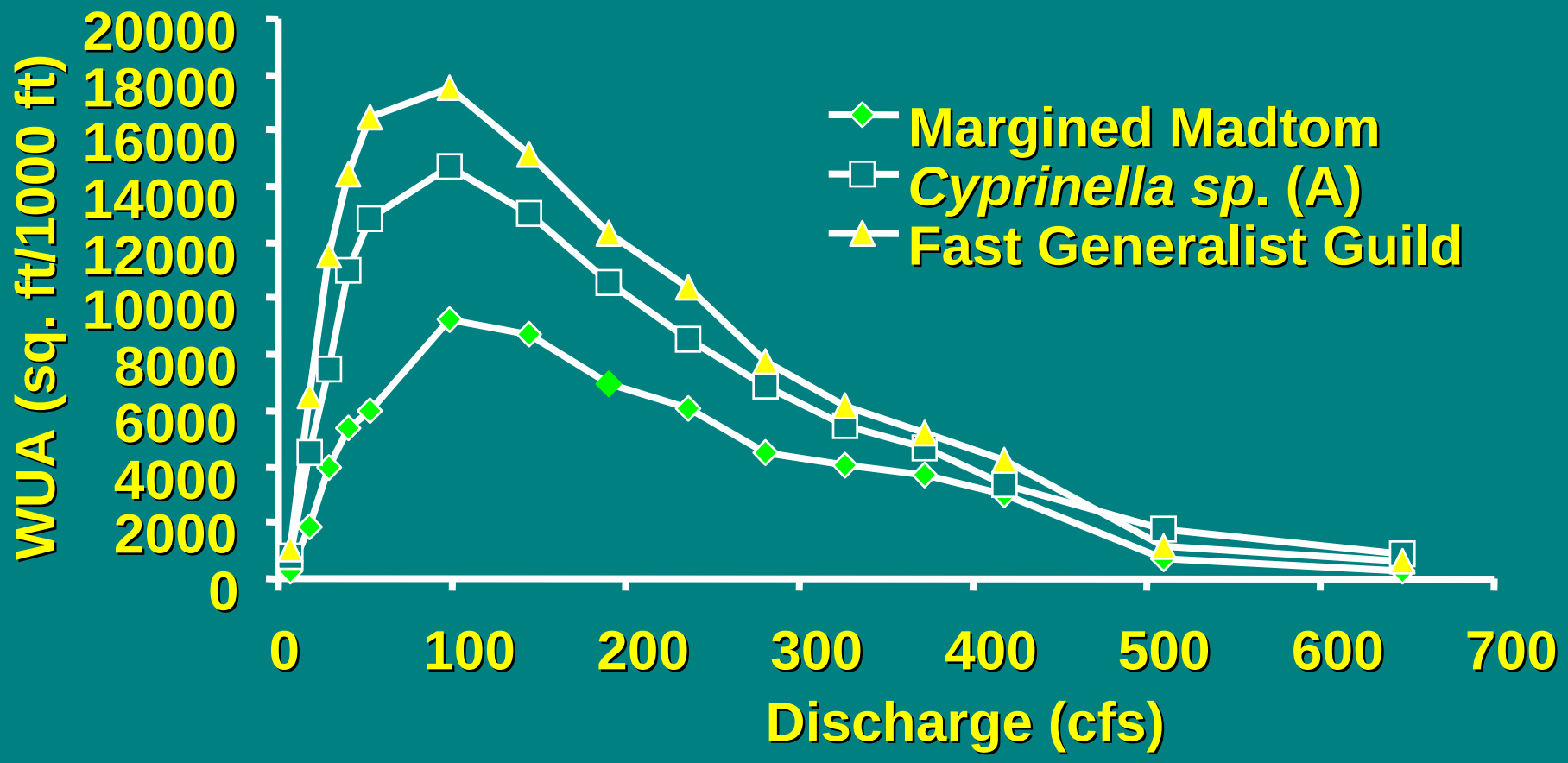
Guild Velocity Criteria



Orth 2003

PHABSIM Model Output

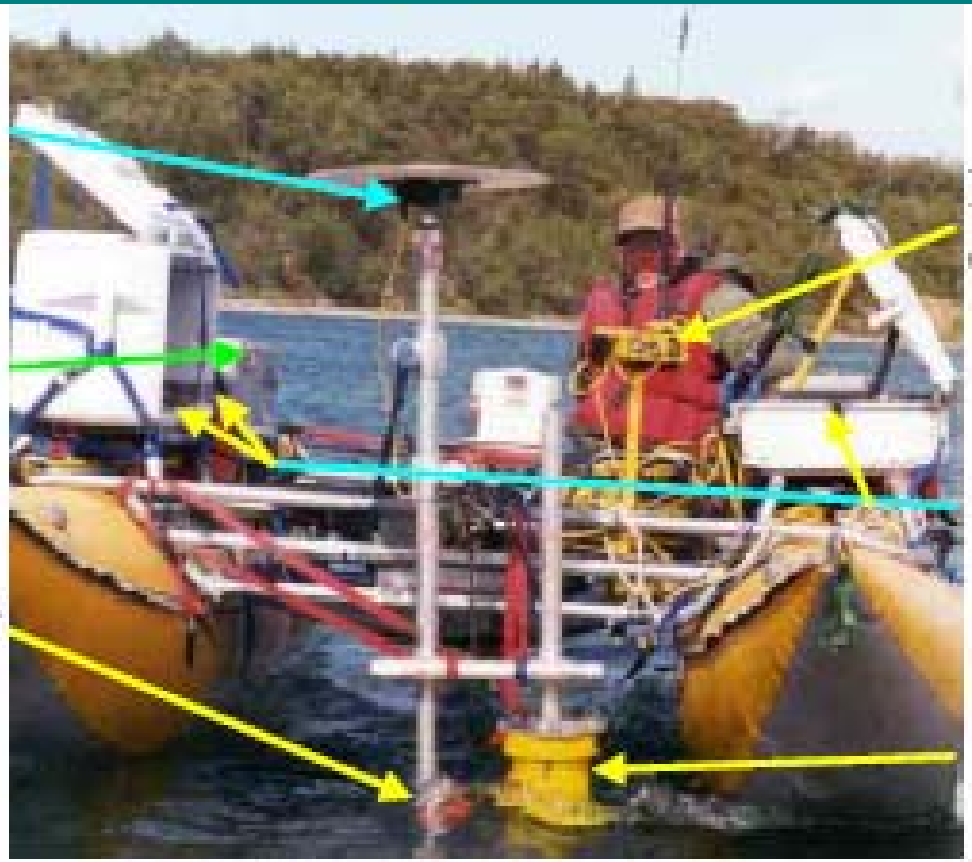
Depth, Velocity, and Channel Index



Orth 2003

PHABSIM – 2D

- Normally conducted by using 1D cross-section data and extrapolating across reaches by conducting inventory of sites
- 2D methods which utilize mesh design over larger area are now used too, more complex
- E.g. Hardy Phase II Study Report. Klamath River. Dam Operation: BOR.
- Hardy et al. 2001.
- Joint Project with USFWS


GPS
Real time correction
Power Supply
Computers
Sonar
ADP

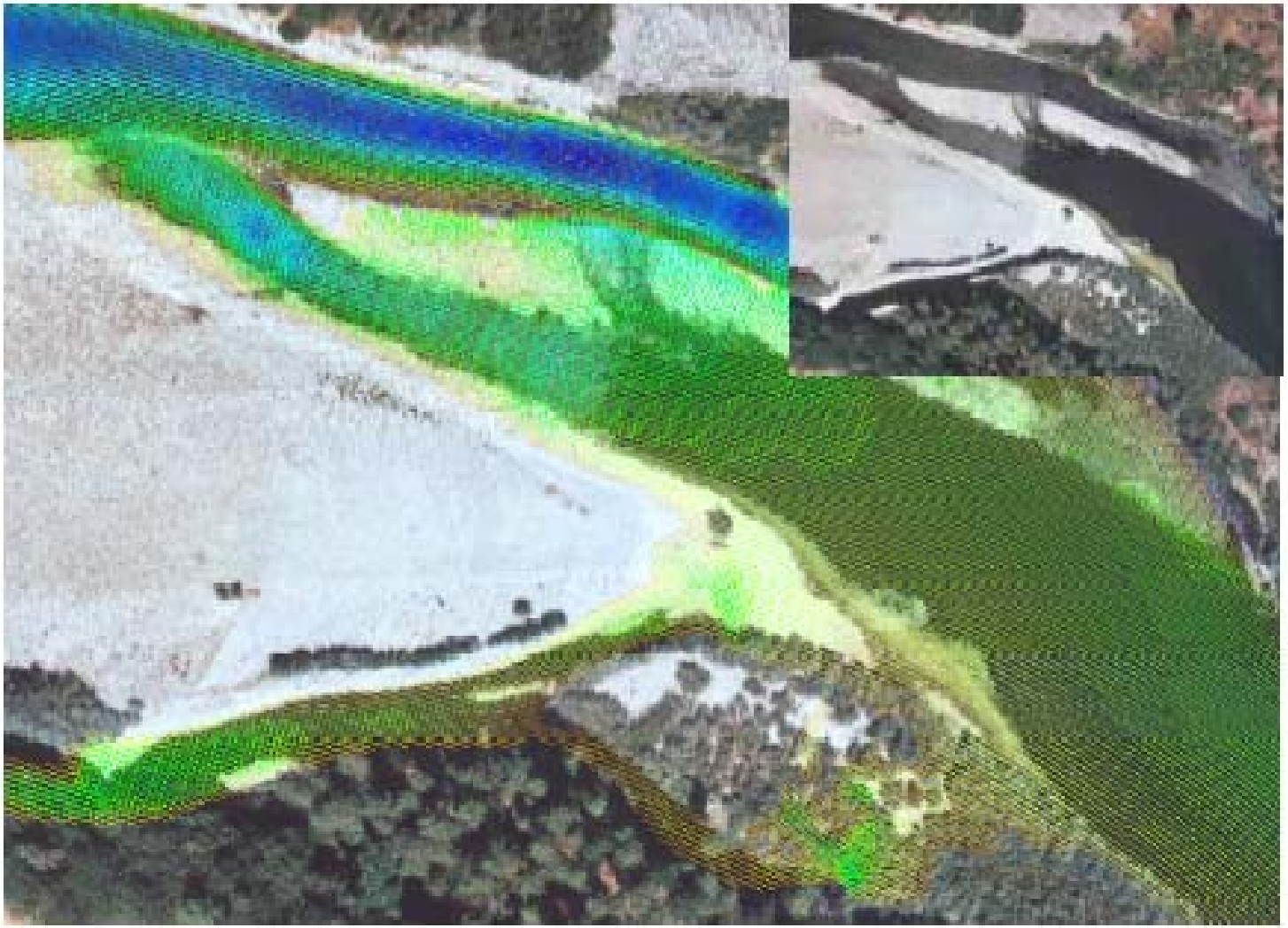


Figure 33. Example of the predicted velocity magnitude and their directions at the USU Seiad study site.

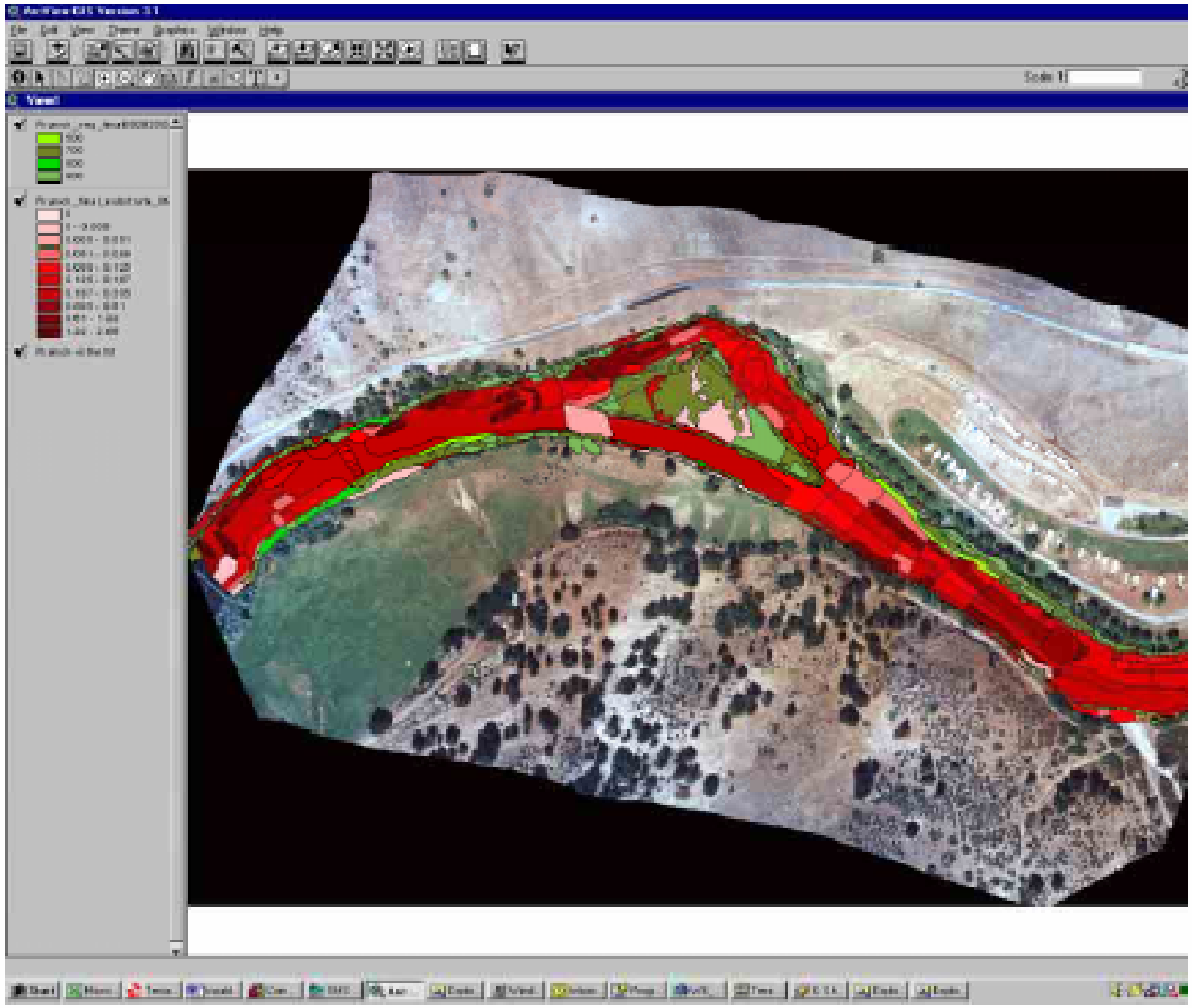


Figure 31. Example of spatially explicit assignment of variable roughness for different substrate and vegetation codes within the USU RRanch study site (vegetation roughness is in green and substrate roughness is in red).

Figure 23. Spatial distribution of delineated substrate and vegetation at the USU Seiad study site.

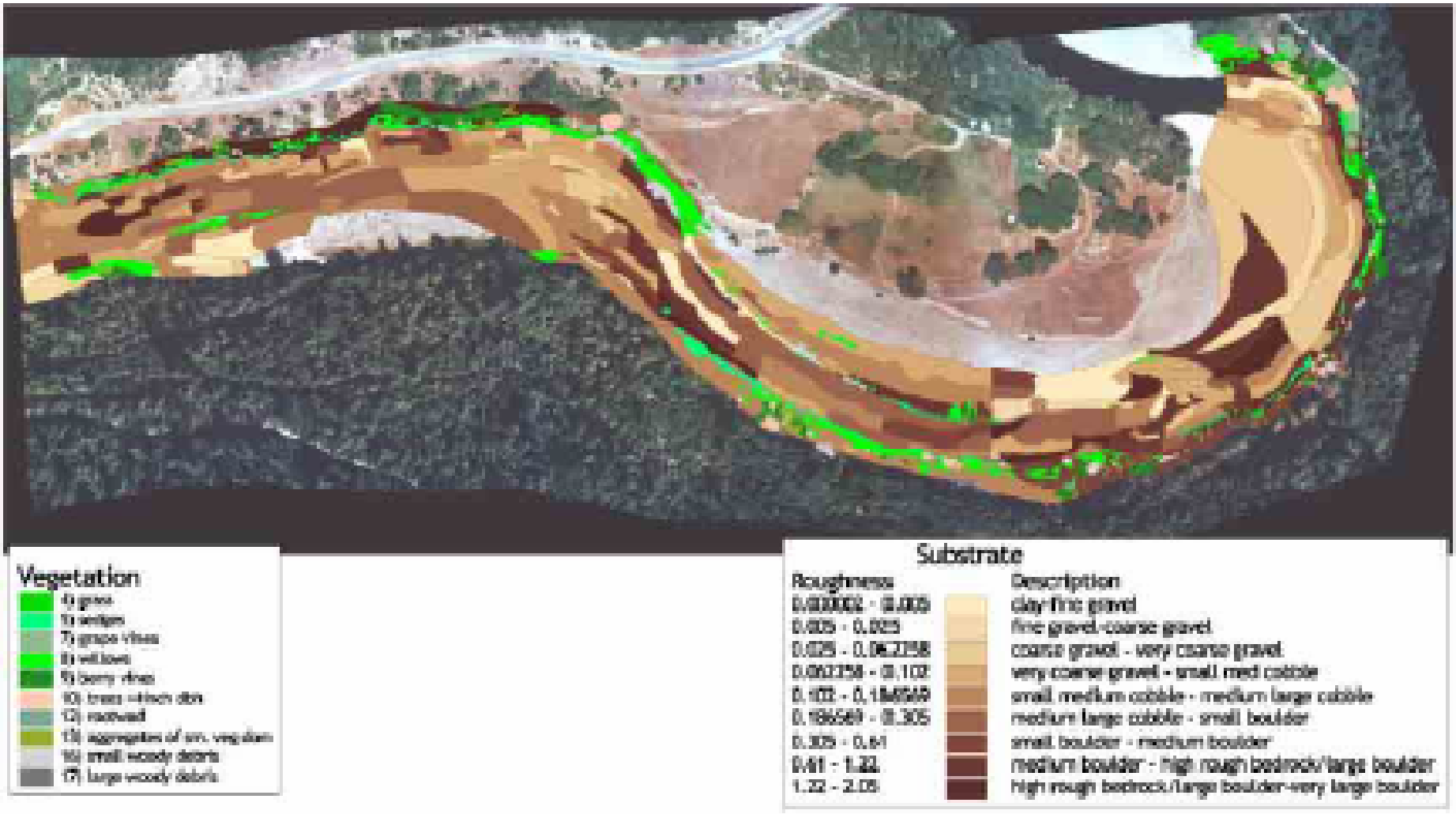


Table 29. Species and life stage periodicities for the main stem Klamath River between Iron Gate Dam and the estuary (hatching indicates occasional usage for that month).

Iron Gate to Shasta	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Chinook Fry												
Chinook Juvenile												
Chinook Spawning/Inc.												
Coho Fry												
Coho Juv												
Steelhead Fry												
Steelhead Spring Juv												
Steelhead Summer Juv												
Steelhead Generic Juv												

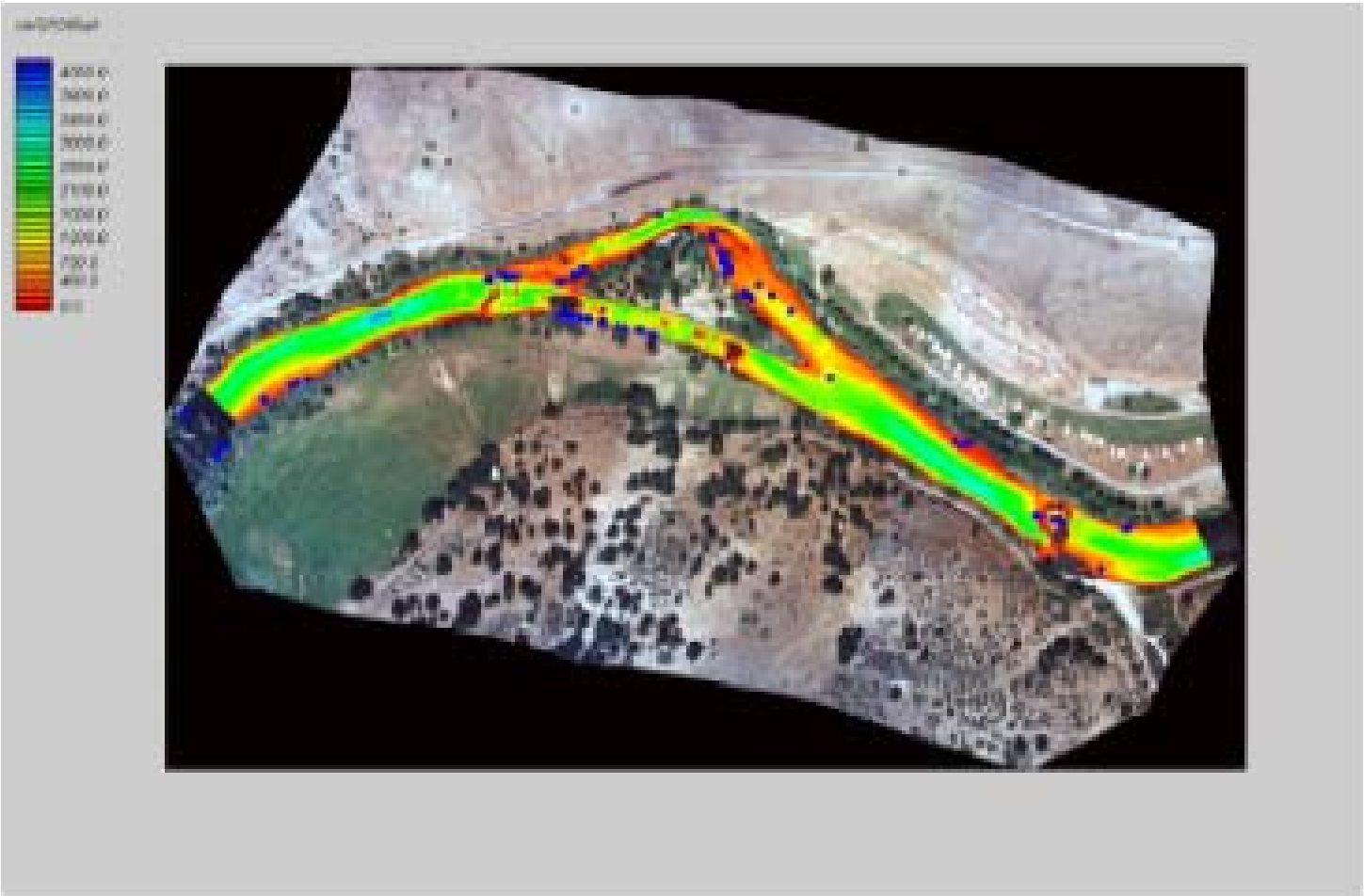


Figure B2. NEI Magnitude, with fish observations, for RRanch, Steelhead 160mm at 38cms.

VALIDATION !!!

Table 52. Percent of maximum habitat for the recommended monthly flows in the Iron Gate to Shasta River Reach at each exceedence flow level.

Composite Matrix	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
10	38	99	96	97	100	87	78	63	81	97	90	53
20	51	100	99	100	100	81	74	68	86	98	93	68
30	68	95	100	100	97	73	69	73	70	100	95	85
40	78	91	98	97	94	67	64	77	73	100	97	90
50	85	85	94	93	91	61	61	81	77	100	99	94
60	90	79	88	85	82	55	60	86	82	99	100	98
70	94	72	77	72	69	50	58	90	86	97	100	100
80	99	63	68	63	62	48	57	90	88	97	99	100
90	100	58	58	58	58	46	57	90	90	96	97	99

chinook spawning
chinook fry
coho fry
steelhead fry
steelhead 1+

Very complex project. Collection of life history data 10 year project, federal funding. Main management factors – reservoir operations, irrigation diversion, hydropower.

Continued work

- Additional species – Green Sturgeon, non-target species
- Determination of flow effects on migration and spawning.

MesoHABSIM

- Mesohabitat Simulation Model (MesoHABSIM) addresses the requirements of watershed-based management of running waters.
- It builds upon pre-existing physical habitat simulation models (e.g. PHABSIM) to predict an aquatic community's response to habitat modification.

MesoHABSIM

- Parasiewicz, P. 2001
- Expansion of IFIM Phabsim approach
- Focus on mesohabitat vs. microhabitat
- E.g. Riffle, Rapids, Cascades, Glide, Runs, Fast Run, Pool, Plunge Pool etc.
- 2D models
- Intensive Data Collection

Mesohabitat type	Description
Riffle	Shallow stream reaches with moderate current velocity, some surface turbulence and higher gradient. Convex streambed shape.
Rapid	Higher gradient reaches with faster current velocity, coarser substrate, and more surface turbulence. Convex streambed shape.
Cascade	Stepped rapids with very small pools behind boulders and small waterfalls.
Glide	Moderately shallow stream channels with laminar flow, lacking pronounced turbulence. Flat streambed shape.
Run	Monotone stream channels with well determined thalweg. Streambed is longitudinally flat and laterally concave shaped.
Fast run	Uniform fast flowing stream channels.
Pool	Deep water impounded by a channel blockage or partial channel obstruction. Slow flow. Concave streambed shape.
Plunge pool	Where main flow passes over a complete channel obstruction and drops vertically to scour the streambed.
Backwater	Slack areas along channel margins, caused by eddies behind obstructions.
Side arm	Channels around the islands, smaller than half river width, frequently at different elevation than main channel.

Figure 2. Spatial distribution of hydro-morphological units measured in site 4 of the Quinebaug river during 0.6 m³/s (top), 1.1 m³/s (middle) and 2 m³/s (bottom) release from East Brimfield Lake.

Figure 3. The spatial distribution of habitat suitable for selected community indicating number of supported species.

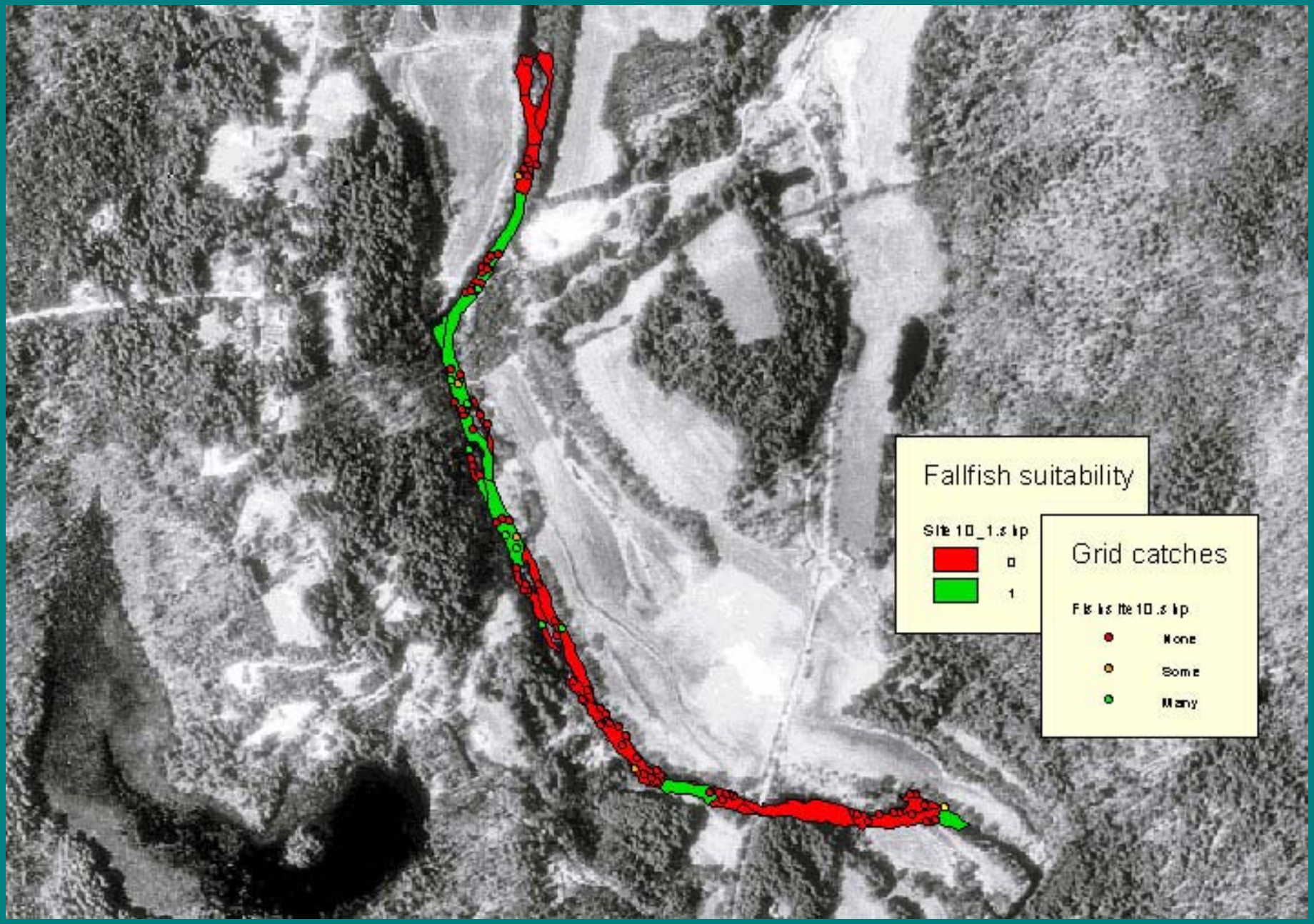

Fallfish suitability
Site 10_1.shp
0
1
Grid catches
Fishes site 10.shp
None
Some
Many

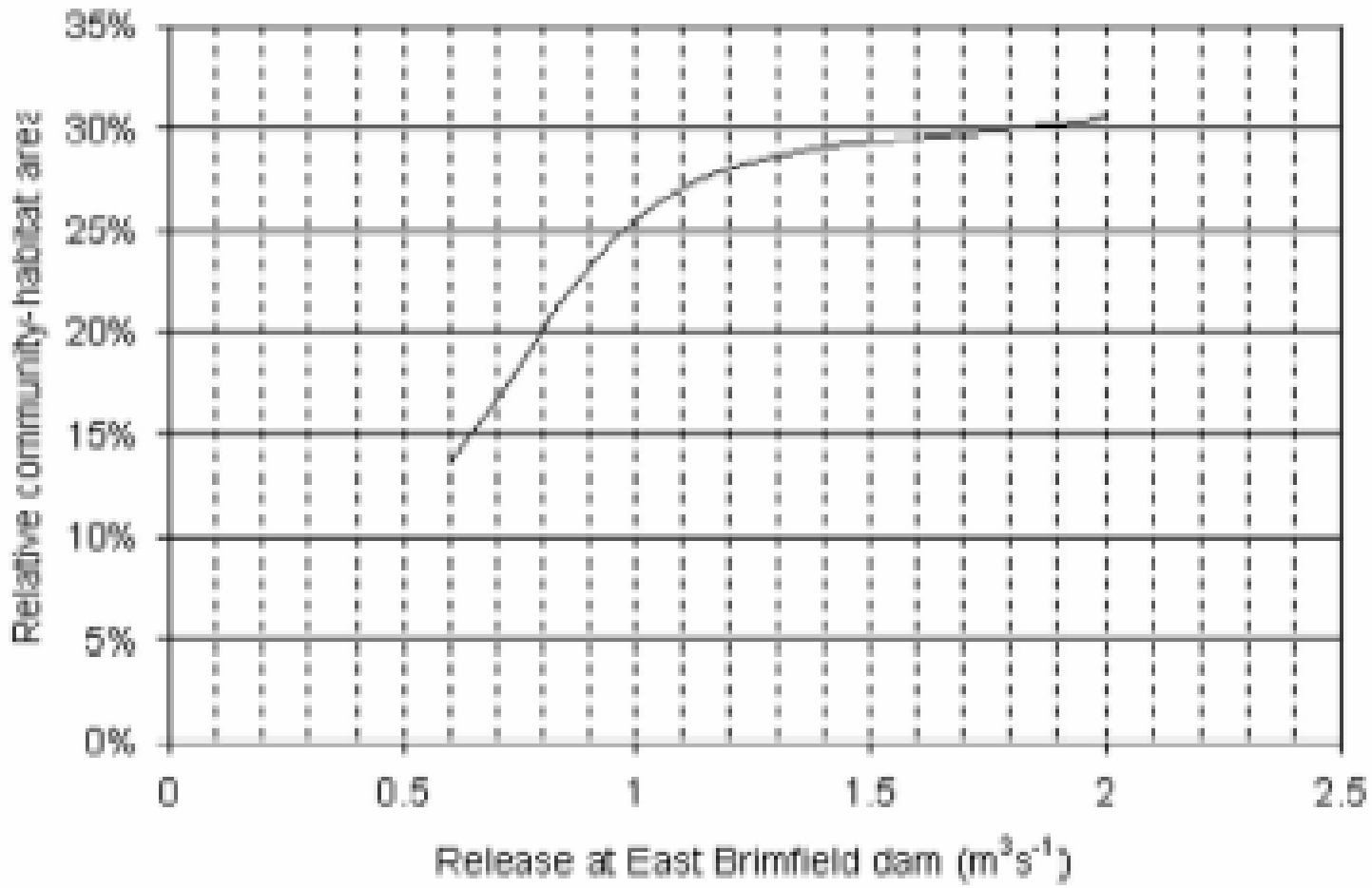
Table 2: Physical attributes used to establish logistic regression with fish absence and presence.

Attribute (value)	
Categories of Hydro-morphological units (yes/no)	(see table 1)
Cover sources (no/some/much)	Undercut bank, woody debris, overhanging vegetation, submerged vegetation, boulder, riprap, canopy cover shading, shallow margin
Chorlotop (% of random samples)	Pelal, psamal, akal, micro-lithal, meso-lithal, macro-lithal, mega-lithal, phytal, xytal, sapropel, detritus (for exact definitions see Austrian Standard ON62232)
Depth (% of random samples)	6 classes in 25 cm increments (range 0–125 cm and above)
Mean column velocity (% of random samples)	8 classes in 15 cm/s increments (range 0–105 cm/s and above)
Froude number	Average

Table 3: The results of regression calculation for bluegill and fallfish. The table shows significant habitat attributes and their beta coefficients. Positive numbers indicate positive reaction and vice versa.

Bluegill		Fallfish	
Attribute	Beta	Attribute	Beta
Velocity 15-30 cm/s	2.02	Boulder	1.95
Shading	1.06	Shading	-1.07
Glide	-2.19	Depth 0-25 cm	-1.76
Velocity 30-45 cm/s	1.07	Velocity 45-60 cm/s	1.06
Submerged vegetation	-0.75	Run	-0.57

Figure 4. The rating curve of relative habitat area versus flow release for study area on Quinebaug River.



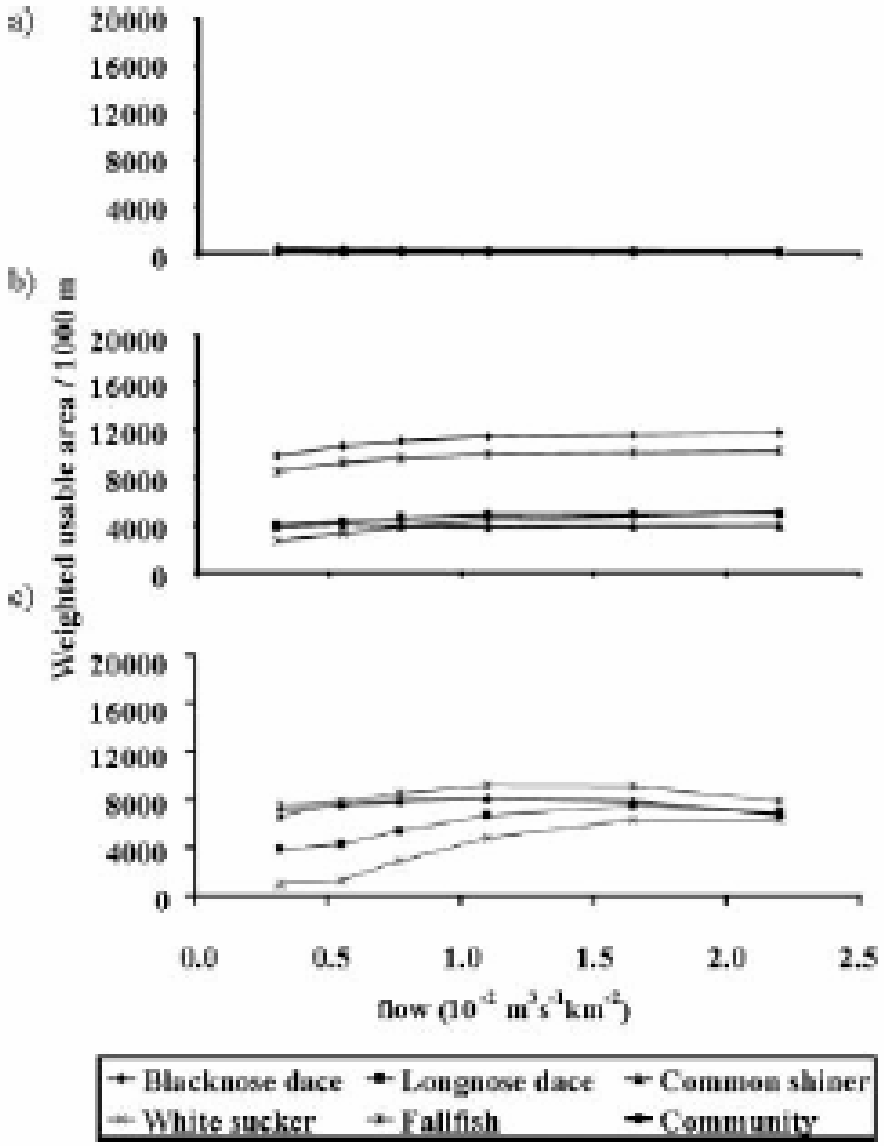


Figure 14. Habitat versus flow rating curves calculated for the representative Site 10: (a) PHABSIM, (b) HARPHA, (c) MesoHABSIM

Comparison to traditional methods: Sometimes different answer!!

Geomorphology/Hydrology Approaches

e.g. Richter 2008 Flow 2008
e.g. Trinity River California

Paradigm Shift in Instream Flow Recommendations

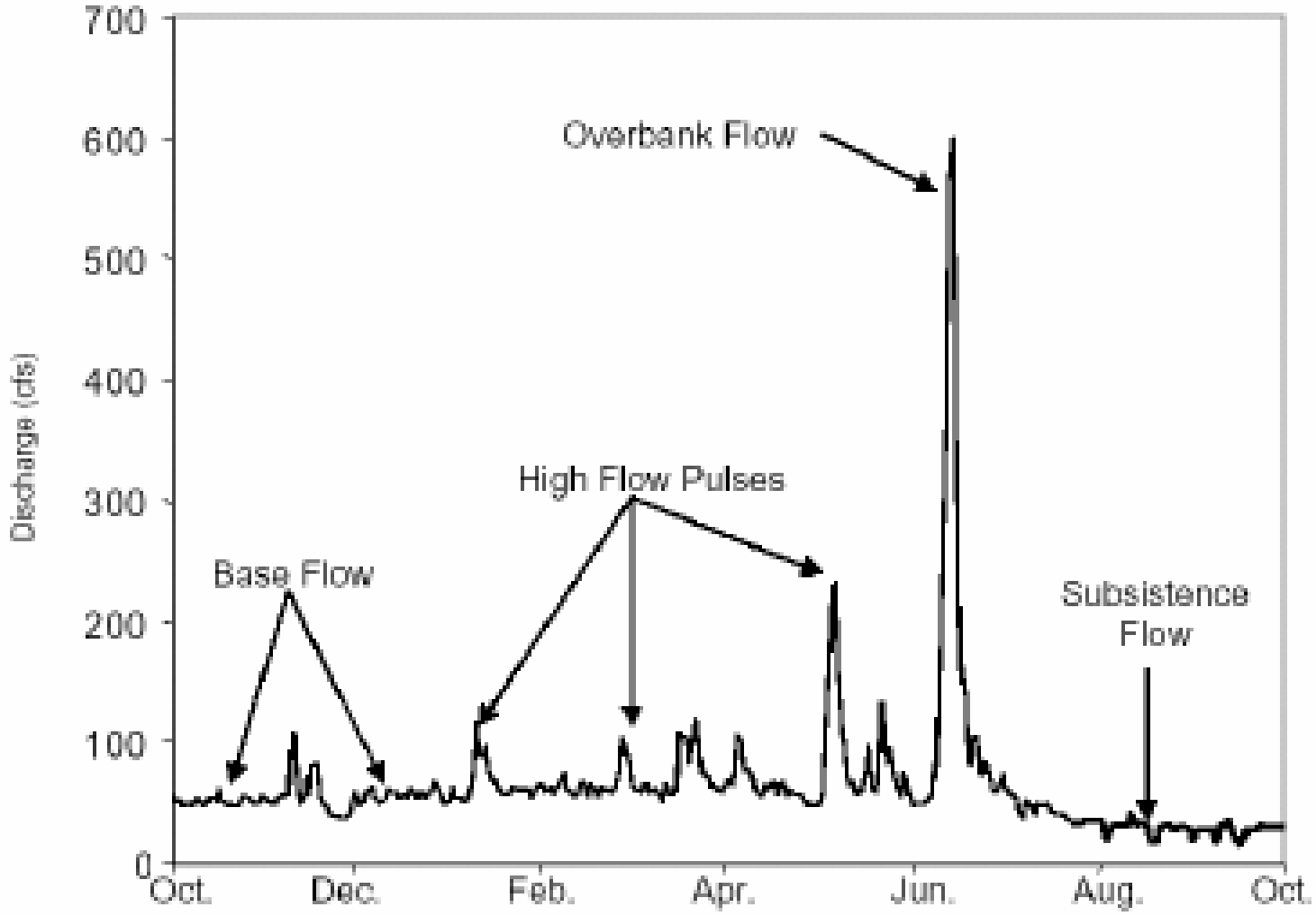
- 1950-80’s development of first instream flow methods yielding single minimum flow
- Growing knowledge that the natural flow regime is important (frequency, peaks, shape of hydrography, duration, ramping rates)
- Recent shift toward consideration of entire flow regime: subsistence, base, high flow pulse, overbank

WHY?? Basic Principles

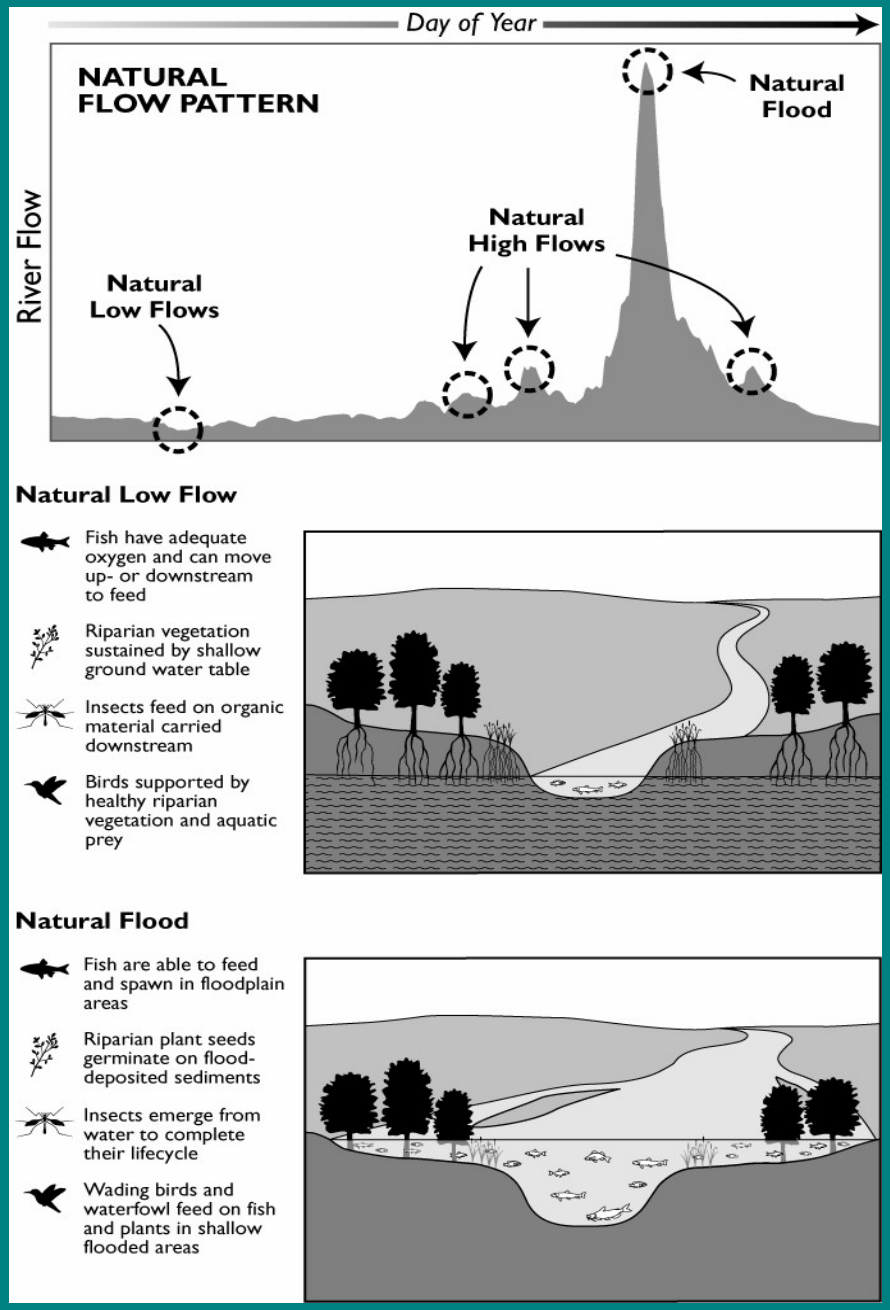
- River flows are inherently variable on daily, seasonal, and inter-annual time scales
- The life cycles and population dynamics of many aquatic, riparian, and estuarine organisms are <u>tightly linked to natural river flow variability</u>
- Why: Evolution and adaptation of organisms
- Geomorphology of stream

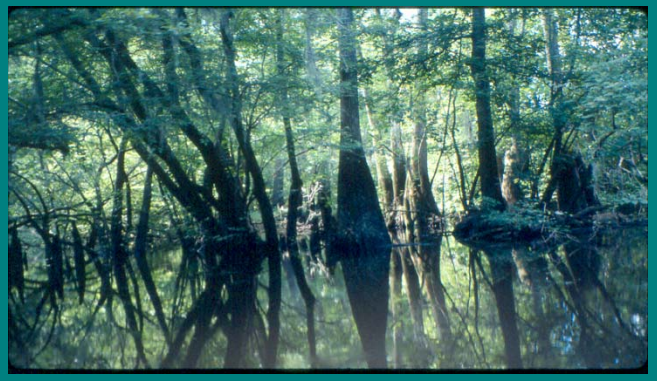
Instream Flow Components

(recommended by National Research Council 2005)

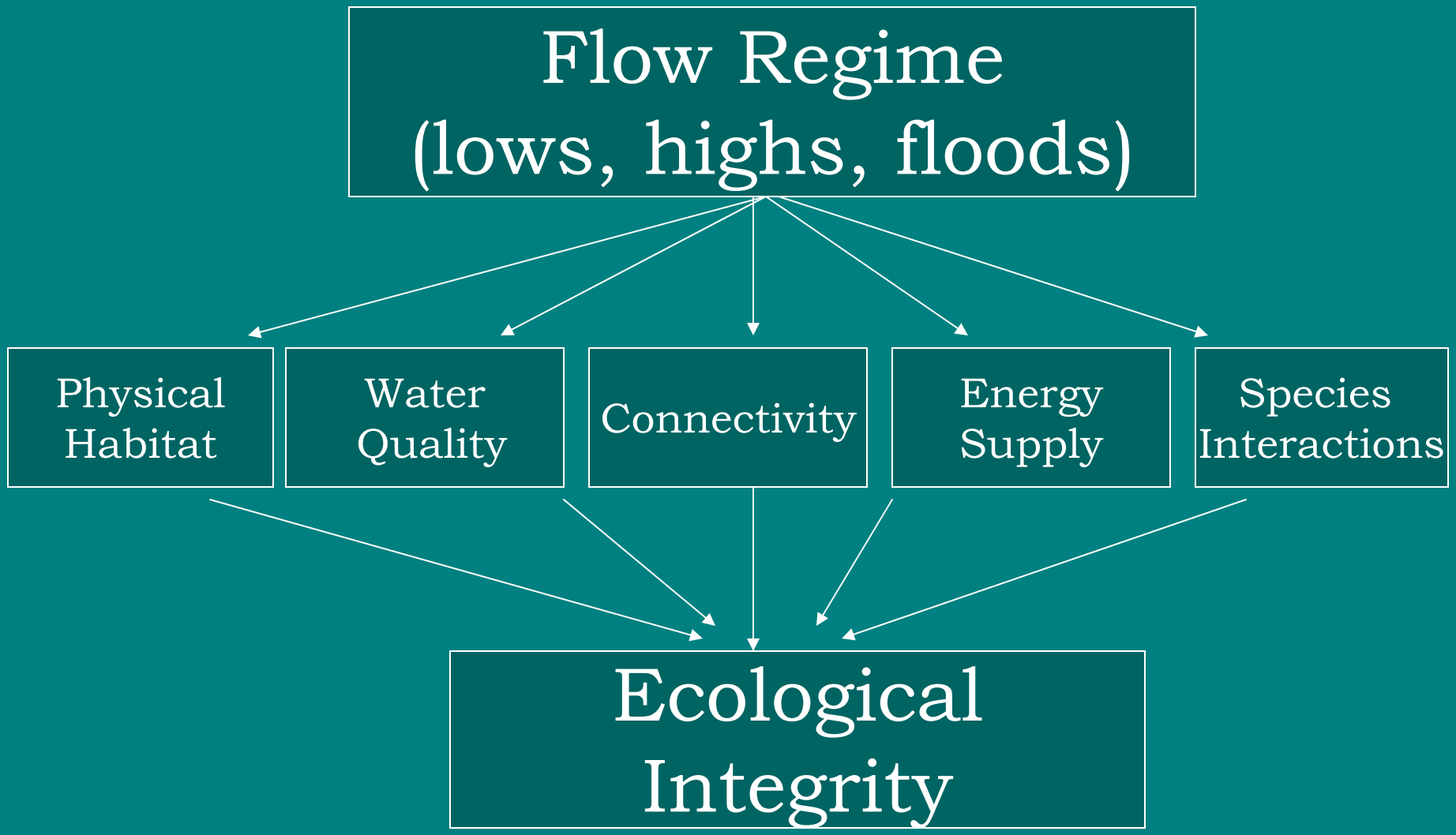


Richter 2008





Richter 2008 Flow 2008



Flow regime is a "master variable" in river ecosystems

Richter 2008 Flow 2008

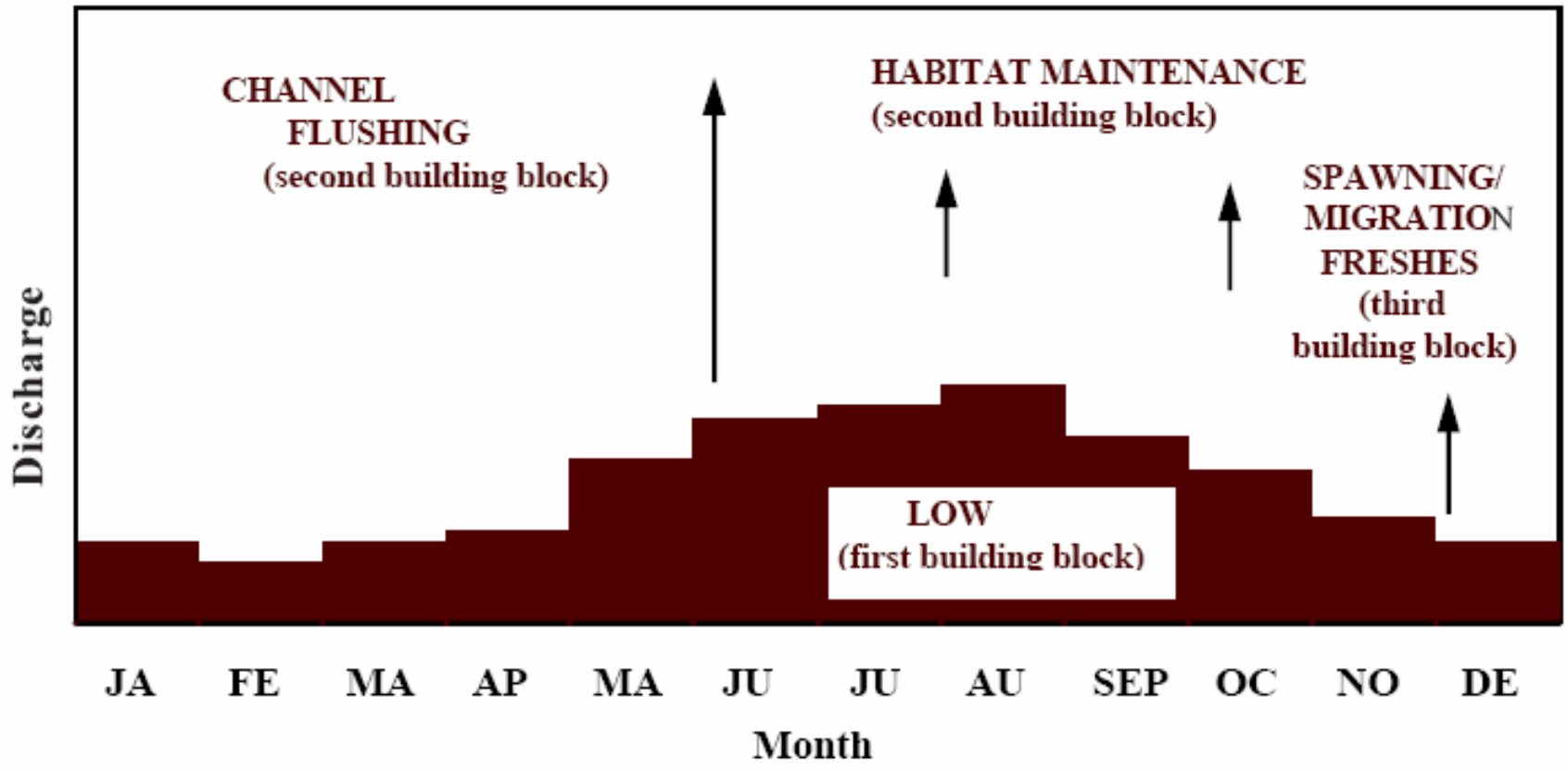


Fig. 2. *Example of flow regime built up using building blocks.*

Very Basic Approach: Expert Input: Hydro & Biology; Build Block Approach. Acreman and Dunbar 2004.

Flow Regime Evaluation Tools

- The Nature Conservancy (TNC) has developed and implemented environmental flow recommendations in the United States and abroad.

- TNC uses a collaborative process in conjunction with software tools to develop flow recommendations to benefit natural freshwater ecosystem health and biodiversity, and implements these recommendations in an adaptive management framework.

Indicators of Hydrologic Alteration

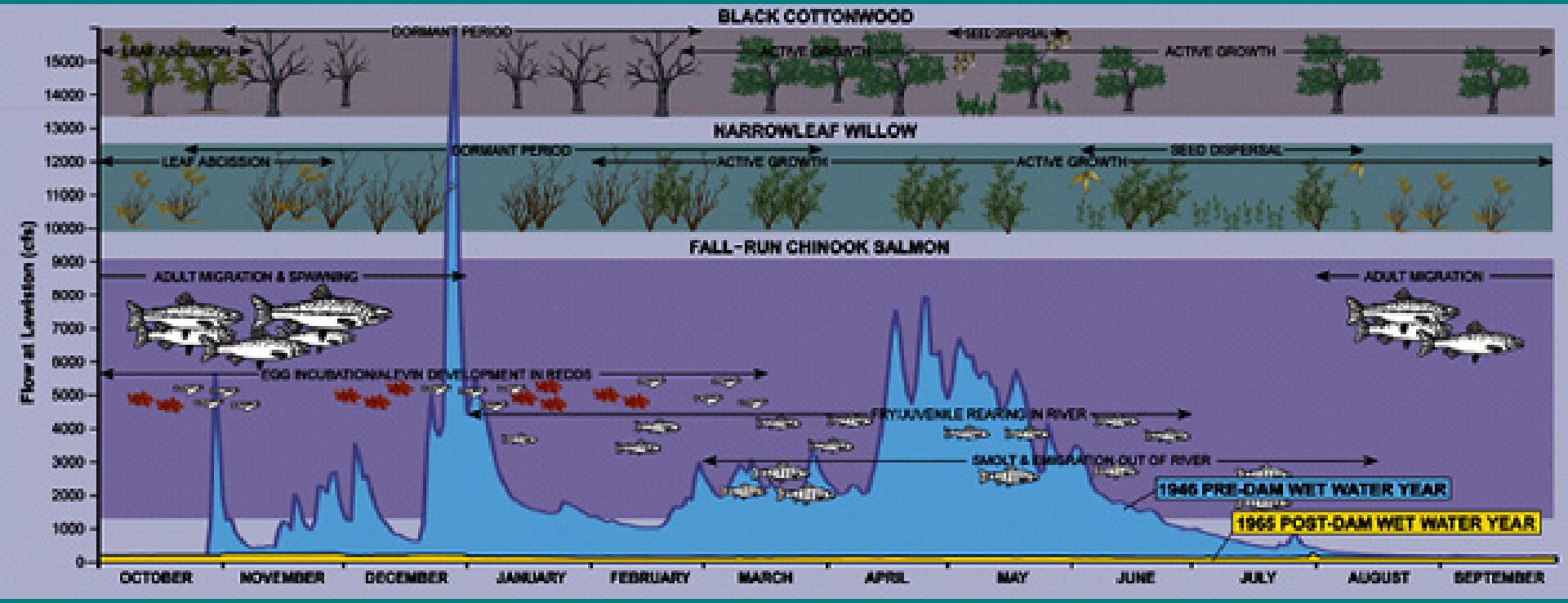
- The primary software tools used by TNC are the Indicators of Hydrologic Alteration (IHA) software, which uses daily streamflow data to compute a series of flow statistics that can be used to assess hydrologic change; AND
- The Regime Prescription Tool, which is a visualization tool jointly developed with the U.S. Army Corps of Engineers that can be used to display environmental flow recommendations in workshop settings.

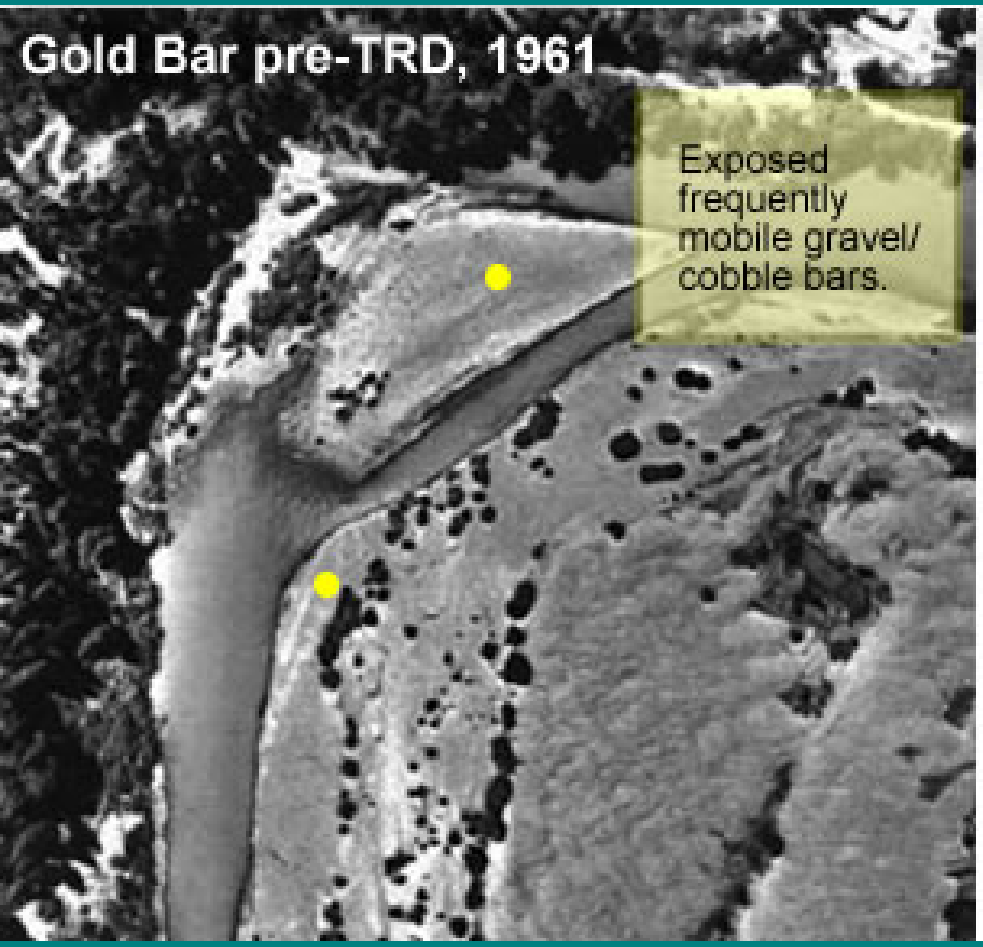
IHA

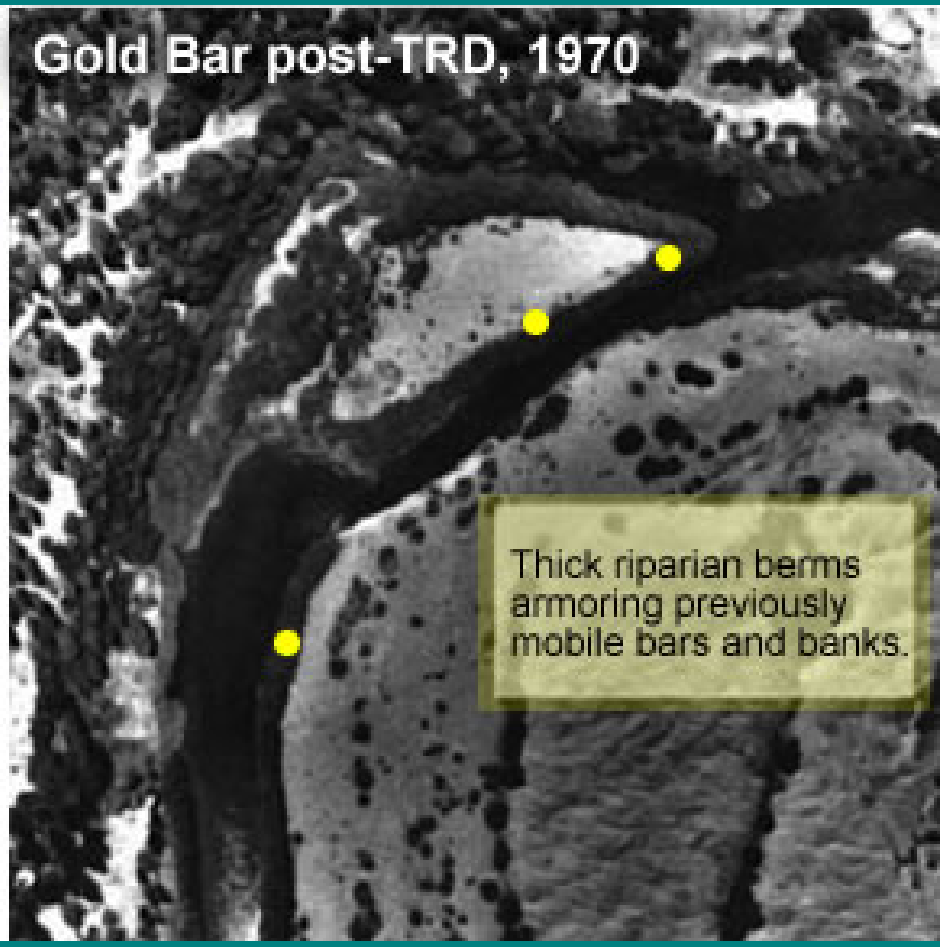
- The IHA software computes 67 different flow statistics, including 34 statistics based on five Environmental Flow Components (large floods, small floods, high flow pulses, low flows, extreme low flows), which are particularly useful for environmental flow projects.
- Compare before and after, different index periods

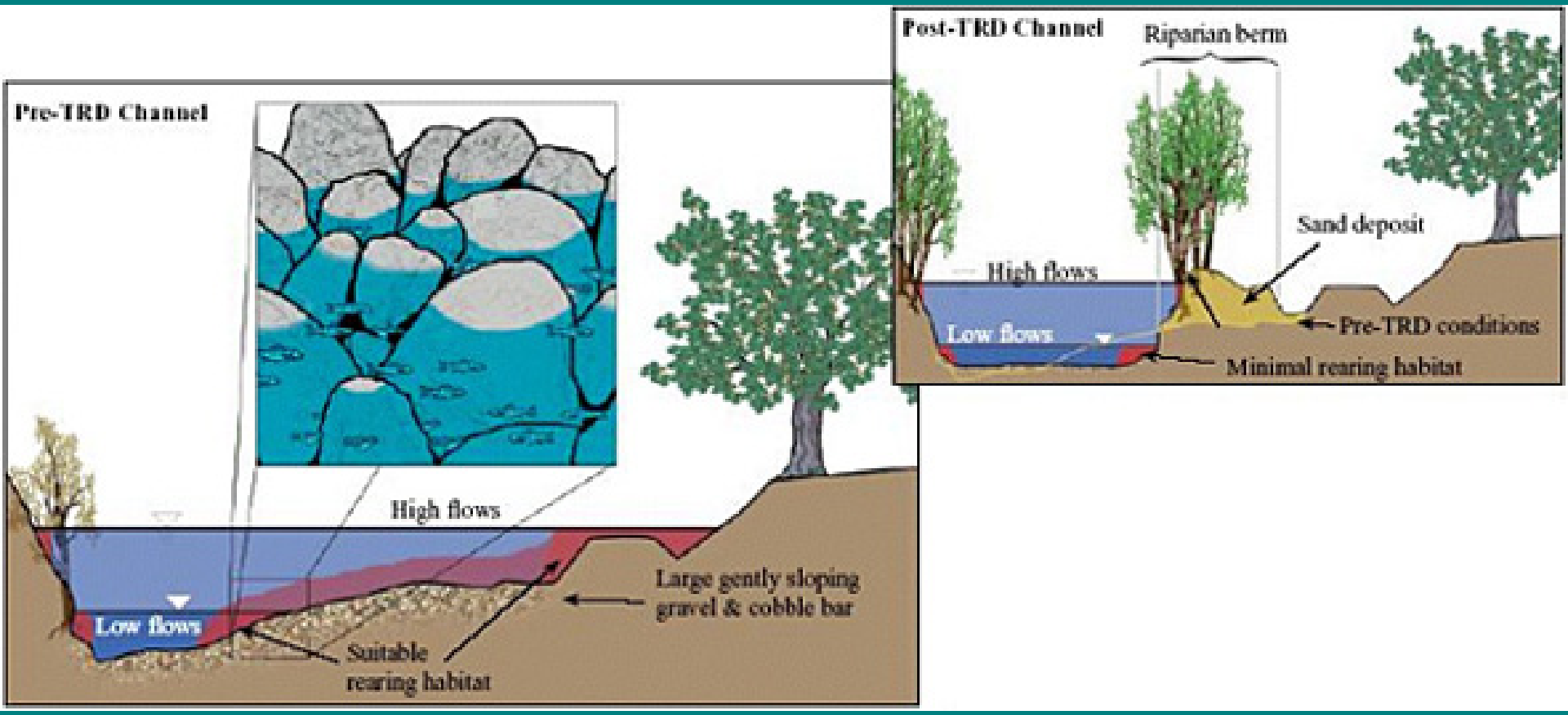
Geomorphology: Trinity River Restoration - California

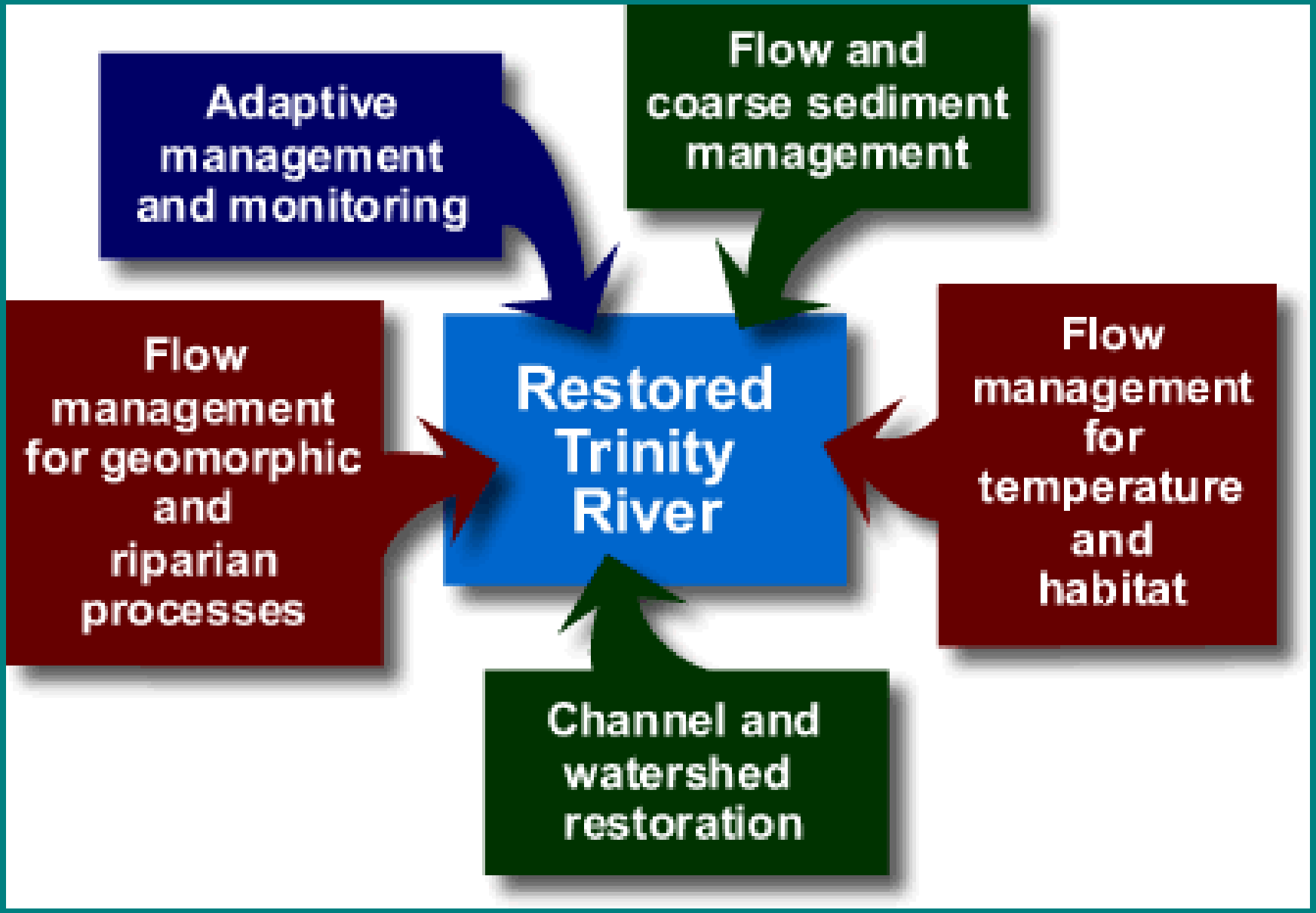
- Dam built in 1964, diverted 90% of flow to Central Valley.
- **15 year Study starting in mid 1980's**
- Develop flow, habitat fish population relationships
- Evaluate influence of impacts of dam placement on hydrology, sediment loads, and temperature
- Focus on restoration of "structure" of natural hydrograph for geomorphology, temperature regimes and fish life history needs (e.g. spawning, rearing etc).
- Geomorphology – McBain and Trush studies
- Focus on commercially and recreationally important salmonids.
- Adaptive Management – flow management, sediment replacement etc. – Tribes, State, FWS, BOR, NMFS
- Continue monitoring populations of fish.

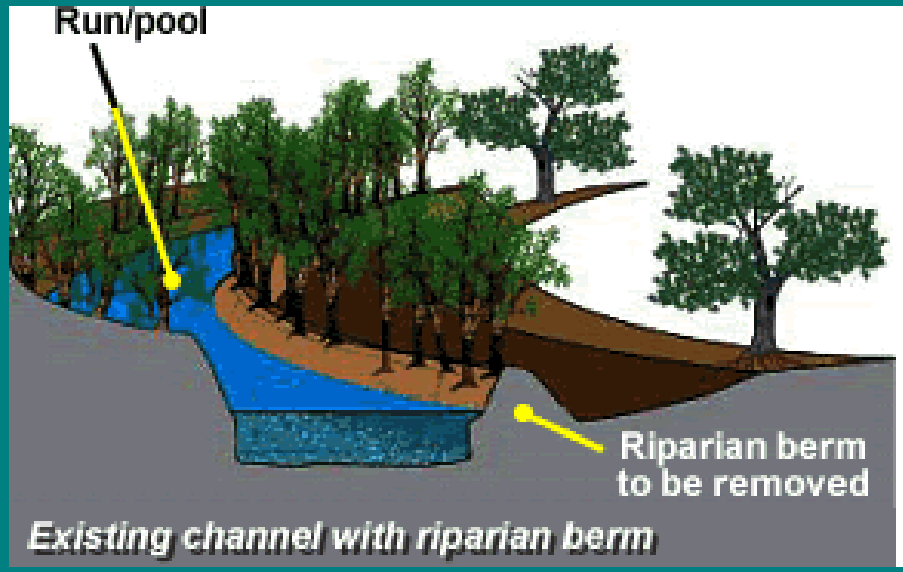

BLACK COTTONWOOD
DORMANT PERIOD
LEAF ABSCISSION
ACTIVE GROWTH
SEED DISPERSAL
ACTIVE GROWTH
NARROWLEAF WILLOW
DORMANT PERIOD
LEAF ABSCISSION
ACTIVE GROWTH
ACTIVE GROWTH
SEED DISPERSAL
FALL-RUN CHINOOK SALMON
ADULT MIGRATION & SPAWNING
ADULT MIGRATION
EGG INCUBATION/ALEVIN DEVELOPMENT IN REDDS
FRY/JUVENILE REARING IN RIVER
SMOLT & EMIGRATION OUT OF RIVER
1946 PRE-DAM WET WATER YEAR
1965 POST-DAM WET WATER YEAR
Flow at Lewiston (cfs)
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER

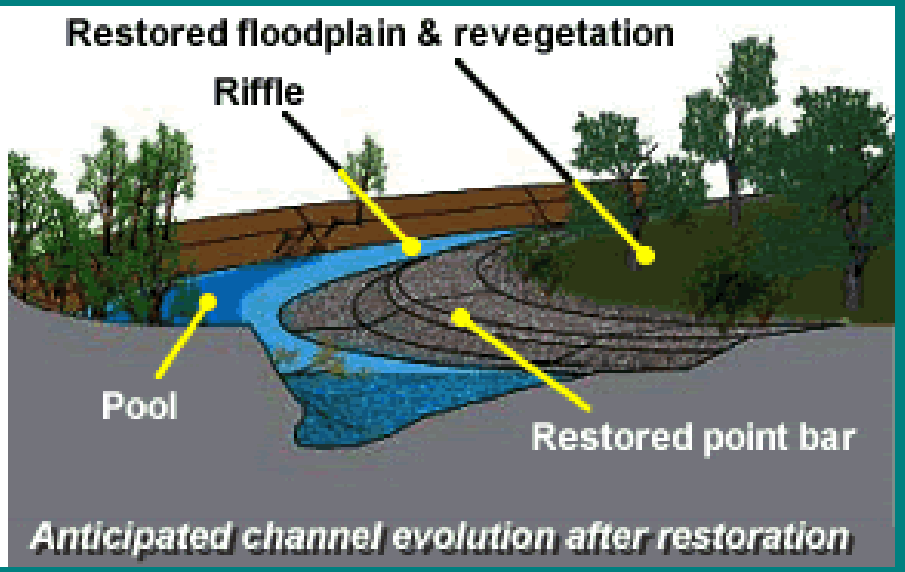

Gold Bar pre-TRD, 1961
Exposed frequently mobile gravel/ cobble bars.


Gold Bar post-TRD, 1970
Thick riparian berms armoring previously mobile bars and banks.


Pre-TRD Channel
High flows
Low flows
Large gently sloping gravel & cobble bar
Suitable rearing habitat
Post-TRD Channel
Riparian berm
Sand deposit
High flows
Low flows
Pre-TRD conditions
Minimal rearing habitat


Adaptive management and monitoring
Flow and coarse sediment management
Flow management for geomorphic and riparian processes
Restored Trinity River
Flow management for temperature and habitat
Channel and watershed restoration


Run/pool
Riparian berm
to be removed
Existing channel with riparian berm


Restored floodplain & revegetation
Riffle
Pool
Restored point bar
Anticipated channel evolution after restoration

The Texas method of preliminary instream flow assessment

Mathews, RC Jr | Bao, Yixing

Rivers. Vol. 2, no. 4, pp. 295-310. Oct 1991.

- The new method, referred to as the Texas Method, considers riverine fishes as primary target species, flow needs during the critical periods in the life stage of the fishery, and maintenance of the natural streamflow pattern.
- The Texas Method is an advancement over existing preliminary planning methods because it is the first such technique to treat the recommended flow percentage for each month as a variable along with the biological characteristics (e.g., spawning/incubation periods) and regional hydrological characteristics (e.g., highly variable monthly flows with positive skewness).

The Texas method of preliminary instream flow assessment

- The method has been used to determine the instream flow needs of 25 potential reservoir sites identified in the Texas Water Plan.
- Results are compared with recommendations of five other commonly used preliminary planning methods.
- Comparatively, the Texas Method provides consistent performance for flow recommendations in different rivers and streams

Texas Instream Flow Studies: Technical Overview

Report 369
May 2008

Texas Commission on Environmental Quality
Texas Parks and Wildlife Department
Texas Water Development Board

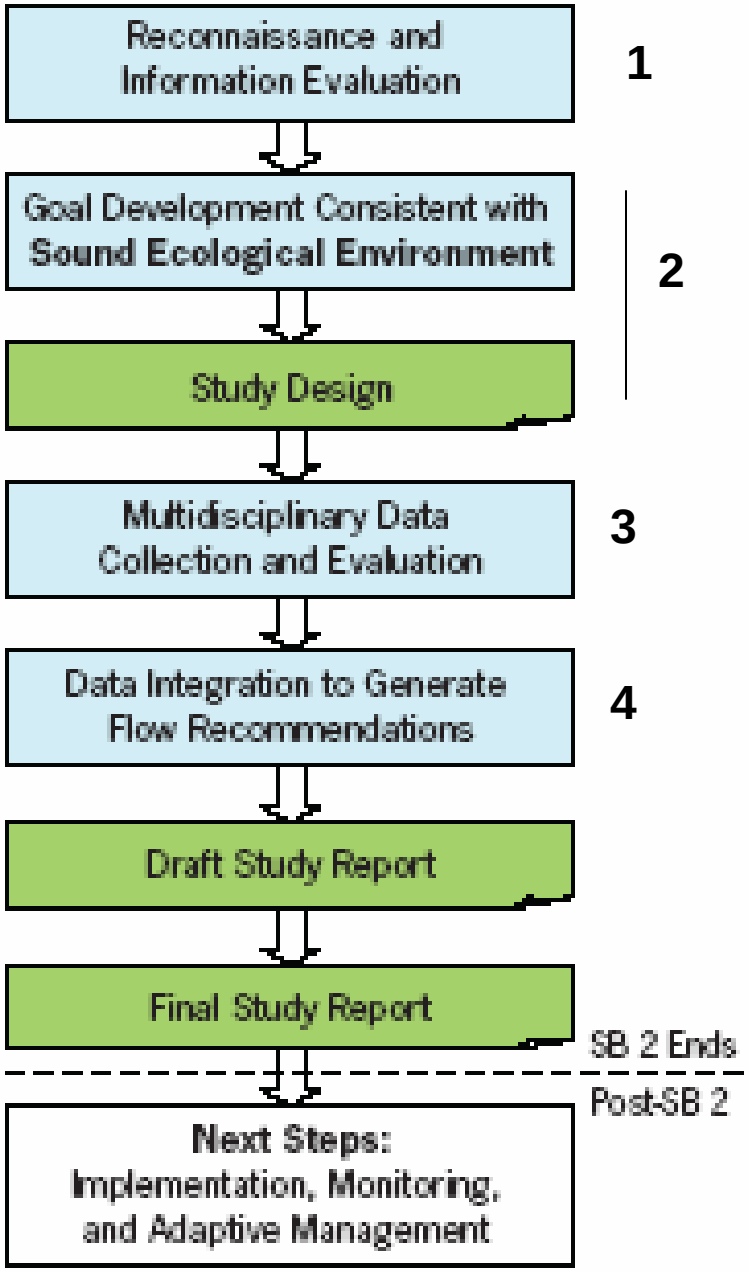


Figure 1-1. Steps in sub-basin studies of the Texas Instream Flow Program.

Table 1-1. Summary of sub-basin study activities during Step 1.

Step 1: Reconnaissance and Information Evaluation

Purpose

- Compile, review, and georeference available studies/data.
- Identify historic and current conditions, significant issues, and concerns.
- Conduct preliminary field surveys and analysis.

Data Sources

- U.S. Geological Survey and other gage data.
- Federal/state/local studies and reports.
- Historic air photos/Digital Orthographic Quarter Quadrangle/maps/soil surveys.
- Current water quality models and standards.

Activities

Stakeholder Participation

- Provide historic and current perspective of resource.
- Identify important concerns and opportunities for study participation.
- Select sub-basin workgroup.

Hydrology and Hydraulics

- Calculate flow statistics for historic and existing conditions.
- Identify existing features (such as tributaries) and existing and proposed alterations (for example, diversions, impoundments, and land uses) affecting hydrologic character.

Biology

- Identify historic and current species assemblages, representative macro- and meso-habitat types, and other biological issues and considerations.
- Assess historic and current condition of stream biota and riparian resources.
- Identify potential study reaches and sites.

Geomorphology

- Analyze aerial photography and other historic data as available.
- Assess channel bed form and banks, active channel and floodplain processes, and changes in sediment regime and causes.
- Make preliminary geomorphic classification of river segment.

Water Quality

- Assess historic and current water quality and aquatic life uses.
- Identify water quality issues and constituents of concern.

Output

- Synthesized summary of available studies/data, including GIS layers.
- Conceptual models describing the relationships between ecological health and flow regime.
- Prioritized list of research needs to address identified knowledge gaps.

Scale: All Scales

Table 1-2. Summary of sub-basin study activities during Step 2.

Step 2: Goal Development and Study Design

Purpose

- Develop sub-basin goals and objectives consistent with a sound ecological environment.
- Create study design, including descriptions of intensive study sites, specific technical tools and sampling criteria, and target flow ranges and seasons for field data collection.

Data Sources

- Goals and objectives of agencies, cooperators, and stakeholders.
- Results of reconnaissance activities from Step 1.

Activities

Stakeholder Participation

- Sub-basin workgroup assists Agencies in developing study design.

Hydrology and Hydraulics

- Determine data collection requirements for hydraulic modeling to support biological, geomorphic, and water quality studies.
- Assess hydraulic conditions within study sites.

Biology

- Confirm location of key/representative habitats within study sites.
- Choose appropriate sampling methods and estimate resource requirements.

Geomorphology

- Determine appropriate methods subject to constraints (including available historical data).
- Confirm presence of suitable geomorphic features within study sites.

Water Quality

- Confirm location of key water quality areas of concern within study sites.
- Assess need for additional water quality modeling and determine data collection requirements.

Output

- Study design consistent with Technical Overview.

Scale: All Scales

Table 1-3. Summary of sub-basin study activities during Step 3.

Step 3: Multidisciplinary Data Collection and Evaluation

Purpose

- Collect input data required for models and analyses.
- Continuously monitor water quality and flow conditions at study sites.
- Determine relationships between flow, water quality, biology, habitat, channel, and floodplain conditions.

Data Sources

- Hydrologic measurements and bathymetric mapping.
- Biological data collection and habitat mapping.
- Geomorphic data collection and mapping.
- Water quality data collection.

Activities

Stakeholder Participation

- Sub-basin study and data collection workshops/field demonstrations.

Hydrology and Hydraulics

- Monitor stage/discharge continuously during study period.
- Map substrate, woody debris, and variations in hydraulic roughness.
- Model hydraulic characteristics in relation to flow, including extent of inundation associated with flood events.

Biology

- Collect appropriate biological and habitat use data.
- Describe habitat criteria and significant conditions for key species/guilds/life stages.
- Conduct habitat modeling to assess habitat-flow relationships, including diversity.
- Conduct riparian studies and estimate riparian requirements.

Geomorphology

- Develop sediment budgets.
- Identify factors controlling geomorphic behavior of river segment.
- Assess channel adjusting and overbank flow behavior, including flow conditions that initiate sediment and large woody debris movement and deposition.

Water Quality

- Monitor water quality at site during study period.
- Validate previous models and conduct water quality modeling studies as needed.
- Assess flow/water quality relationships.

Output

- Documentation of methods and data (hardcopy and electronic formats).
- Habitat versus flow relationships.
- Flows required to maintain water quality and channel/riparian areas.
- Refined conceptual models that describe ecological health and flow regime.

Scale: Study Sites

Table 1-4. Summary of sub-basin study activities during Step 4.

Step 4: Data Integration to Generate Flow Recommendations

Purpose

- Construct instream flow regime (including subsistence, base, and overbank flows and high flow pulses) that best meets sub-basin goals and objectives.

Data Sources

- Results of previous studies from Step 1.
- Sub-basin study goals and objectives from Step 2.
- Results of multidisciplinary studies from Step 3.

Activities

Stakeholder Participation

- Sub-basin workgroup provides input on data synthesis and interpretation.
- Review and comment on study report.

Hydrology and Hydraulics

- Calculate occurrence of various flow rates during historical and current conditions.
- Determine annual variability of hydrologic characteristics, including description of wet, average, and dry hydrologic conditions.
- Develop hydrologic time series to evaluate habitat suitability of proposed flow regime.
- Calculate variability of proposed flow regime and compare with historic/current conditions.
- Evaluate how proposed flow regimes would impact current operating conditions.

Biology

- Develop flow ranges at appropriate temporal scales for key species/guilds/life stages.
- Construct habitat time series for historic, current, and proposed flow regimes.

Geomorphology

- Estimate, if possible, historic channel conditions.
- Evaluate consequences of various flow regimes for channel/riparian areas.
- Estimate feasibility of alternative intervention actions.

Water Quality

- Identify flow conditions that satisfy key water quality/biology relationships.
- Consider water quality issues related to proposed flow regime components.

Output

- Instream flow study report, including description of flow recommendations, ecological significance of flow components, and study methods and analysis.

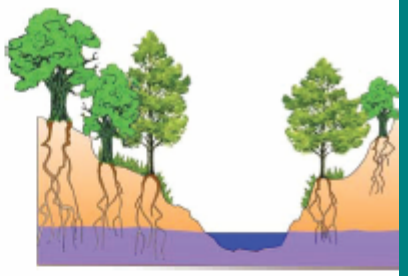
Scale: River Segment

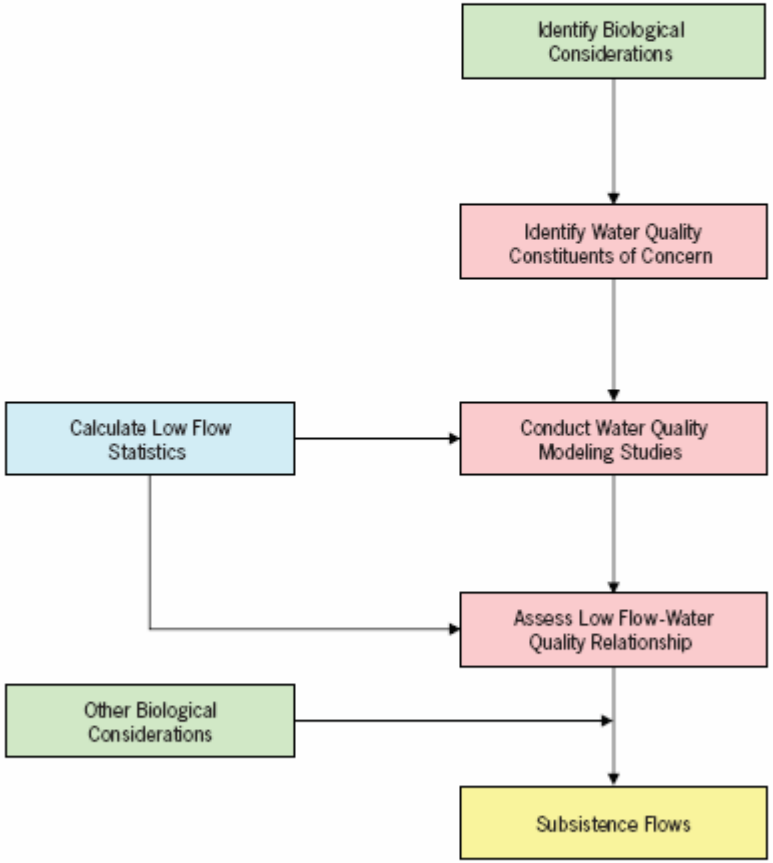
Subsistence Flows

Spatial scale:
River Reach

Temporal scale:
Hourly Flow, Varies from Month to Month

Primary discipline:
- Hydrology/Hydraulics
- Biology
- Geomorphology
- Water Quality





Subsistence flows are low flows maintained during times of drought.

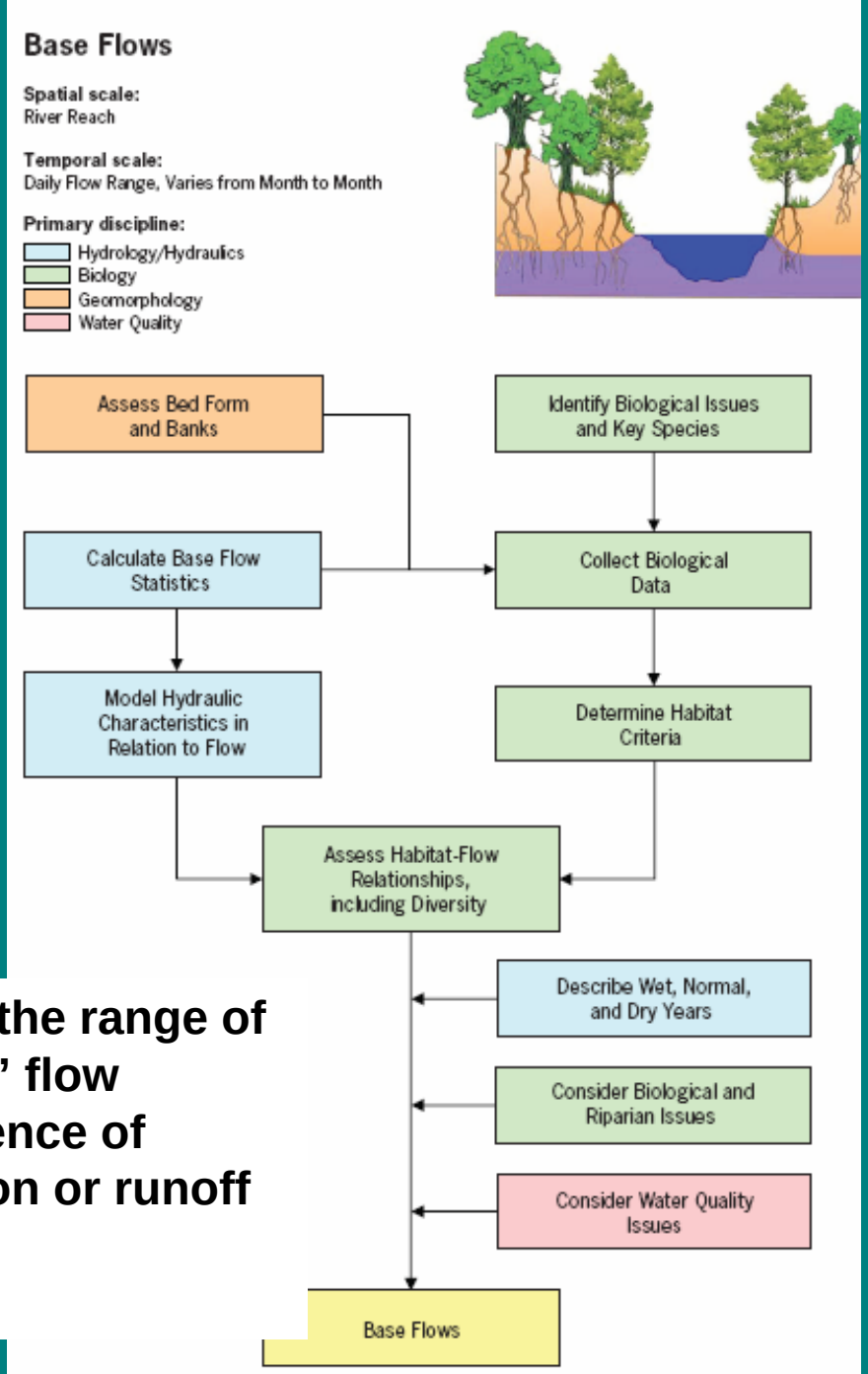


Figure 1-3. Development of base flow recommendations from results of multidisciplinary activities.

Base flows represent the range of "average" or "normal" flow conditions in the absence of significant precipitation or runoff events.

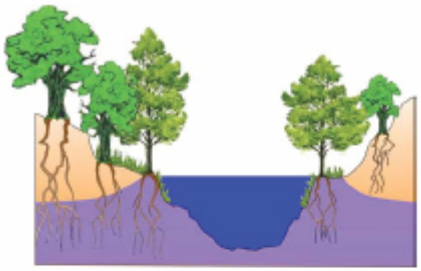
High flow pulses are short duration, high magnitude (but still within channel) flow events that occur during or immediately following storm events.

High Flow Pulses

Spatial scale:
River Segment

Temporal scale:
Multiple High Flow, Pulses Throughout the Year

Primary discipline:
- Hydrology/Hydraulics
- Biology
- Geomorphology
- Water Quality



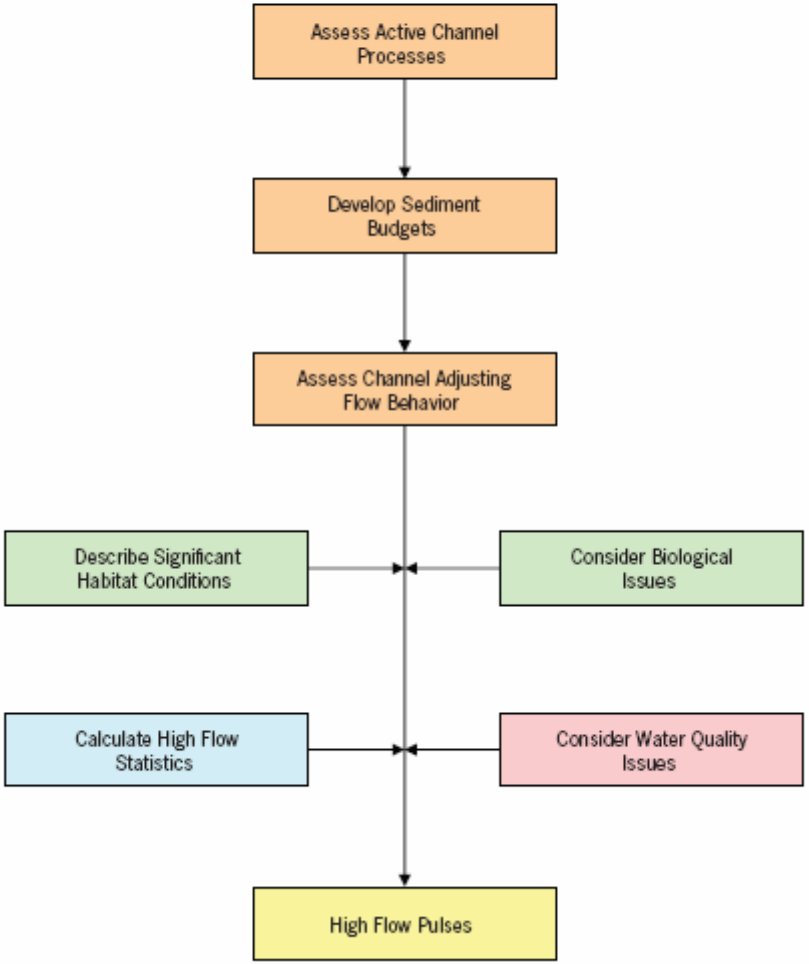


Figure 1-4. Development of high flow pulse recommendations from results of multidisciplinary activities.

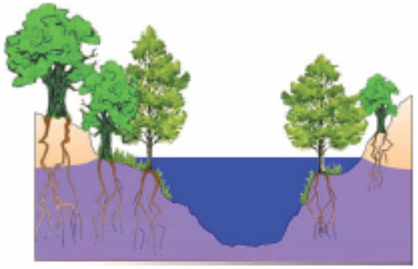
Overbank flows are infrequent, high magnitude flow events that exceed channel banks and enter the floodplain.

Overbank Flows

Spatial scale:
River Segment

Temporal scale:
Extreme Flow Events, Occur Less Than Once per Year

Primary discipline:
- Hydrology/Hydraulics
- Biology
- Geomorphology
- Water Quality



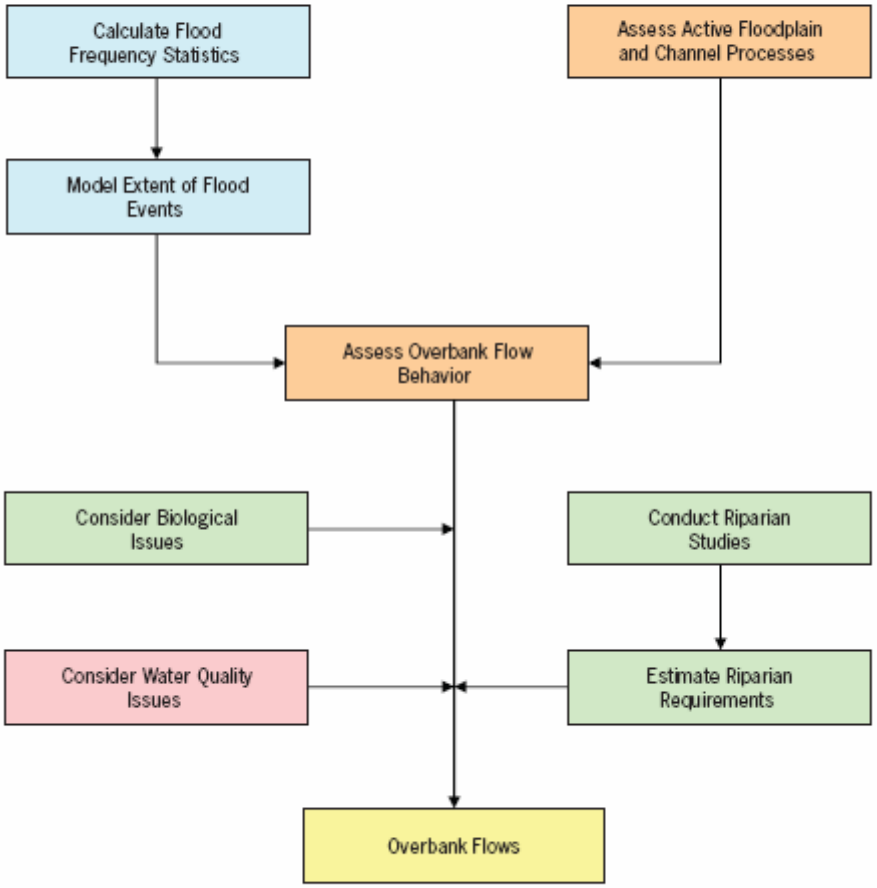


Figure 1-5. Development of overbank flow recommendations from results of multidisciplinary activities.

THE SCIENCE OF

INSTREAM FLOWS

A Review of the Texas Instream Flow Program

Committee on Review of Methods for Establishing
Instream Flows for Texas Rivers

Water Science and Technology Board

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

Reviewed: Texas Instream Flow Programmatic Work Plan (PWP)
& Technical Overview Document

Major Conclusions

- “Developing instream flow recommendations for rivers is one of the most difficult and important challenges in the applied ecological and physical sciences today”.
- “The Texas agencies are commended for proposing a prospective, comprehensive instream flow program. Implementation of a statewide instream flow program will involve many agencies, significant resources, and time; nevertheless, the program will provide enormous benefits to the state over the next several decades and beyond”

Major Conclusions

- “The Texas instream flow program will need to be flexible to meet the unique challenges and opportunities presented by the state’s rich mixture of river ecosystems, culture, water law, and water development.
- Clear and specific programmatic and scientific instream flow goals need to be set at both the state and river basin levels, and methods used in setting instream flow recommendations need to be consistent for the several river systems that will be studied across the state”.

Major Conclusions

- “The Texas instream flow framework should elicit comparable results at the basin level in order to realize statewide consistency, maintain continuity over the long term through proper delegation and delineation of responsibilities among the various involved agencies, and incorporate scientific findings as well as social and economic concerns by involving stakeholders during key phases of the design and implementation process”.

NAS Major Recommendations

- 1) The Programmatic Work Plan (PWP) should present a state-wide context for individual sub basin studies. This can be accomplished with two levels of oversight: one at the state level for management and program consistency and the second one at the sub basin level for goals and approaches tailored to the specific needs of the study basin.

- 2) A clear definition of the phrase “sound ecological environment” needs to be provided to supply context for instream flows in Texas.

- 3) The PWP should present clear and specific goals for the state-wide instream flow program and recognize the need to develop individual sub basin goals that nest within the state-wide instream flow programmatic goal(s).

Recommendations

- 4) The PWP and the TOD should describe how existing information and reconnaissance studies will be used to guide the detailed technical evaluations of hydrology, physical processes, biology, and water quality.

- 5) The PWP flowchart for instream flow studies should be revised to include several important steps in planning and conducting an instream flow study as suggested in the report.

- 6) A suite of measurable, ecological indicators should be established for the state-wide program and each basin-specific study; the indicators should be responsive to instream flows. These indicators can be used in adaptive management, monitoring and validation activities to measure progress towards achieving a sound ecological environment in Texas rivers.

Recommendations

- 7) The Technical Overview Document should be revised to provide for consistent spatial scale and level of detail for the hydrology, biology, physical processes, and water quality technical evaluations.

- 8) Clearer direction should be provided for the process by which the individual technical evaluations will be integrated into instream flow recommendations.

Hydrology Based Environmental Flow Regime (HEFR) Method

- Brandes et al. 2009. Draft.
- Reviews Hydrologic Methods (e.g. IHA etc)
- Generally supports TPWD approach (i.e. HEFR)
- Flexible, recognizes gaps in knowledge needed for PHABSIM type analyses
- Need to address subsistence flows, base flows, high flows and overbank flows

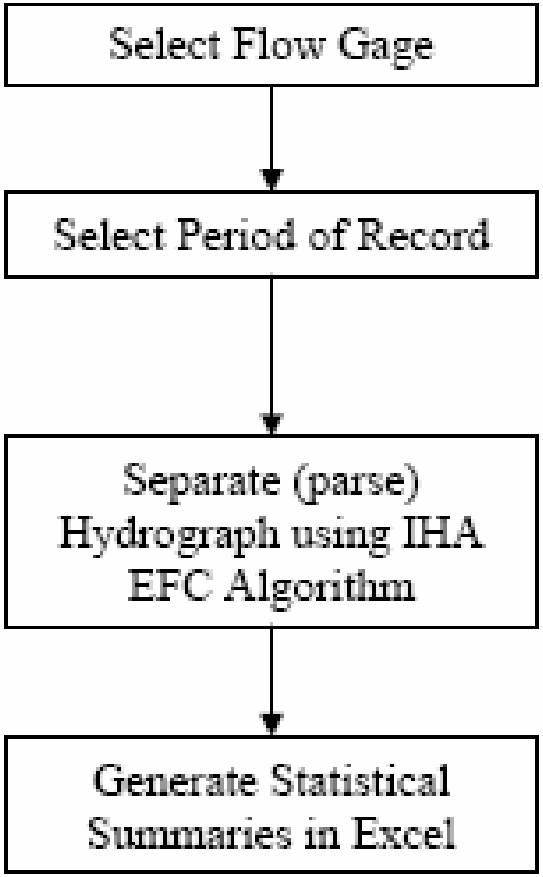


Figure 1. Flow Chart of HEFR Methodology

EFC = Environmental Flow Components

Overbank Flows	Return Period (R) : 1 (years)						Duration (D) : 49 (days)					
	Volume (V) : 1743452 (ac-ft)						Peak Flow (Q) : 30000 (cfs)					
High Flow Pulses	F: 0	D: 18		F: 0	D: 22		F: 0	D: 17		F: 0	D: 12	
	Q: 14125	V: 352171		Q: 15550	V: 433473		Q: 11825	V: 278202		Q: 8570	V: 90605	
	F: 1	D: 11		F: 1	D: 14		F: 0	D: 9		F: 0	D: 9	
	Q: 10500	V: 148305		Q: 10500	V: 233782		Q: 8850	V: 89449		Q: 3700	V: 52621	
	F: 1	D: 7		F: 1	D: 7		F: 0	D: 6		F: 0	D: 6	
	Q: 4903	V: 57962		Q: 8735	V: 93710		Q: 3630	V: 36786		Q: 2373	V: 22191	
Base Flows (cfs)	4910			5700			2110			1839		
	2350			3670			1839			1839		
	1839			2258			1839			1839		
Subsistence Flows (cfs)	1839			1839			1839			1839		
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	Winter			Spring			Summer			Fall		

Hydrologic Conditions
Wet
Average
Dry
Subsistence

High Flow Pulse Characteristics
F = Frequency (per season)
D = Duration (days)
Q = Peak Flows (cfs)
V = Volume (ac-ft)

Figure 7. Example Flow Regime Matrix for the Neches River at Evadale

Relate these selected metrics back to various flow periods identified (subsistence, Base, flood,overbank.

Summary

- Flow Habitat Fish Models
  - data intensive, require hydrology, habitat measures, fish life history and habitat utilization data
  - Directly answers questions regarding instream flow needs for aquatic organisms
- Desktop Hydrology Models (e.g. IHA).
  - Relatively easy
  - Assumes organisms have evolved to natural hydrology
  - Integrates geomorphology functions
  - Requires good record of hydrology (before, after etc).
  - How much flow and historical signature do you protect???

Thanks!