# EVALUATING EFFECTS OF POTENTIAL FLOW MODIFICATIONS AND FLOW MITIGATION OPTIONS ON FISH HABITATS RELATED TO THE PROPOSED PEBBLE MINE


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THE pebble PARTNERSHIP

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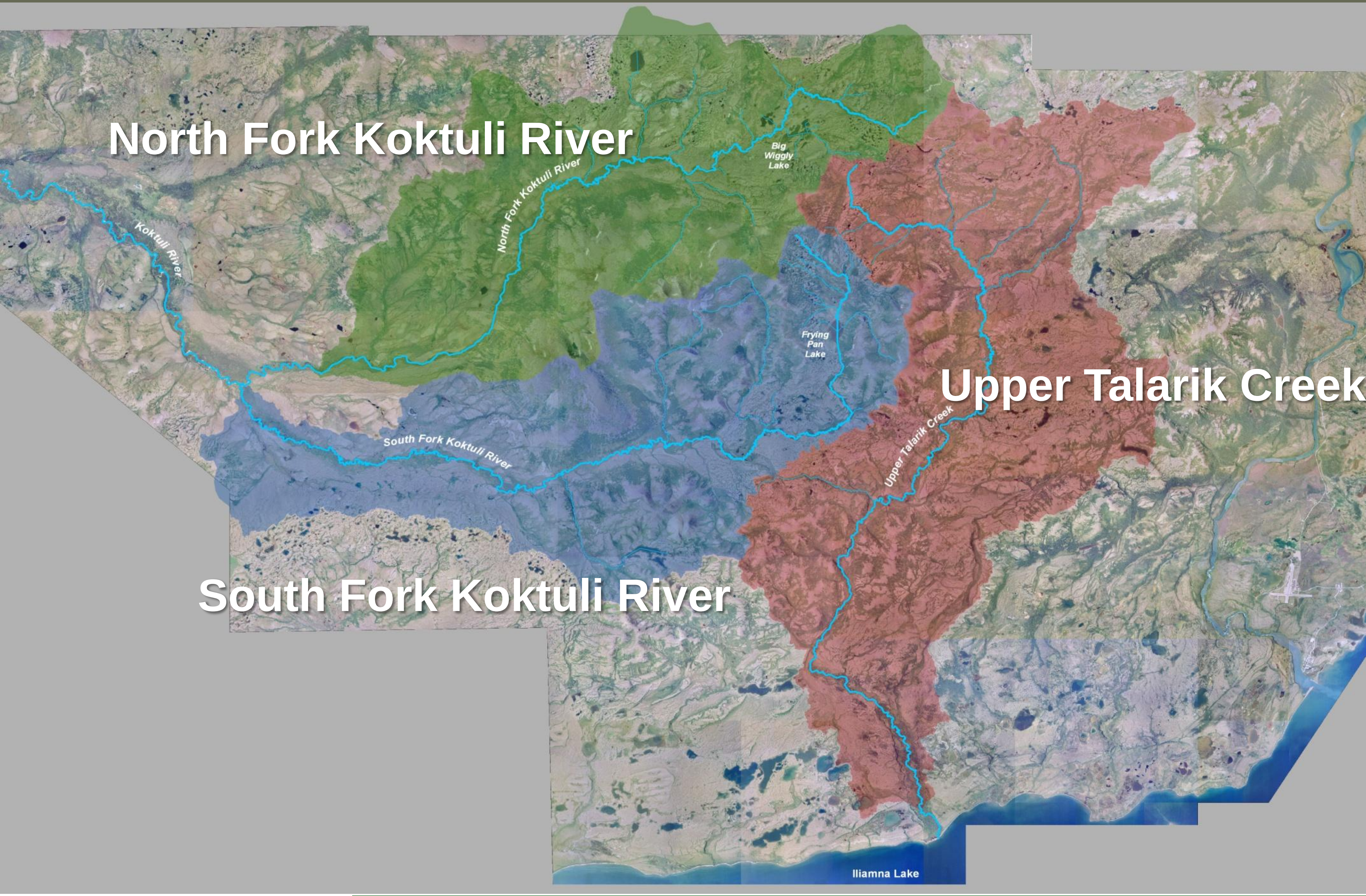
r2

# Outline of Presentation

- Overview of Project
- General Instream Flow Assessment Approach
  - Habitat Mapping
  - Physical Habitat Simulation (PHABSIM) – 1D Hydraulic Model
  - Hydrology
  - Habitat Suitability Criteria (HSC) curves
  - HABITAT MODELING
- Preliminary Results




# Major Drainages Within Pebble Project Area

# Potential Project Flow Related Effects

* No Change – hydrology not affected

* Temporal changes – alteration in the frequency and timing of flow metrics (e.g. peak flows, base flows, etc.)

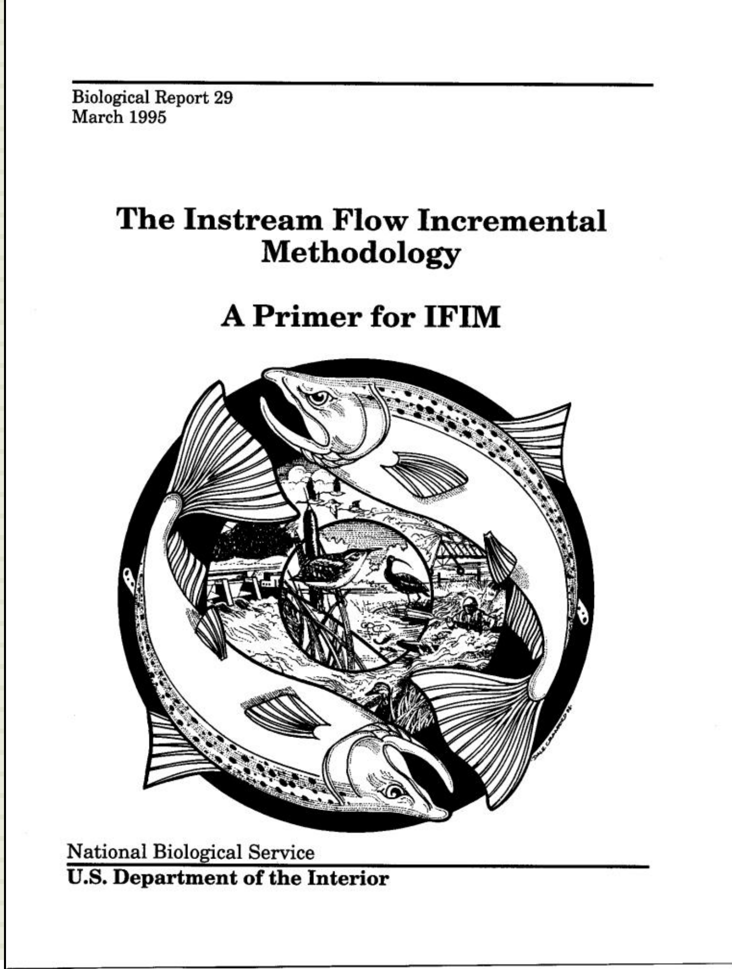
* Spatial changes – alterations in hydrology at specific locations

* Flow magnitude changes

* Changes in rate of change of flow

# Study Needs

- Develop an approach that would allow for the determination of when, where, and to what extent changes in flows within streams in the Pebble Project study area influence habitats of important fish species and lifestages – BASELINE CHARACTERIZATION
- Approach needs to consider local hydrologic conditions
- Approach needs to be able to quantify habitats under different flow conditions – locally, longitudinally, cumulatively.
- Approach needs to be adaptable to be able to consider potential flow related project effects.

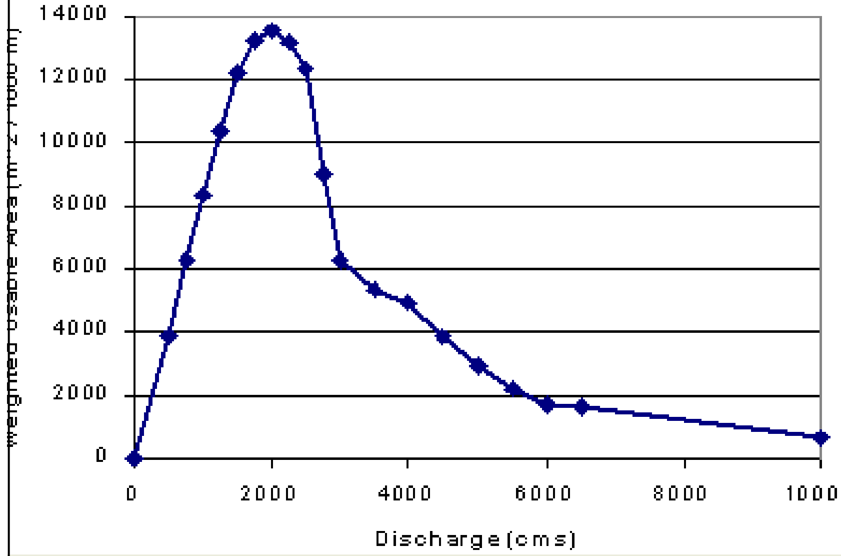

Biological Report 29
March 1995

The Instream Flow Incremental Methodology

A Primer for IFIM

National Biological Service
U.S. Department of the Interior

# Primary Approach




## Terminology – PHABSIM Physical Habitat Simulation

**PHABSIM – is a set of computer programs that is part of the Instream Flow Incremental Methodology (IFIM) (developed by the U.S. Fish and Wildlife Service in the 1970s) that using data collected along cross-channel transects of a stream, provides predictive relationships between flow changes and habitat (termed Weighted Useable Area – WUA)**

# PHABSIM Components

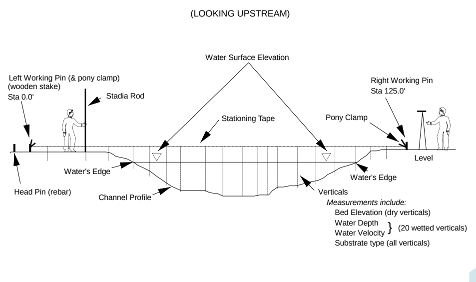
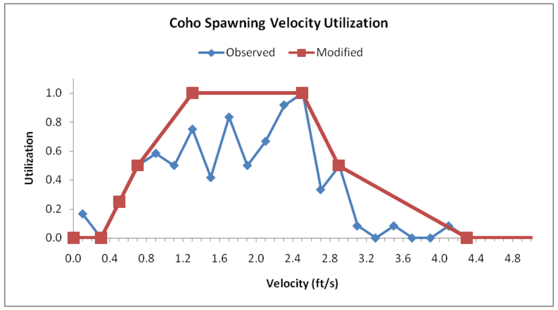



Figure 1. Example IFIM Cross Channel Transect

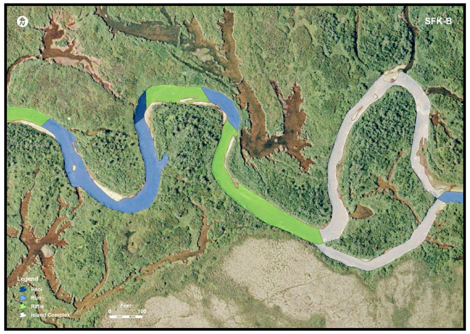
Transect Selection & Measurement



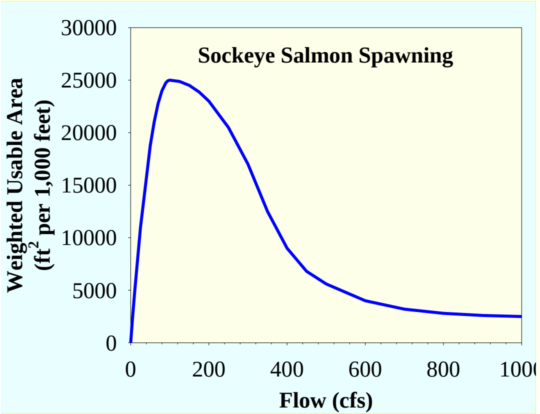

Habitat Mapping

PHABSIM

HSC Curves

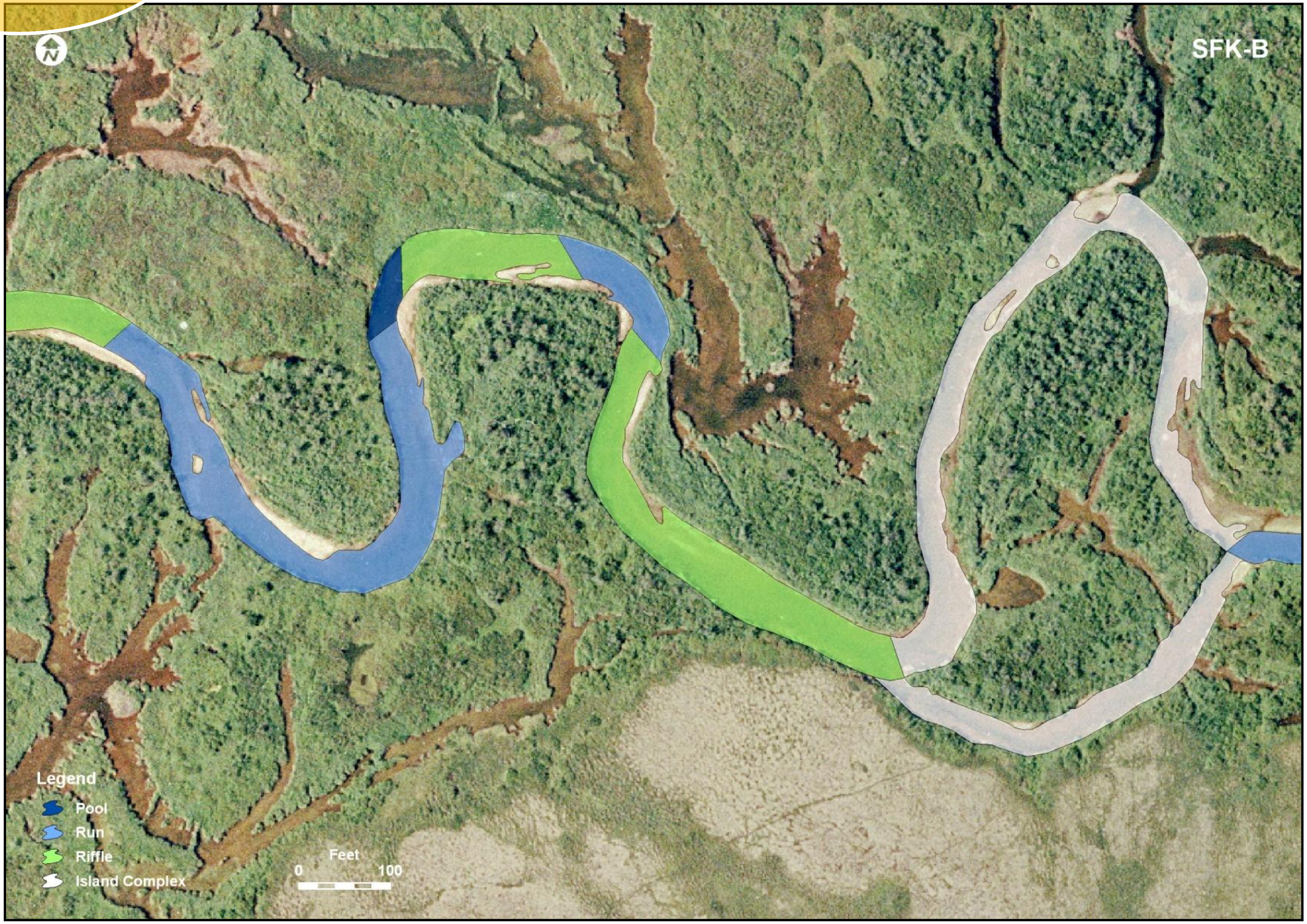



Habitat-Q Relationships

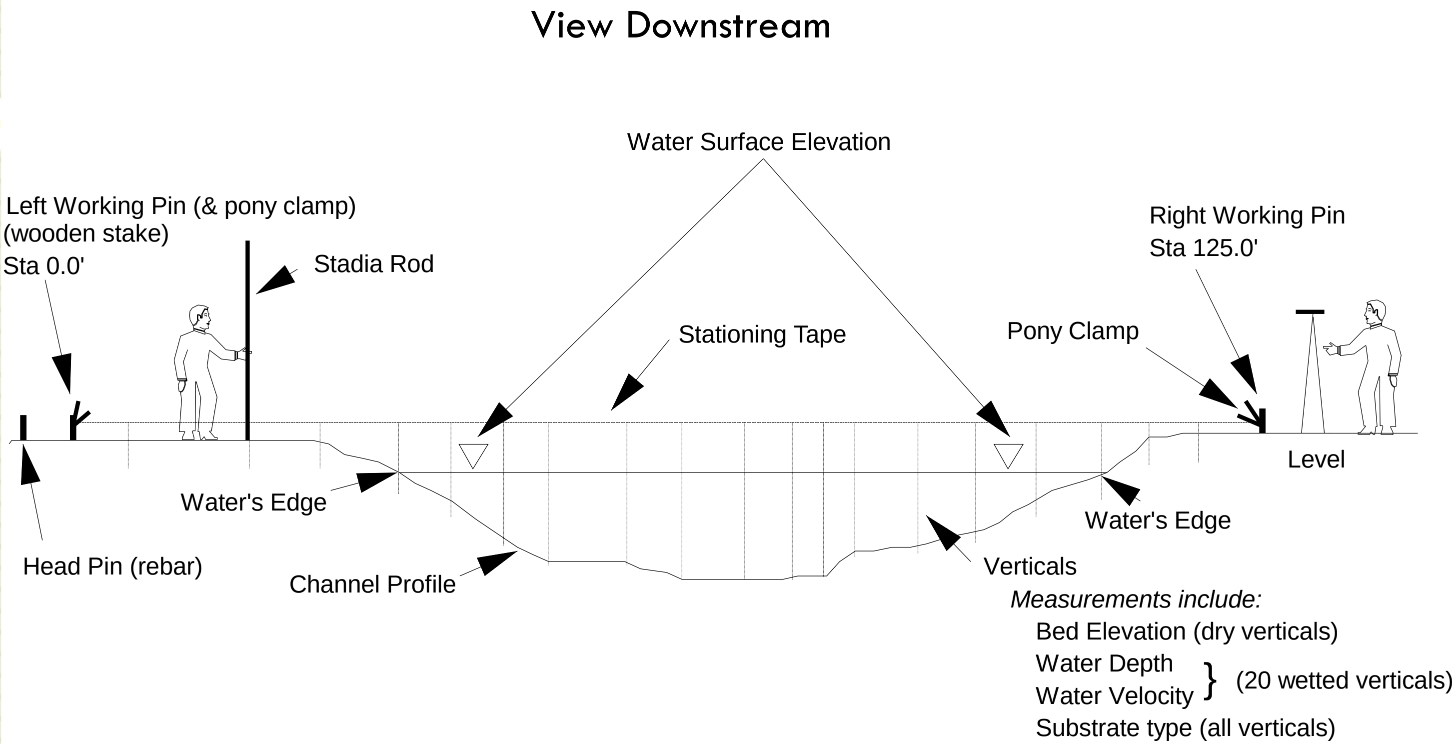


Habitat Mapping

# Habitat Units



Transect Selection & Measurement




# Primary Measurement point = Transect

**Transect – A predetermined line across a section of stream along which depth, velocity and substrate measurements are made under different flows. Data serve as input into PHABSIM modeling.**

Transect Selection & Measurement

# PHABSIM Sites
# Summary of Field Data Collection

**Total of 117 Transects**

North Fork Koktuli River Mainstem – 27 transects

North Fork Koktuli River Tributary – 3 transects

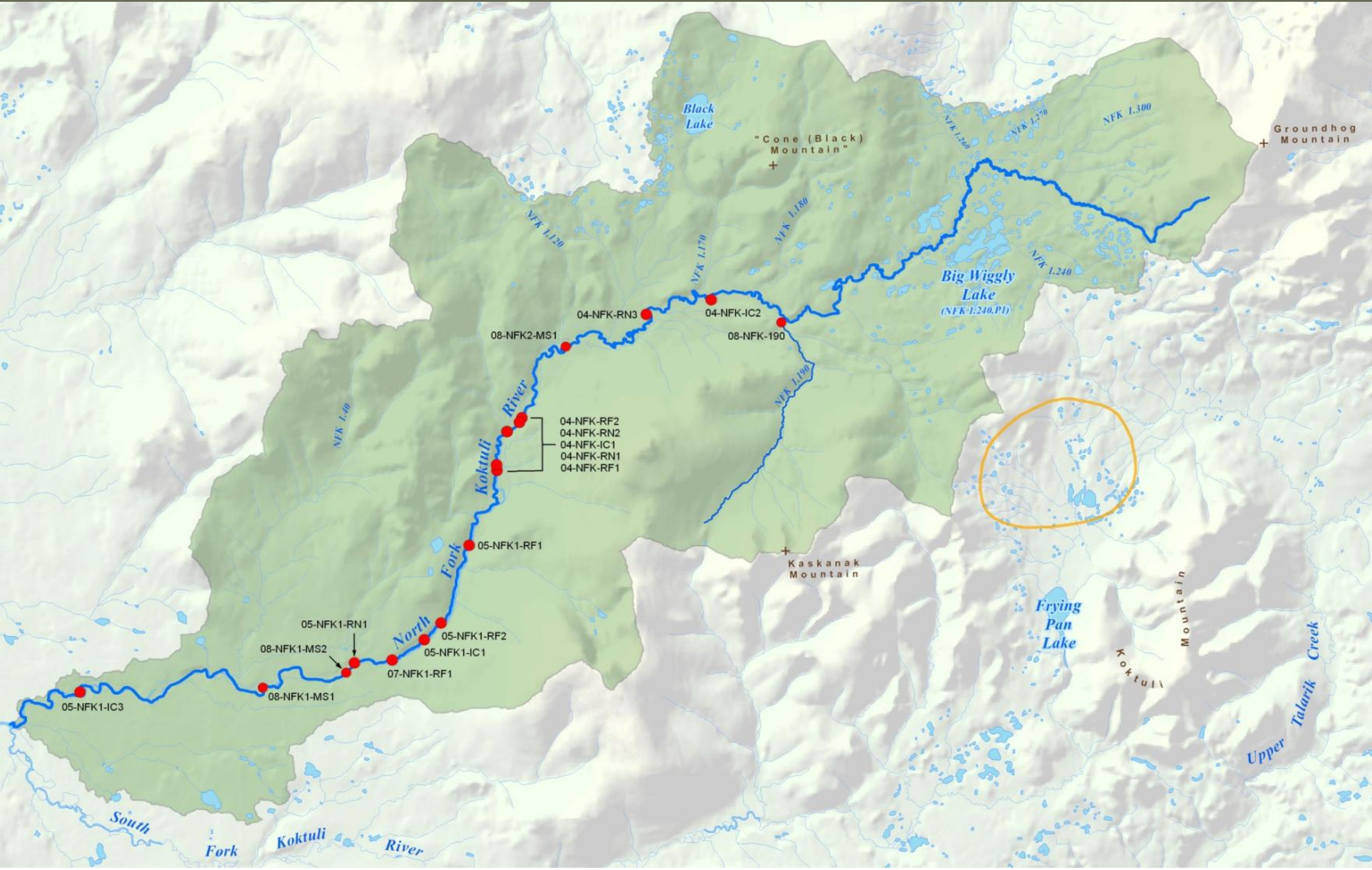
South Fork Koktuli River Mainstem – 37 transects

South Fork Koktuli River Tributary – 6 transects

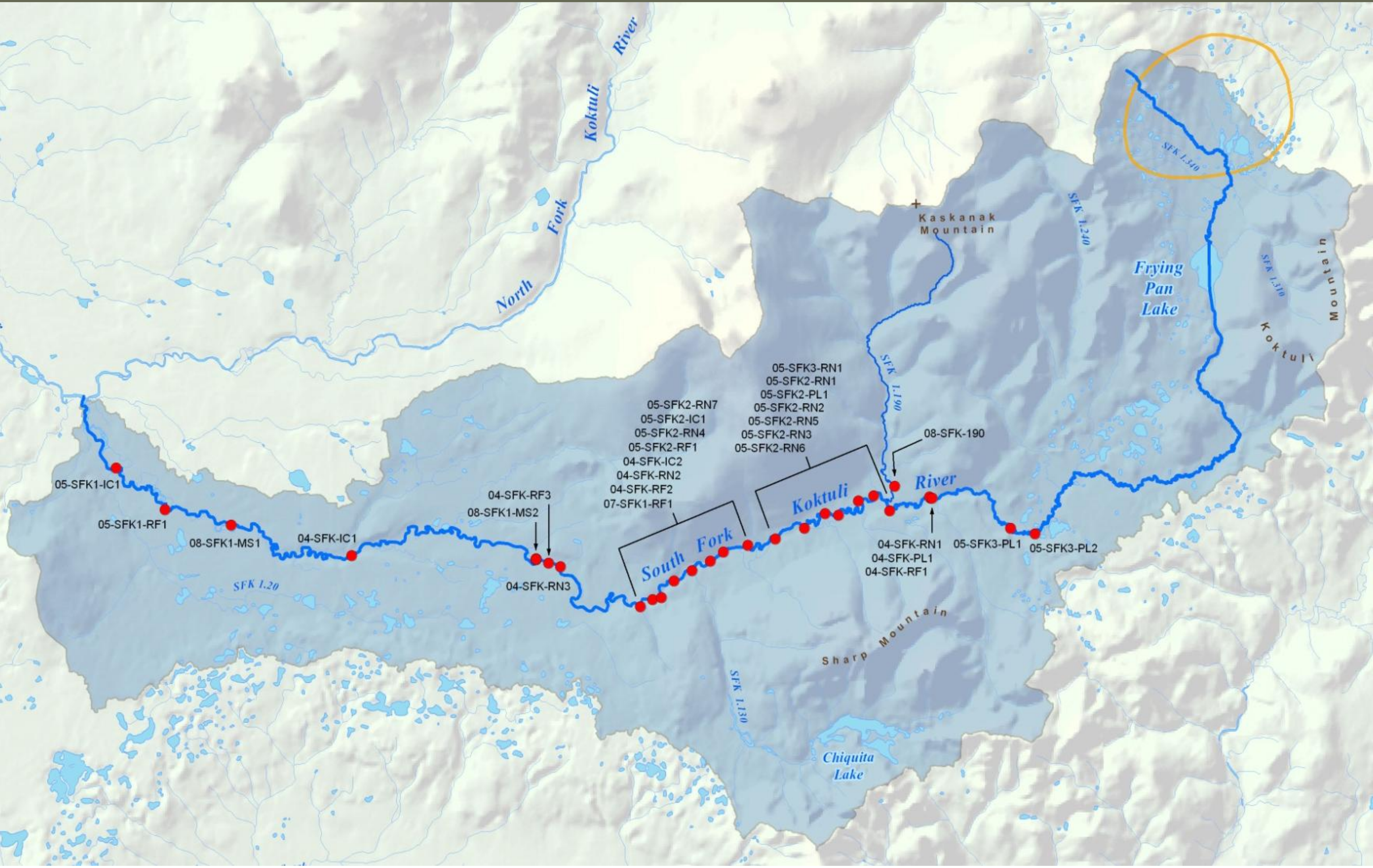
Mainstem Koktuli River – 4 transects

Upper Talarik Creek Mainstem – 35 transects

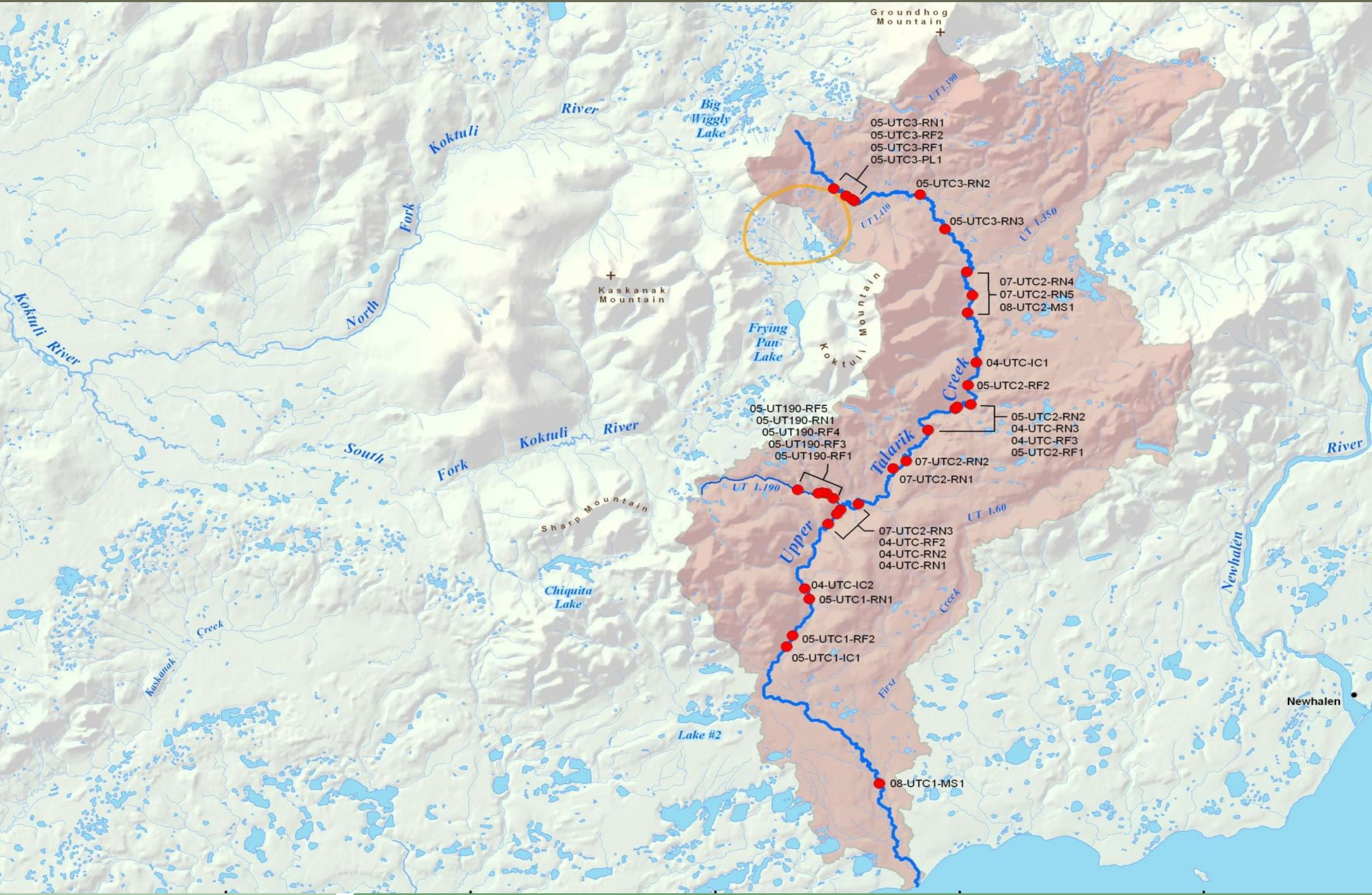
Upper Talarik Creek Tributary – 5 transects




# NORTH FORK KOKTULI – Transect Locations




# SOUTH FORK KOKTULI – TRANSECT LOCATIONS



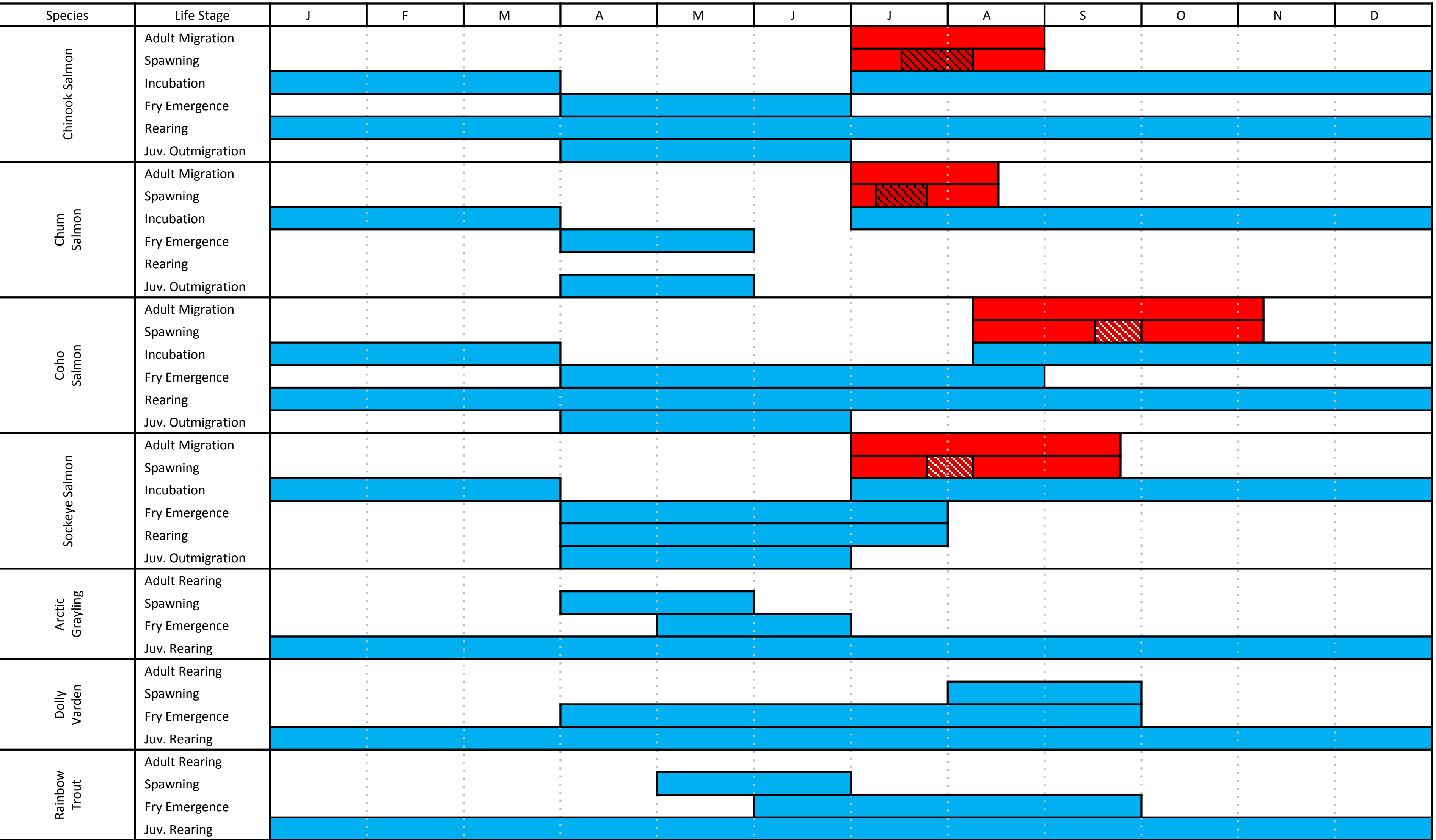

# UPPER TALARIK CREEK – Transect Locations

# Habitat Modeling - Transects

- **Habitat Modeling**
  - Calibrated IFG4 data decks
  - Periodicity – Species and Life Stages
  - Site specific HSC curves (NFK, SFK, UT)
  - WUA (Weighted Usable Area) for individual flow

    - from HABTAV habitat model
  - Composite WUA derived from the WUAs of all measured flows of the transect .

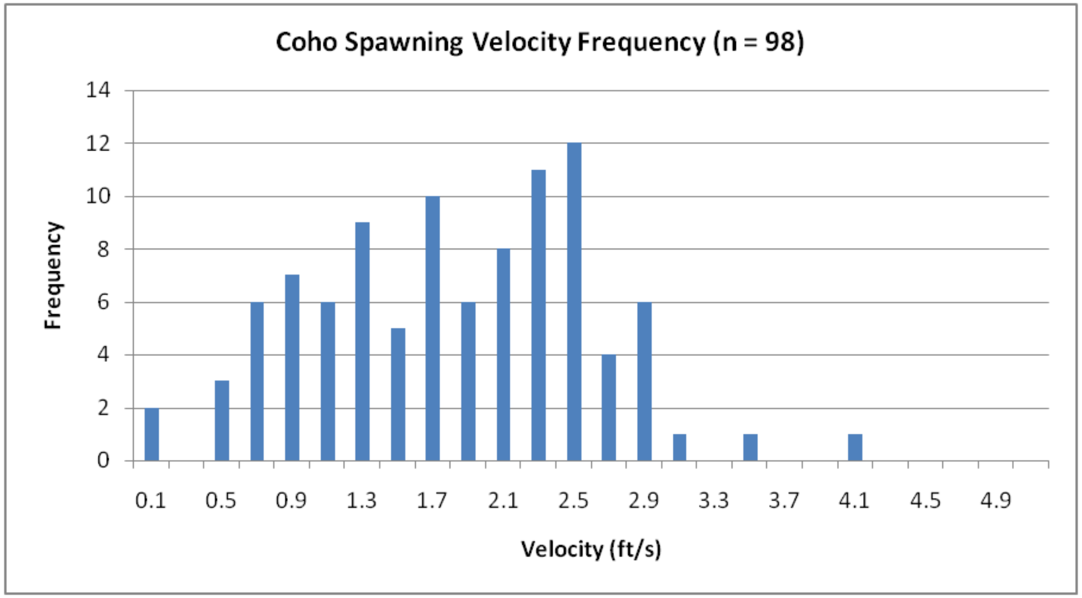
# North Fork Koktuli River Periodicity

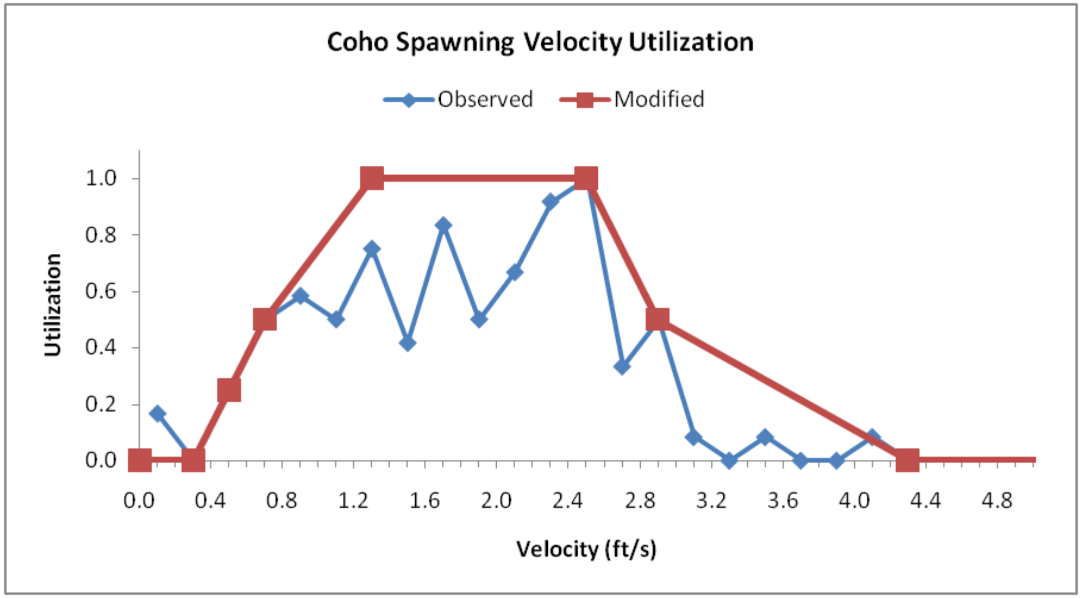


# Habitat Suitability Curves (e.g.) – Velocity

HSC Curves

| Velocity | Modified Utilization |
|---|---|
| 0.0 | 0.00 |
| 0.3 | 0.00 |
| 0.5 | 0.25 |
| 0.7 | 0.50 |
| 1.3 | 1.00 |
| 2.5 | 1.00 |
| 2.9 | 0.50 |
| 4.3 | 0.00 |
| 99.0 | 0.00 |



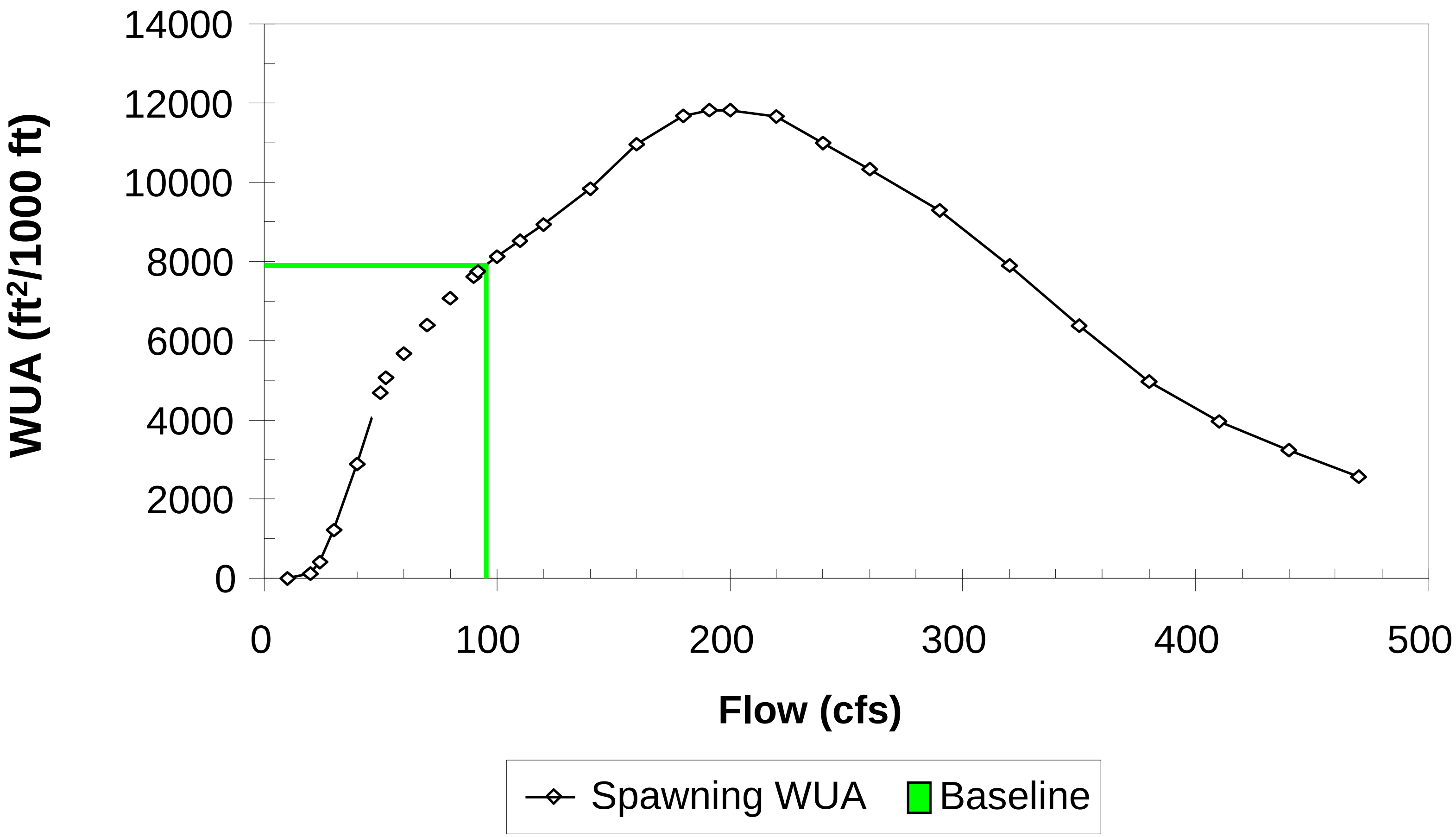
# SOME EXAMPLE WUA – FLOW RELATIONSHIPS

Spawning and Juvenile Lifestages

# 05-SFK2-RN7

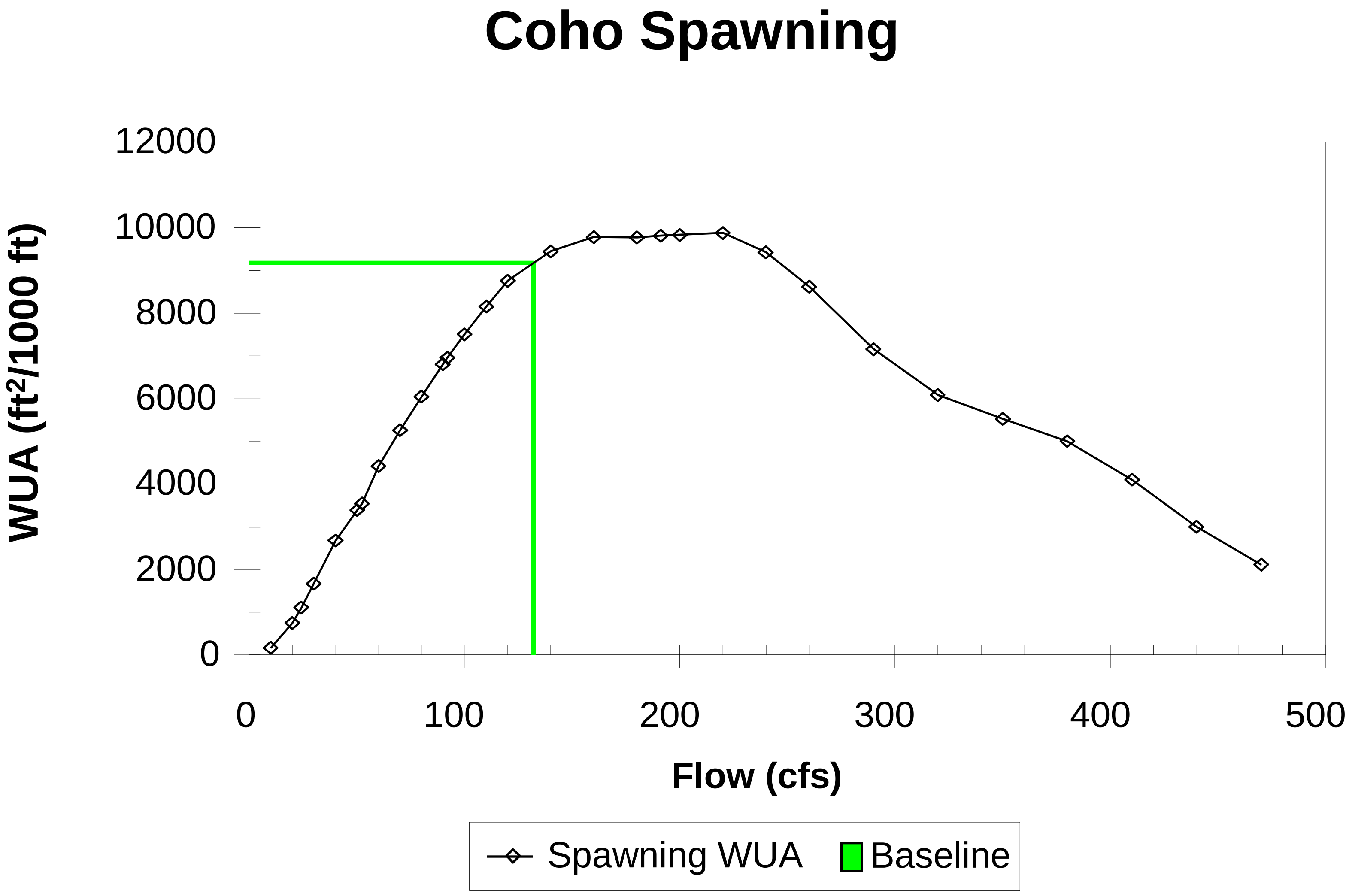
## Average Year

### Chinook Spawning



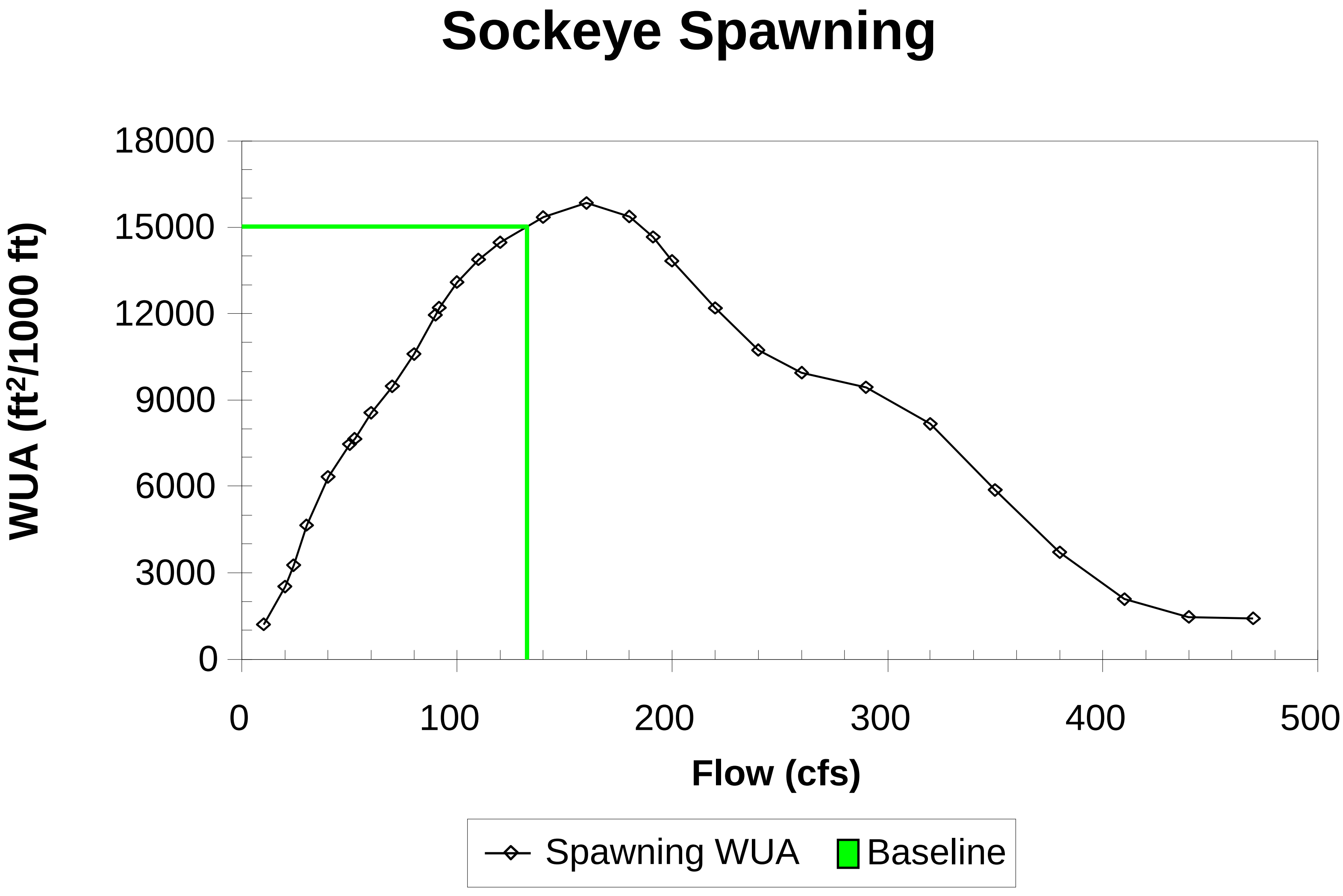
# 05-SFK2-RN7

## Average Year



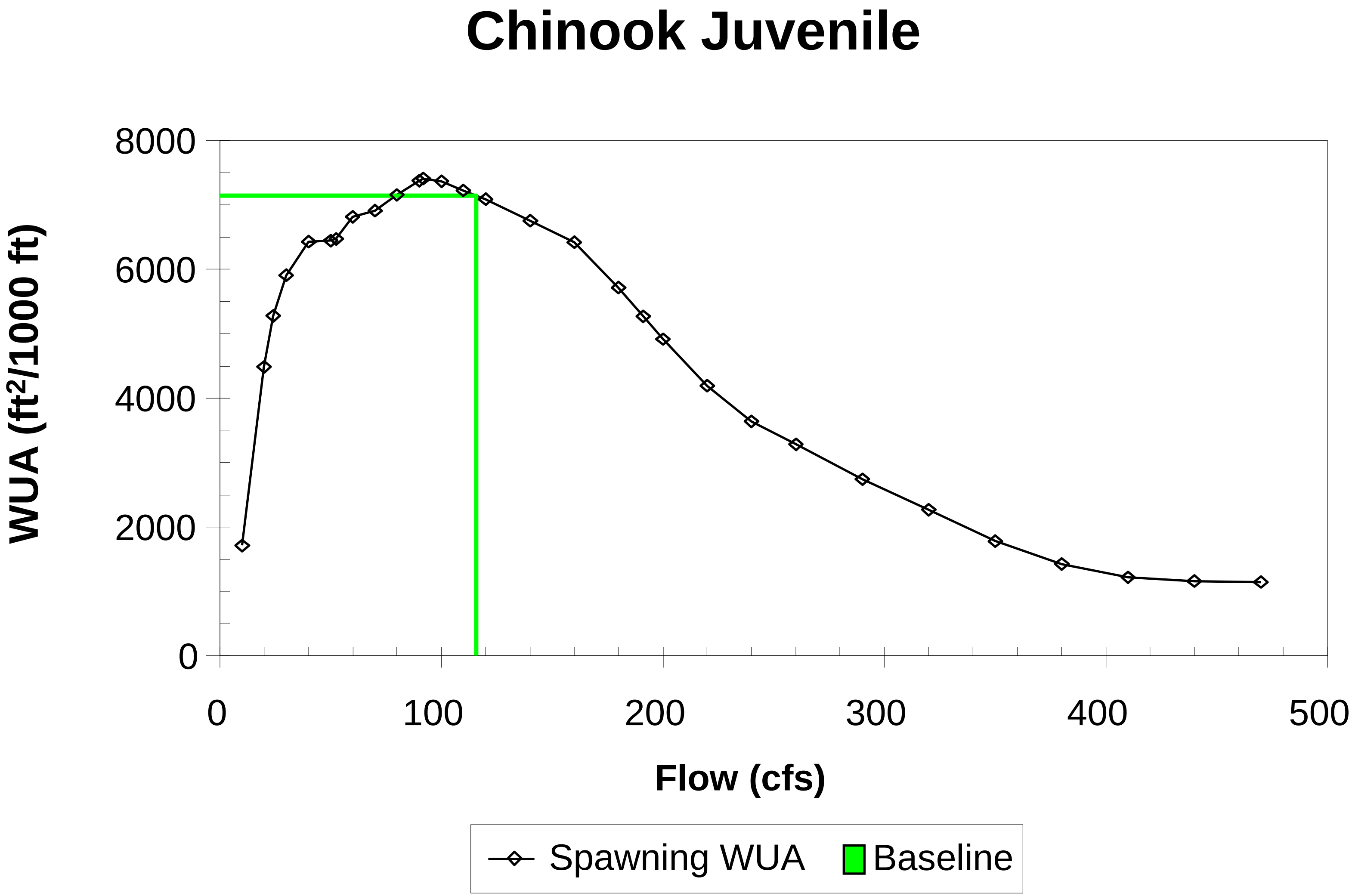
# 05-SFK2-RN7

## Average Year



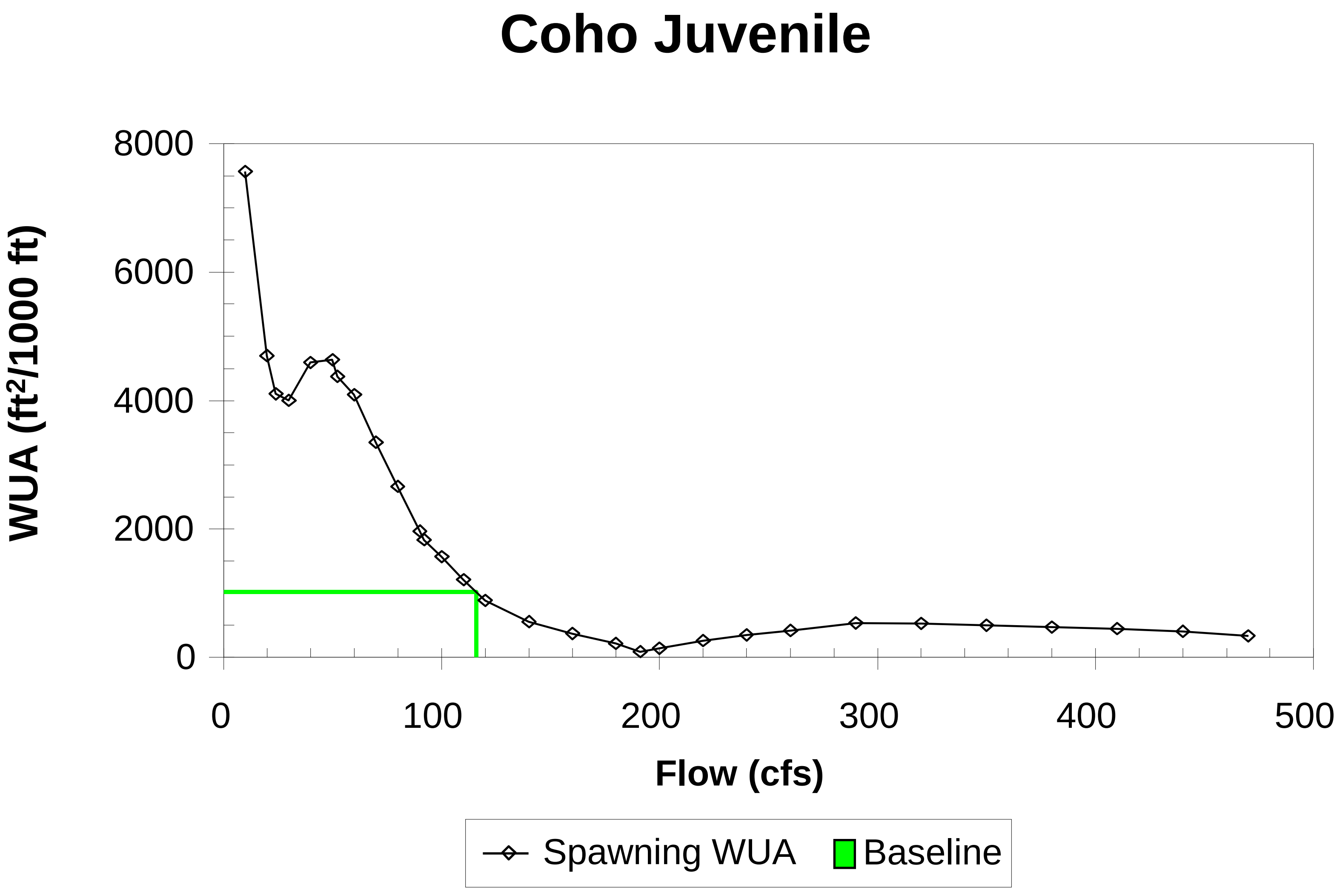
# 05-SFK2-RN7

## Average Year



# 05-SFK2-RN7

## Average Year



# Habitat Modeling - Hydrology

- **Hydrology – Knight Piesold**
  - ➢ 68 years of monthly flows at 30 hydrology sites

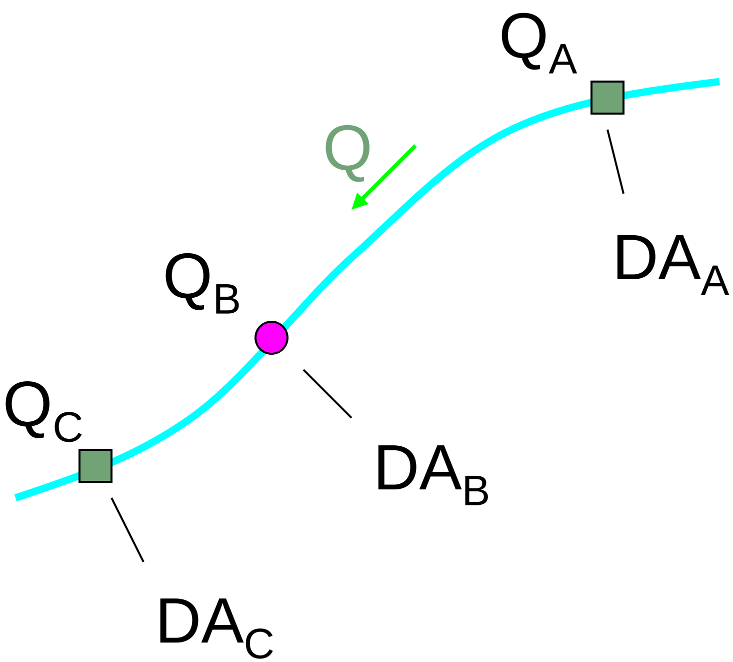
    - Baseline (Natural) flow $Q_{pre\text{-}mine}$

    Interpolate flow at each PHABSIM transect and reach breakpoint using methodology developed by KP
  - ➢ Flows greater than February 10% exceedance flow are assumed to be dominated by surface water – interpolate based on drainage area
  - ➢ Flows less than February 10% exceedance flow are assumed to be dominated by groundwater – interpolate based on longitudinal distance

# Habitat Modeling – Hydrology

## High Flow Hydrology ($Q_A$ > February 10% exceedance flow)

## Flows Change Linearly with Drainage Area




(1) $Q_A$: Q at hydrology site A

$Q_B$: Interpolated Q at site B

$Q_C$: Q at hydrology site C

(2) $DA_A$, $DA_B$, and $DA_C$: Drainage Areas at sites A, B, and C

(3) $W_A = (DA_C - DA_B) / (DA_C + DA_C)$

$W_B = 1 - W_A$

$W_A$, $W_B$ : site weighting factors

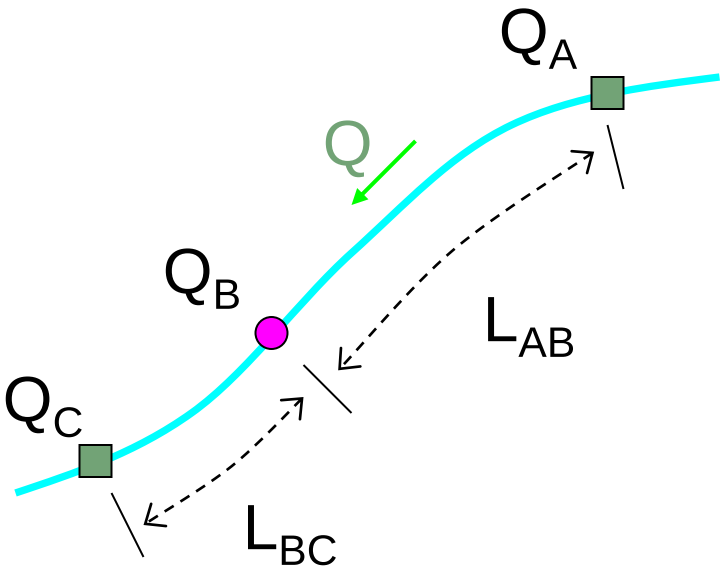
**Estimated Flow at Site B (e.g. habitat unit)**

$$Q_B = Q_A * W_A + Q_C * W_C$$

# Habitat Modeling – Hydrology

## Low Flow Hydrology ($Q_A$ < February 10% exceedance flow)

## Flows Change Linearly with Longitudinal Distance




(1) $Q_A$: Q at hydrology site A

$Q_B$: Interpolated Q at site B

$Q_C$: Q at hydrology site C

(2) $L_{AB}$, $L_{BC}$: distances between sites

(3) $W_A = L_{BC} / (L_{AB} + L_{BC})$

$W_B = 1 - W_A$

$W_A$, $W_B$ : site weighting factors

**Estimated Flow at Site B (e.g. habitat unit)**

$$Q_B = Q_A * W_A + Q_C * W_C$$

# HOW TO EXPAND RESULTS FROM TRANSECT LOCATION TO OTHER LOCATIONS IN THE STREAM?

Habitat mapping

# Habitat Mapping - GIS Based Process Used to Define Habitat Unit Metrics

Generate stream centerline from the mesohabitat low-flow wetted area edges.

# GIS Based Habitat Mapping

Combine adjacent mesohabitat units of the same type (i.e. pool, run, riffle) and then transfer habitat type and area metrics from the unit polygon to the stream centerline.

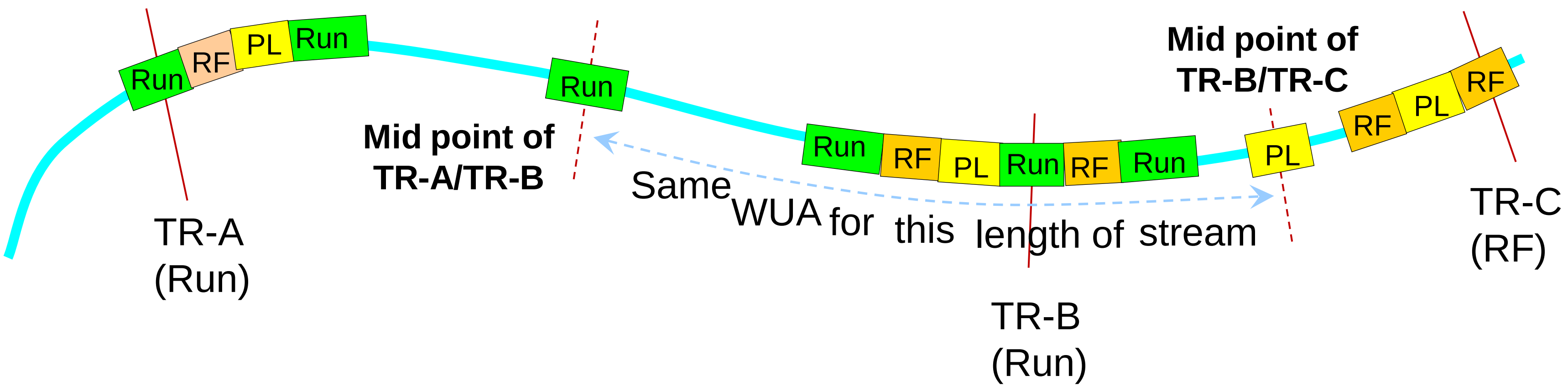
# Habitat Modeling – Mesohabitat Mapping

Number of Habitat Units – 1955 for all streams

| Stream System | Reach | # of Habitat Units | Reach Length (km) | Cumulative Length (km) | Length per Habitat Unit (km) |
|---|---|---|---|---|---|
| NFK | NFK-A | 75 | 13.81 | 13.81 | 0.184 |
| | NFK-B | 42 | 7.42 | 21.23 | 0.177 |
| | NFK-C | 152 | 15.59 | 36.83 | 0.103 |
| | NFK-190 | 272 | 8.03 | 8.03 | 0.030 |
| SFK | SFK-A | 179 | 24.79 | 24.79 | 0.139 |
| | SFK-B | 78 | 9.10 | 33.89 | 0.117 |
| | SFK-C | 201 | 17.52 | 51.41 | 0.087 |
| | SFK-190 | 95 | 6.86 | 6.86 | 0.072 |
| UT | UT-B | 72 | 16.98 | 16.98 | 0.236 |
| | UT-C | 93 | 8.08 | 25.06 | 0.087 |
| | UT-D | 158 | 11.73 | 36.80 | 0.074 |
| | UT-E | 131 | 8.98 | 45.78 | 0.069 |
| | UT-F | 399 | 14.28 | 60.06 | 0.036 |
| | UT-190 | 8 | 2.76 | 2.76 | 0.346 |

Note: Tributary results are from field habitat surveys

# Habitat Modeling – Habitat Area
## (Commonly applied approach)



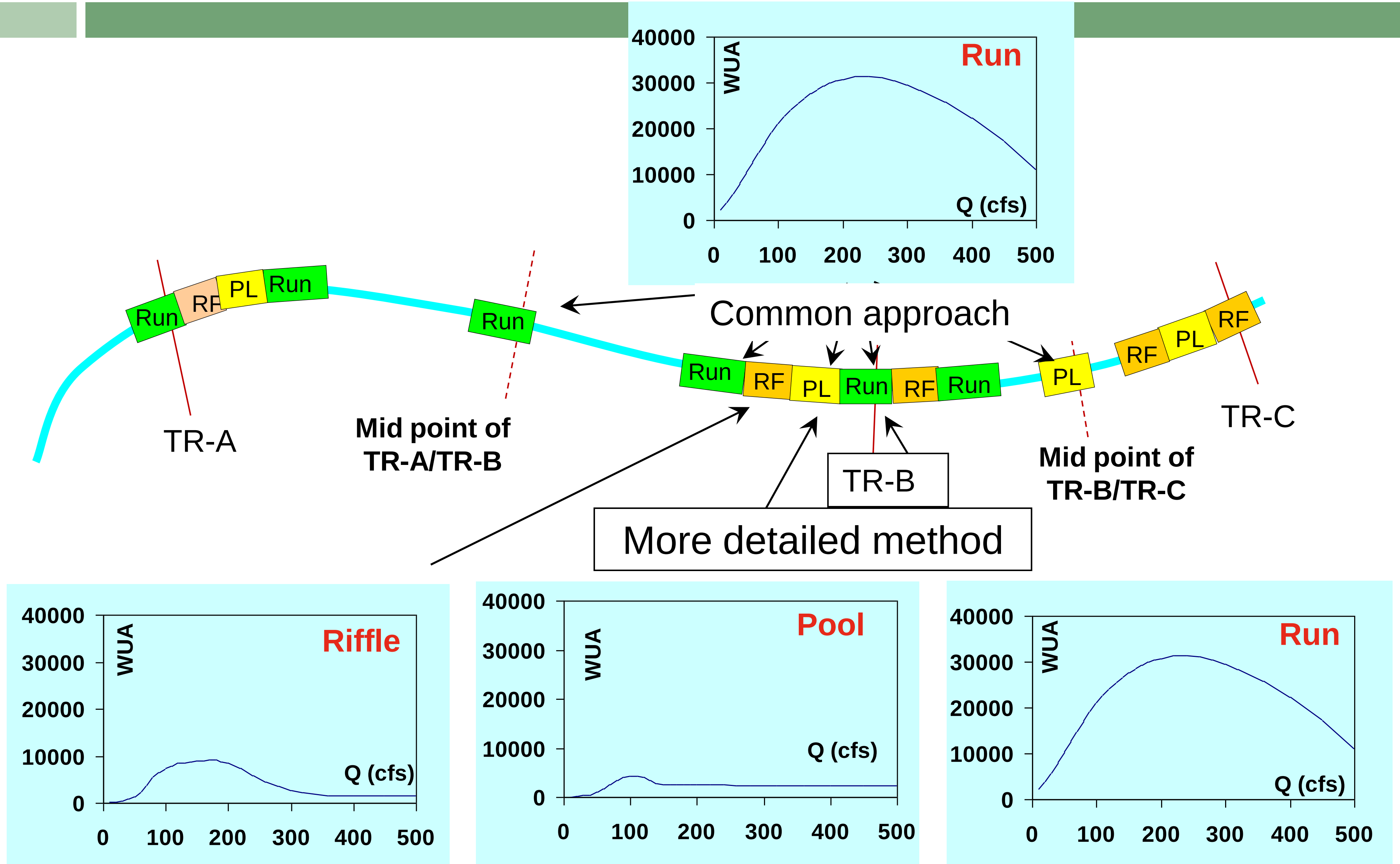

(1) Same WUA applied to the reach length between the mid point of TR-A/TR-B and the mid point of TR-B-/TR-C, regardless of habitat types within the reach.

(2)Habitat areas could be over/under-estimated.

(3)Different habitat types not considered individually.

# Habitat Modeling – Habitat Area

Common approach does not consider WUA variation of individual habitat units



# Habitat Modeling – Habitat Area
## (Detailed method overview)

(A) WUAs of PHABSIM TRs are expanded to each habitat unit of the same habitat type

(B) Synthesized WUAs are calculated for each habitat unit

(C) Data involved in deriving the synthesized WUAs include

(C.1) Channel width - bankfull flow width

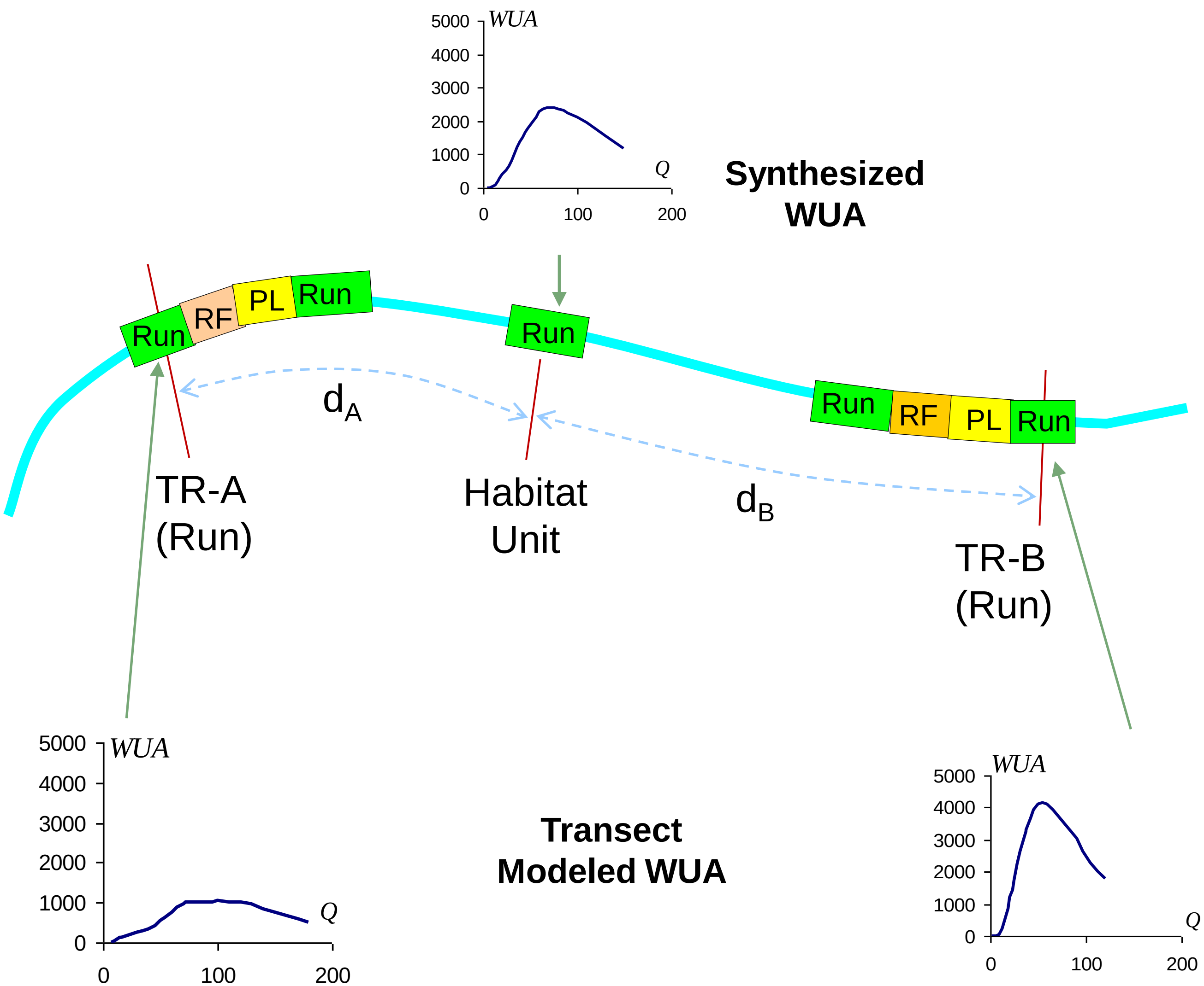
(C.2) Mesohabitat mapping results – River Kilometer, habitat unit length, habitat types for each habitat unit on NFK, SFK, UT mainstems.

(C.3) Field habitat survey – River Kilometer, habitat length,habitat type for the three streams.

(C.4) Monthly flows of 68 years of hydrology

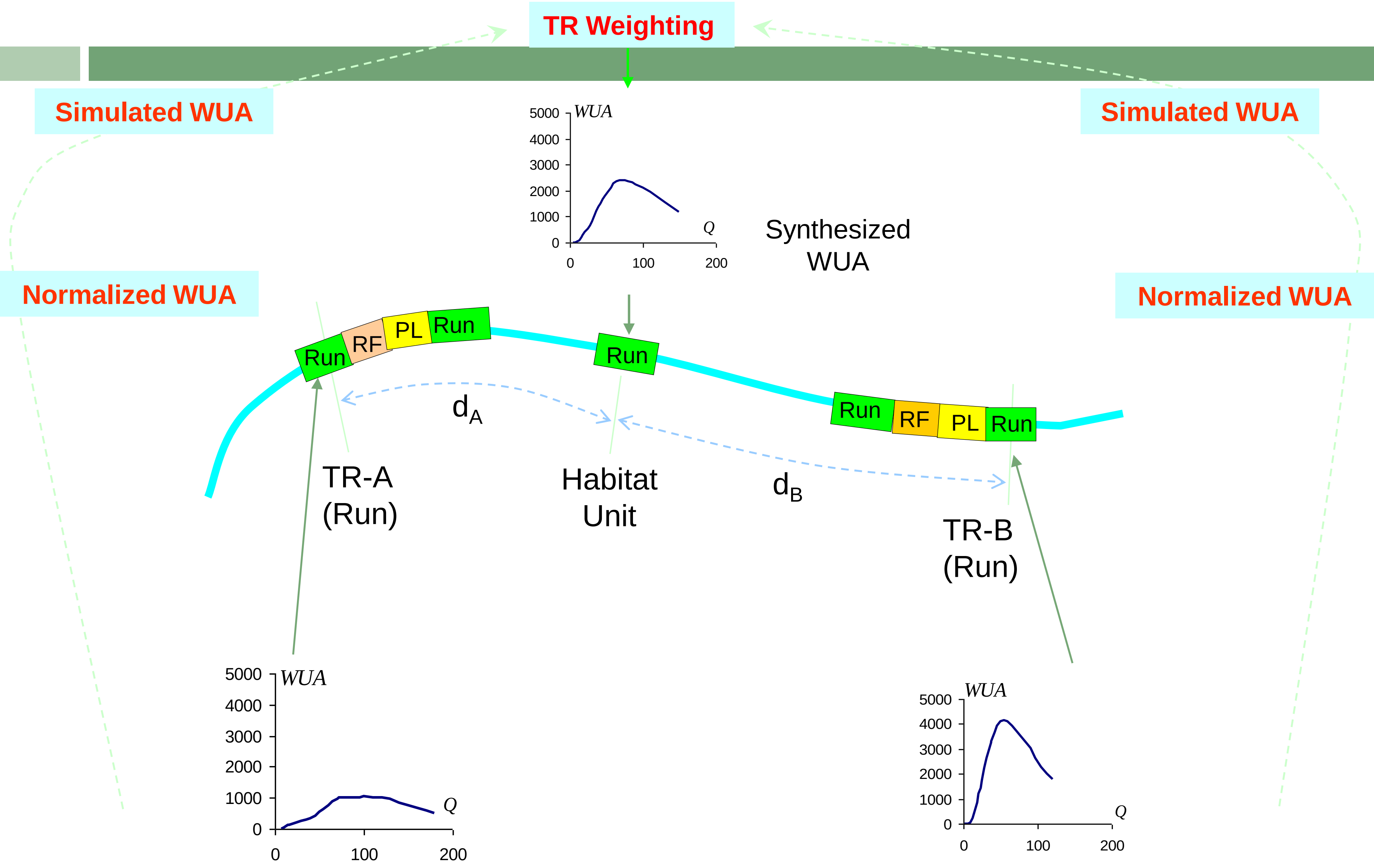
(C.5) WUA curves of all 117 transects from habitat modeling results

# Habitat Modeling – Habitat Unit WUA
## (Detailed method)



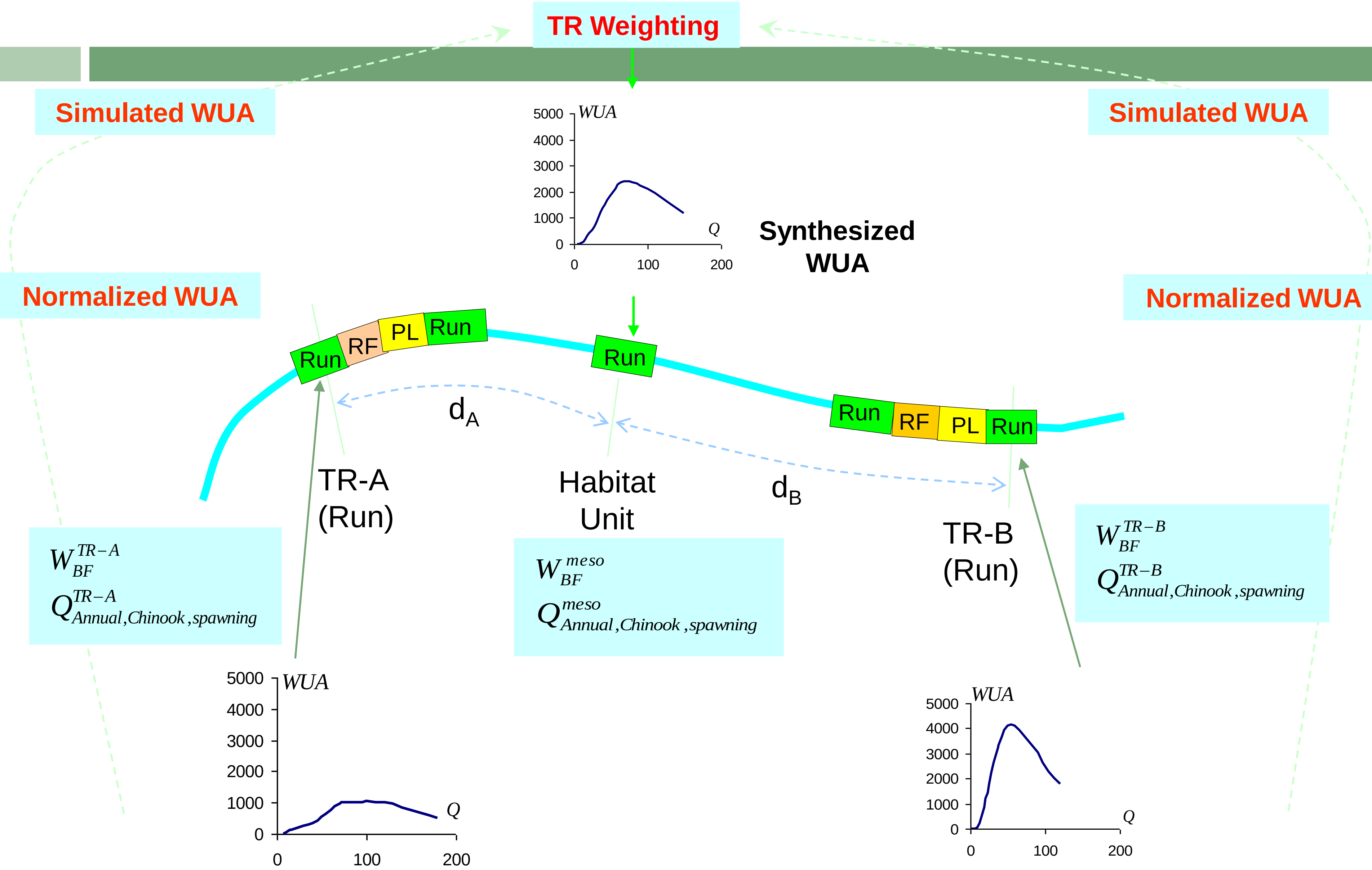
# Habitat Modeling – Habitat Unit WUA

## (Detailed method overview)



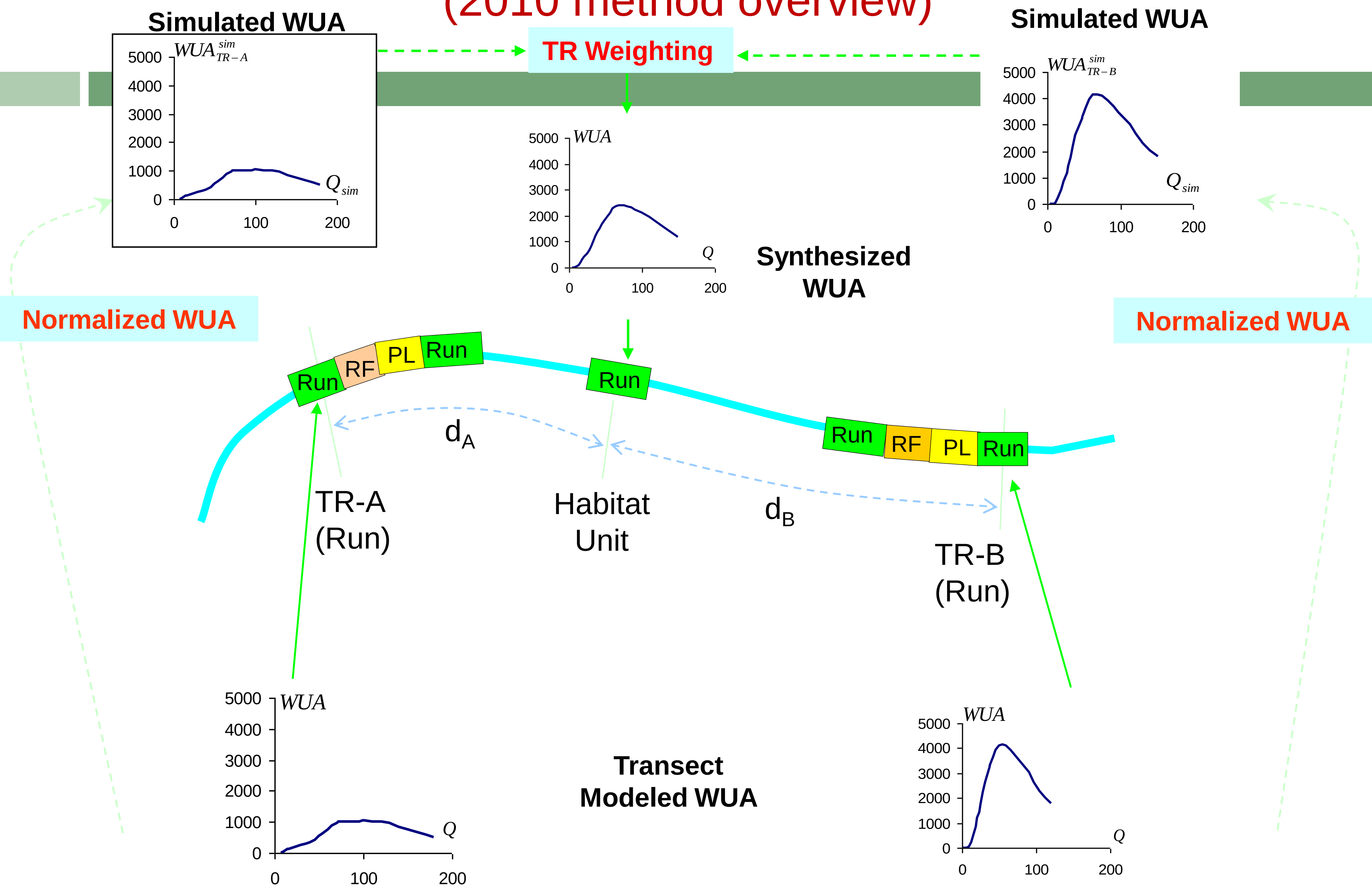
# Habitat Modeling – Habitat Unit WUA

## (2010 method overview)

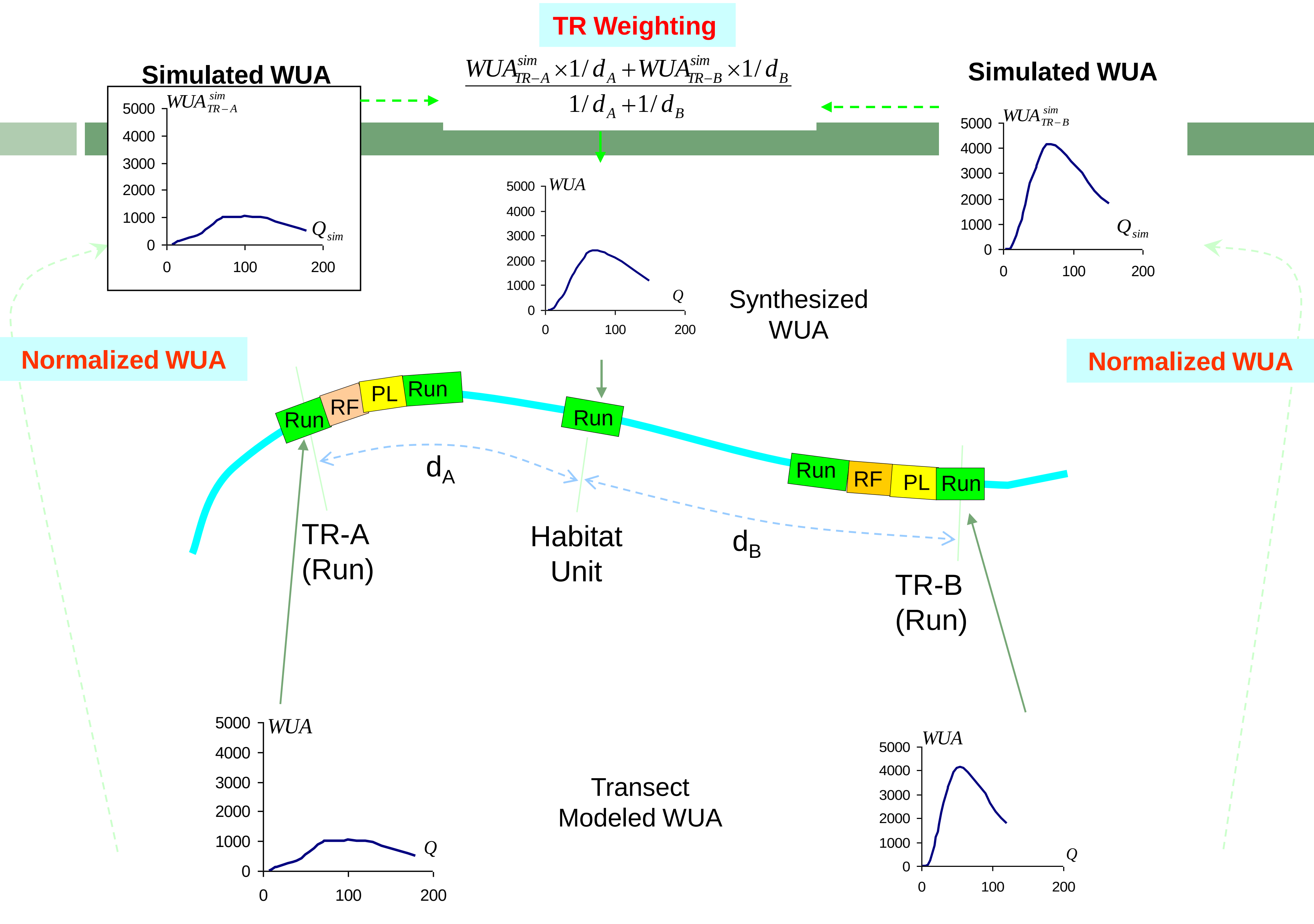


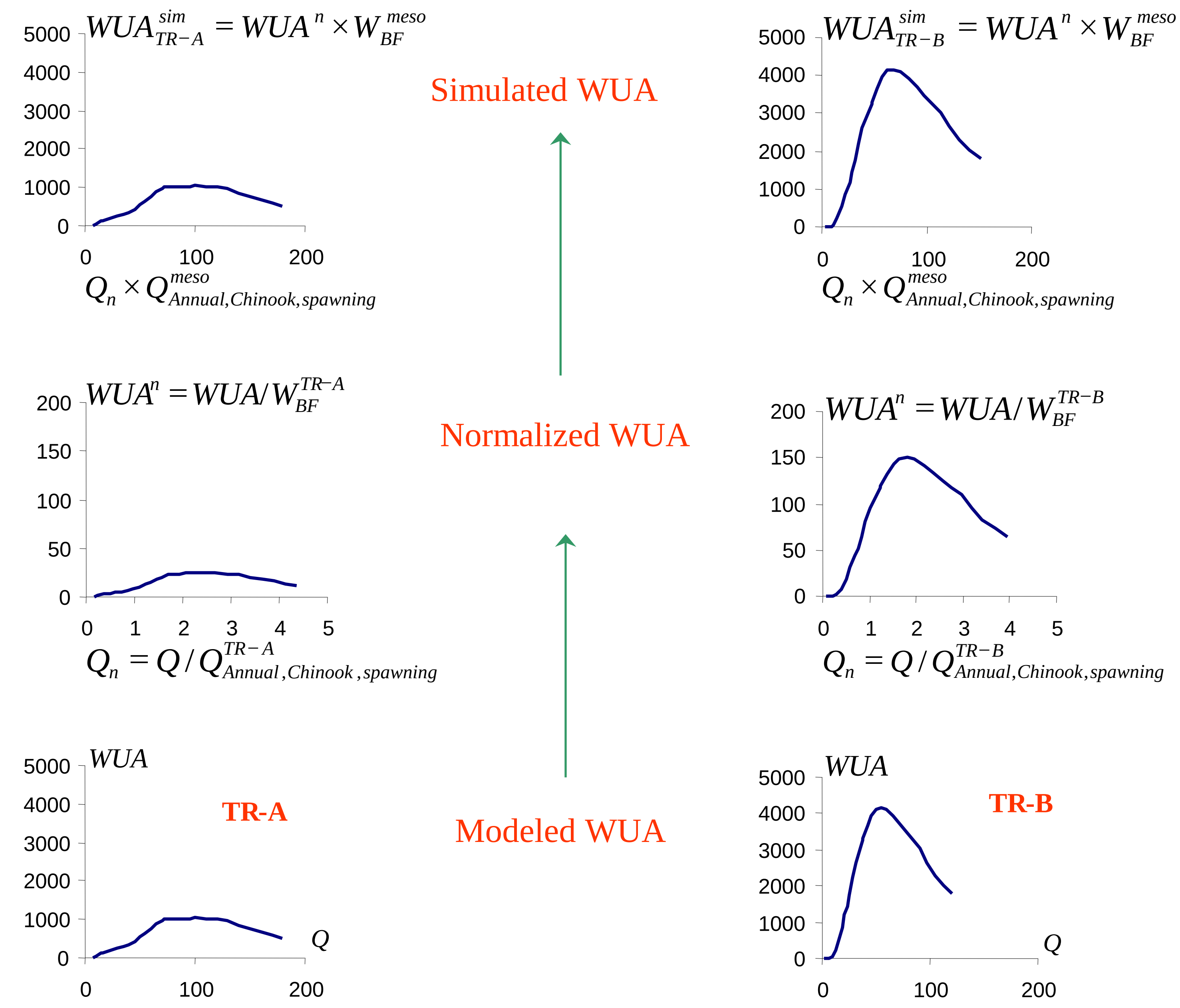
# Habitat Modeling – Habitat Unit WUA

## (2010 method overview)



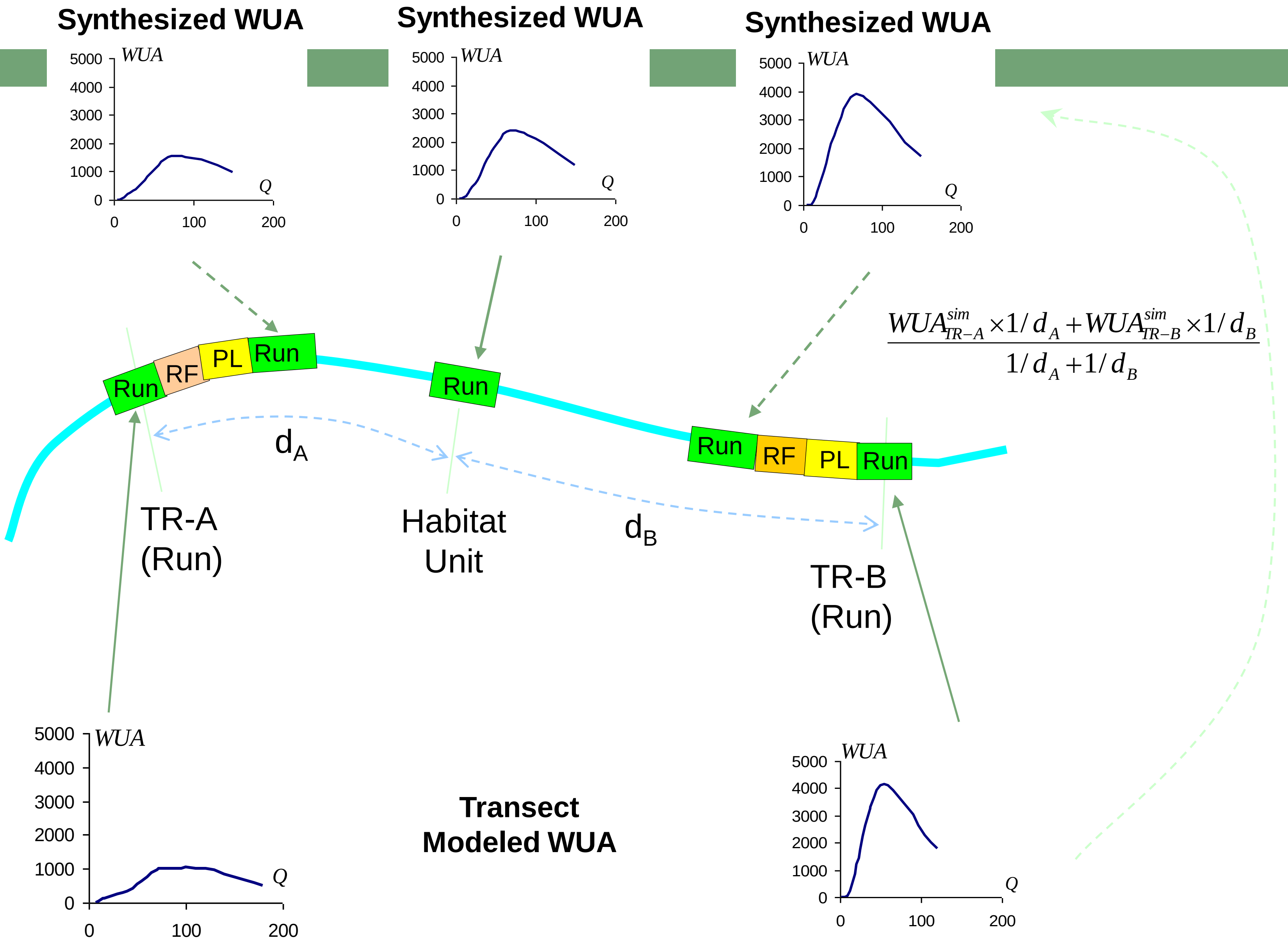
# Habitat Modeling – Habitat Unit WUA





$WUA^{sim}_{TR-A} = WUA^{n} \times W^{meso}_{BF}$
$Q_n \times Q^{meso}_{Annual,Chinook,spawning}$
$WUA^{sim}_{TR-B} = WUA^{n} \times W^{meso}_{BF}$
$Q_n \times Q^{meso}_{Annual,Chinook,spawning}$
Simulated WUA
$WUA^{n} = WUA / W^{TR-A}_{BF}$
$Q_n = Q / Q^{TR-A}_{Annual,Chinook,spawning}$
$WUA^{n} = WUA / W^{TR-B}_{BF}$
$Q_n = Q / Q^{TR-B}_{Annual,Chinook,spawning}$
Normalized WUA
WUA
TR-A
Q
WUA
TR-B
Q
Modeled WUA

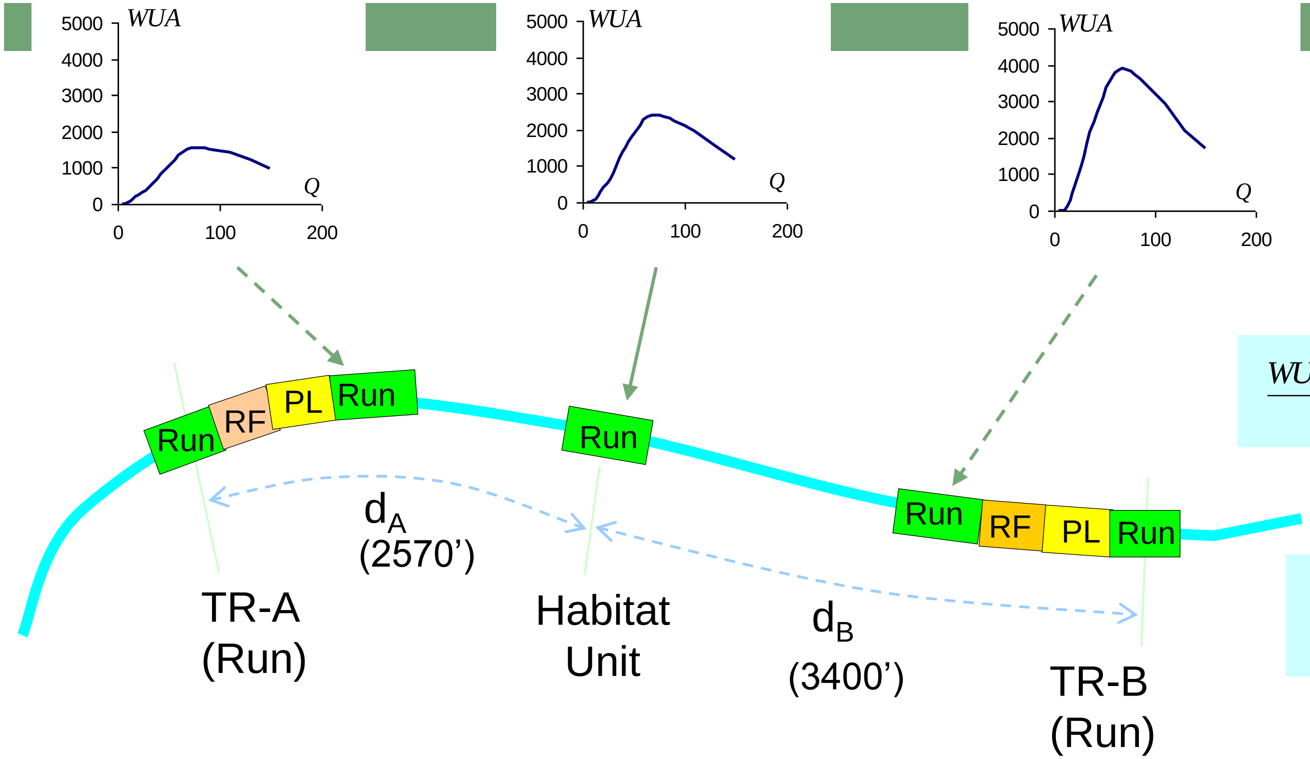
# Habitat Modeling – Habitat Unit WUA
## (Detailed method overview)



# Habitat Modeling – Habitat Unit WUA

## (Detailed method example)

Synthesized WUA | Synthesized WUA | Synthesized WUA




example

$$\frac{WUA^{sim}_{TR-A} \times 1/2570 + WUA^{sim}_{TR-B} \times 1/3400}{1/2570 + 1/3400}$$

$$\frac{WUA^{sim}_{TR-A} \times 1/d_A + WUA^{sim}_{TR-B} \times 1/d_B}{1/d_A + 1/d_B}$$

$W_{BF}^{TR-A}$

$Q^{TR-A}_{Annual,Chinook,spawning}$

(ex:W=42', Q=41cfs)

$W_{BF}^{meso}$

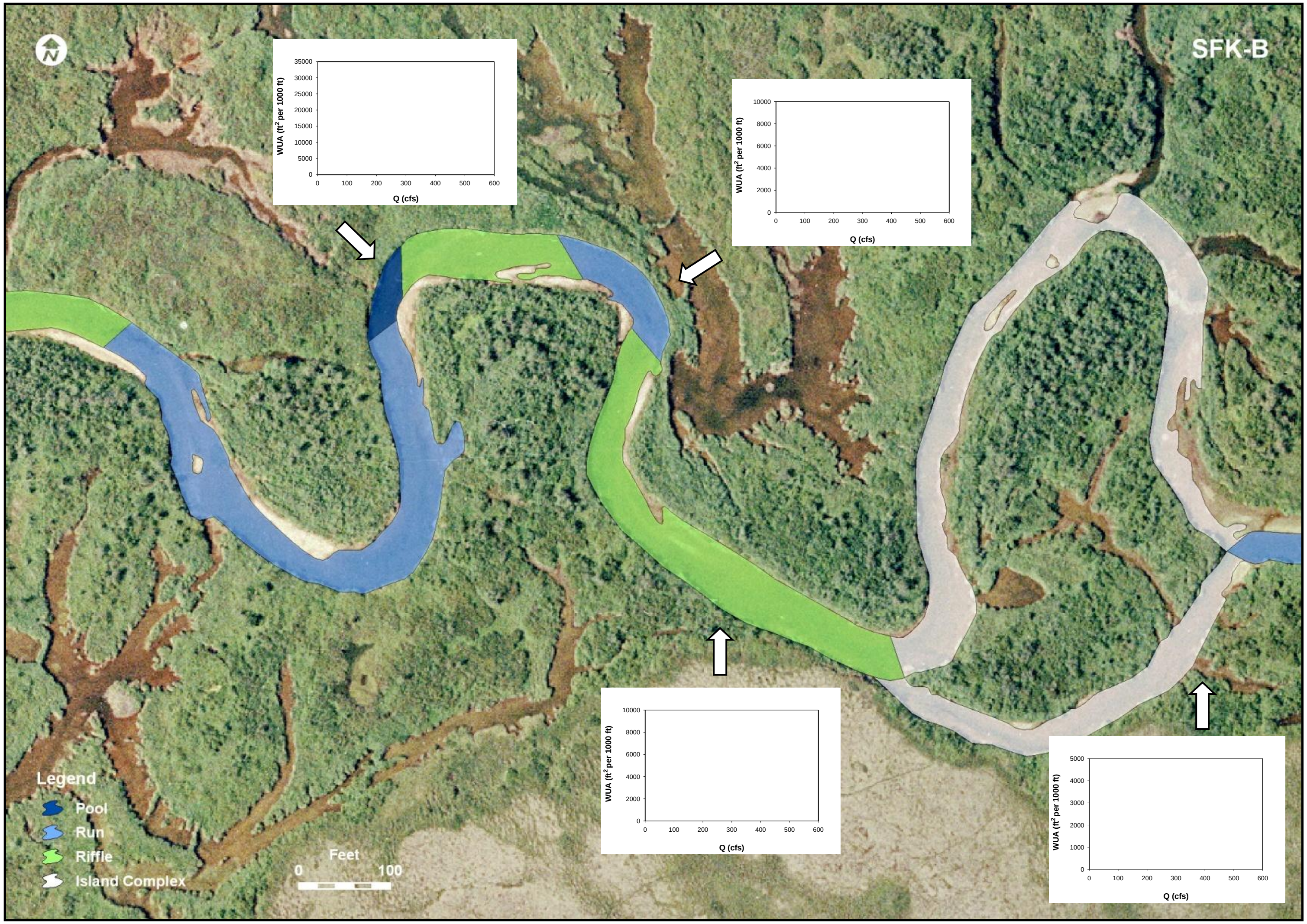
$Q^{meso}_{Annual,Chinook,spawning}$

$W_{BF}^{TR-B}$

$Q^{TR-B}_{Annual,Chinook,spawning}$

(ex: W=28', Q=30cfs)

# End Product - WUA Curves For All Habitat Units



# Habitat Modeling – Baseline Habitat Characterization

## Analysis of flows on fish habitat

- Use three parameters for evaluation:

  a) Weighted Usable Area (WUA), habitat area per 1000 ft stream length

  b) Weighted Usable Width (WUW), habitat area per unit stream length

  b) Cumulative habitat area along the stream.

# Habitat-Flow Modeling

**Analysis of flow on fish habitat**

Wet, average, and dry years were selected in each basin and for each species/life stage combination

Selection was based on synthesized flows at USGS Gaging Stations for NFK, SFK, and UT and on synthesized flows at IFIM Transect 04MSK-RF2 in KR

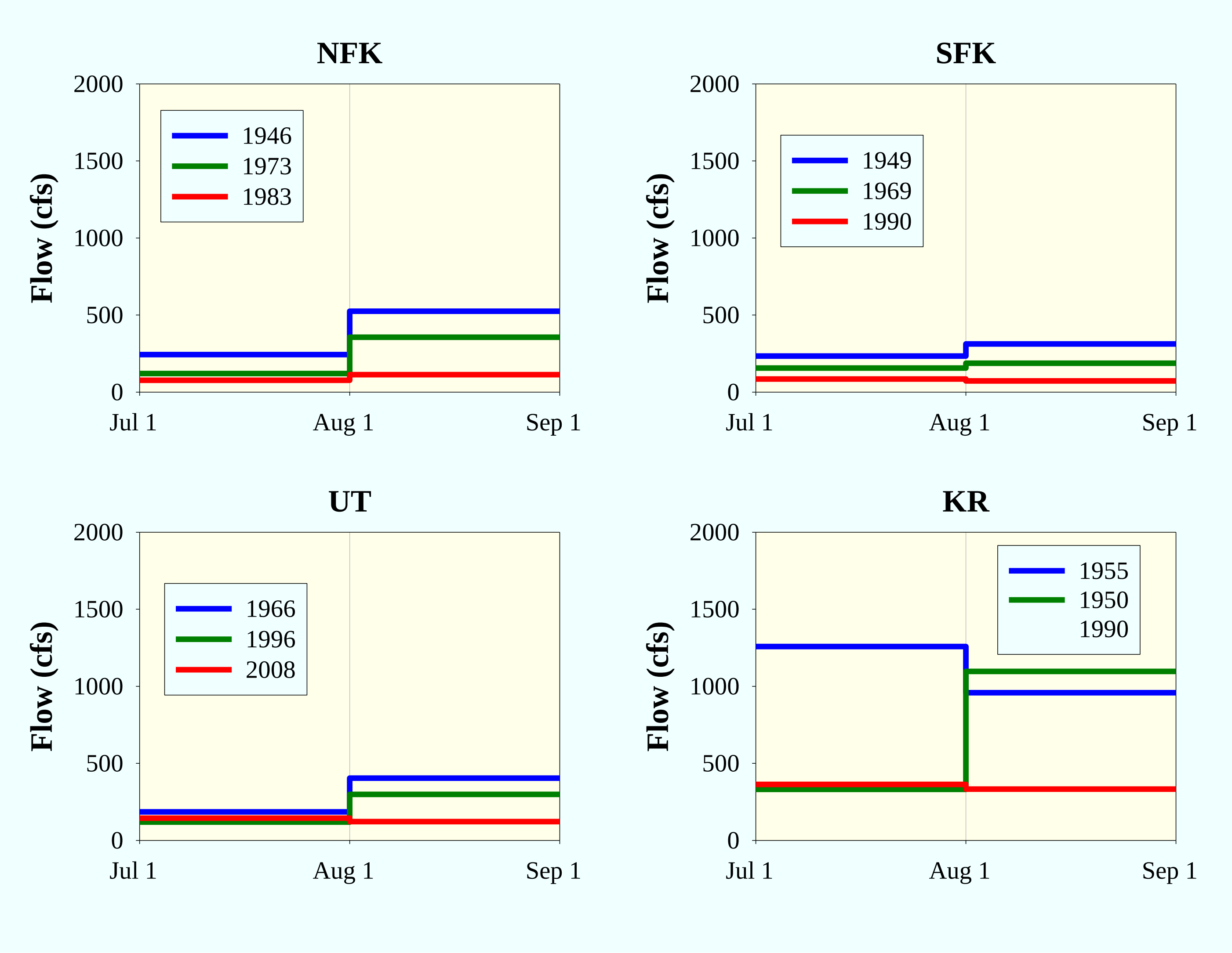
For example, the average flow during the Chinook spawning season (July and August) was determined for each of the 68 years

These average flows were ranked from highest to lowest to determine years with wet (10% exceedance), average, and dry (90% exceedance) conditions

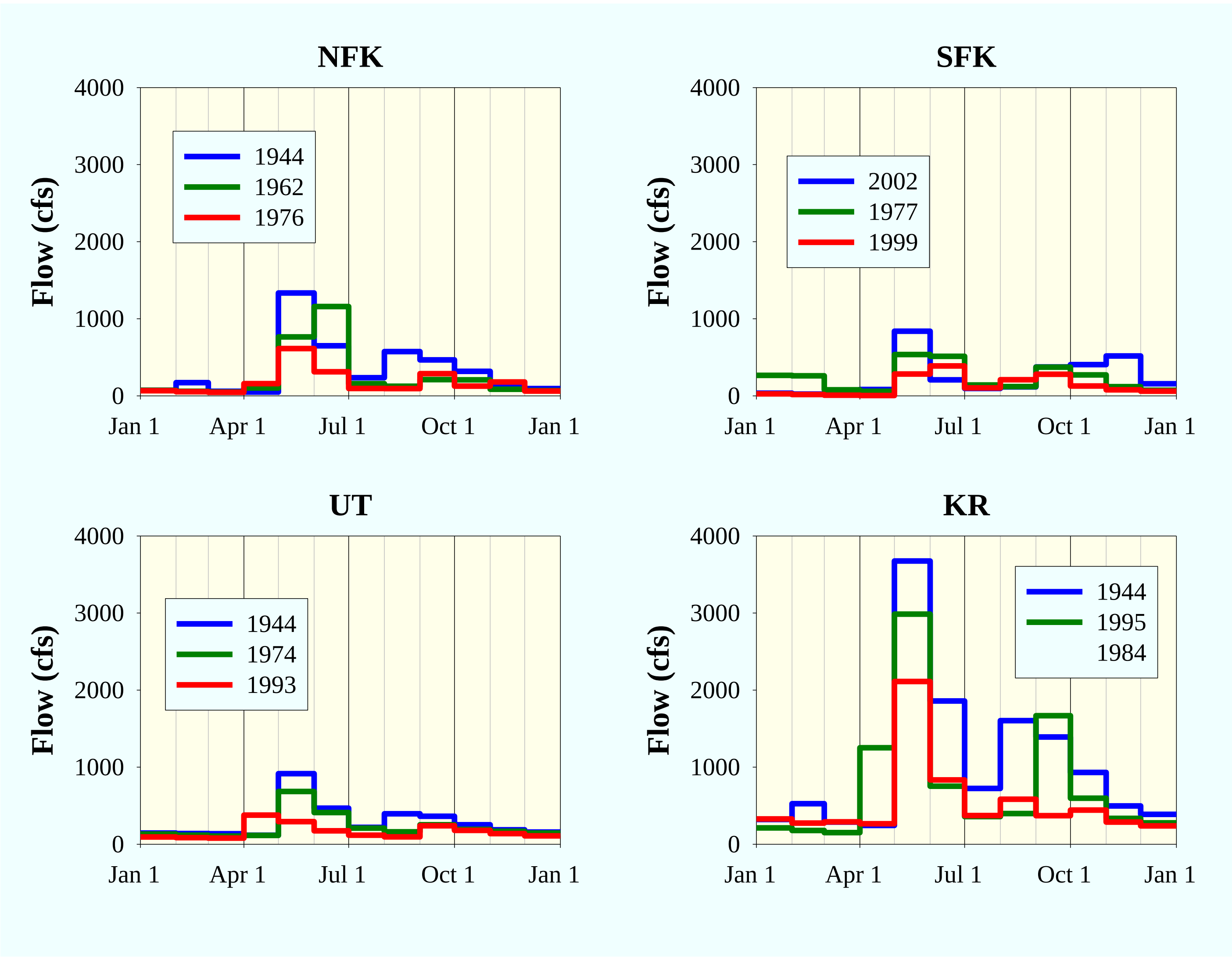
# Wet, Ave, Dry Years for Each Stream

| Target Species | Life stage | NFK | | | SFK | | | UT | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Wet | Average | Dry | Wet | Average | Dry | Wet | Average | Dry |
| Chinook Salmon | Adult Migration | 1946 | 1973 | 1983 | 1949 | 1969 | 1990 | 1966 | 1996 | 2008 |
| | Spawning | 1946 | 1973 | 1983 | 1949 | 1969 | 1990 | 1966 | 1996 | 2008 |
| | Fry Emergence | 1994 | 1954 | 1955 | 2002 | 1977 | 1999 | 2004 | 1962 | 1943 |
| | Rearing | 1944 | 1962 | 1976 | 1944 | 1965 | 1993 | 1944 | 1974 | 1993 |
| | Juv Outmigration | 1985 | 2005 | 1978 | 1944 | 1973 | 1950 | 1962 | 1960 | 2003 |
| Coho Salmon | Adult Migration | 2005 | 1949 | 1976 | 1967 | 1969 | 1957 | 1945 | 1964 | 1976 |
| | Spawning | 1985 | 1982 | 1992 | 1946 | 1949 | 1992 | 1979 | 1966 | 1962 |
| | Fry Emergence | 1994 | 1954 | 1955 | 2002 | 1977 | 1999 | 2004 | 1962 | 1943 |
| | Rearing | 1944 | 1962 | 1976 | 1944 | 1965 | 1993 | 1944 | 1974 | 1993 |
| | Juv Outmigration | 1985 | 2005 | 1978 | 1944 | 1973 | 1950 | 1962 | 1960 | 2003 |
| Chum Salmon | Adult Migration | 1962 | 1953 | 2007 | 1985 | 2001 | 1998 | 1962 | 2009 | 1951 |
| | Spawning | 1946 | 1973 | 1983 | 1949 | 1969 | 1990 | 1966 | 1996 | 2008 |
| | Fry Emergence | 1994 | 1954 | 1955 | 2002 | 1977 | 1999 | 2004 | 1962 | 1943 |
| | Juv Outmigration | 1994 | 1954 | 1955 | 2002 | 1977 | 1999 | 2004 | 1962 | 1943 |
| Sockeye Salmon | Adult Migration | 2005 | 1999 | 1984 | 1972 | 1947 | 1978 | 1960 | 1977 | 1994 |
| | Spawning | 2005 | 1999 | 1984 | 1972 | 1947 | 1978 | 1960 | 1977 | 1994 |
| | Fry Emergence | 1994 | 1954 | 1955 | 2002 | 1977 | 1999 | 2004 | 1962 | 1943 |
| | Rearing | 1985 | 2005 | 1978 | 1944 | 1973 | 1950 | 1962 | 1960 | 2003 |
| | Juv Outmigration | 1985 | 2005 | 1978 | 1944 | 1973 | 1950 | 1962 | 1960 | 2003 |
| Rainbow Trout | Adult Rearing | 1944 | 1962 | 1976 | 1944 | 1965 | 1993 | 1944 | 1974 | 1993 |
| | Spawning | 1962 | 2005 | 1993 | 1987 | 1960 | 1950 | 1955 | 1990 | 1942 |
| | Fry Emergence | 2005 | 1999 | 1984 | 1972 | 1947 | 1978 | 1960 | 1977 | 1994 |
| | Juv Rearing | 1944 | 1962 | 1976 | 1944 | 1965 | 1993 | 1944 | 1974 | 1993 |
| Dolly Varden Trout | Adult Rearing | 1944 | 1962 | 1976 | 1944 | 1965 | 1993 | 1944 | 1974 | 1993 |
| | Spawning | 1944 | 1949 | 1957 | 2005 | 1943 | 1978 | 1986 | 1949 | 1978 |
| | Fry Emergence | 1994 | 1954 | 1955 | 2002 | 1977 | 1999 | 2004 | 1962 | 1943 |
| | Juv Rearing | 1944 | 1962 | 1976 | 1944 | 1965 | 1993 | 1944 | 1974 | 1993 |
| Arctic Grayling | Adult Rearing | 1944 | 1962 | 1976 | 1944 | 1965 | 1993 | 1944 | 1974 | 1993 |
| | Spawning | 1994 | 1954 | 1955 | 2002 | 1977 | 1999 | 2004 | 1962 | 1943 |
| | Fry Emergence | 1962 | 2005 | 1993 | 1987 | 1960 | 1950 | 1955 | 1990 | 1942 |
| | Juv Rearing | 1944 | 1962 | 1976 | 1944 | 1965 | 1993 | 1944 | 1974 | 1993 |

# Wet, Average, and Dry Years
# Chinook Spawning Periodicity



# Wet, Average, and Dry Years
# Chinook Juvenile Rearing - Periodicity

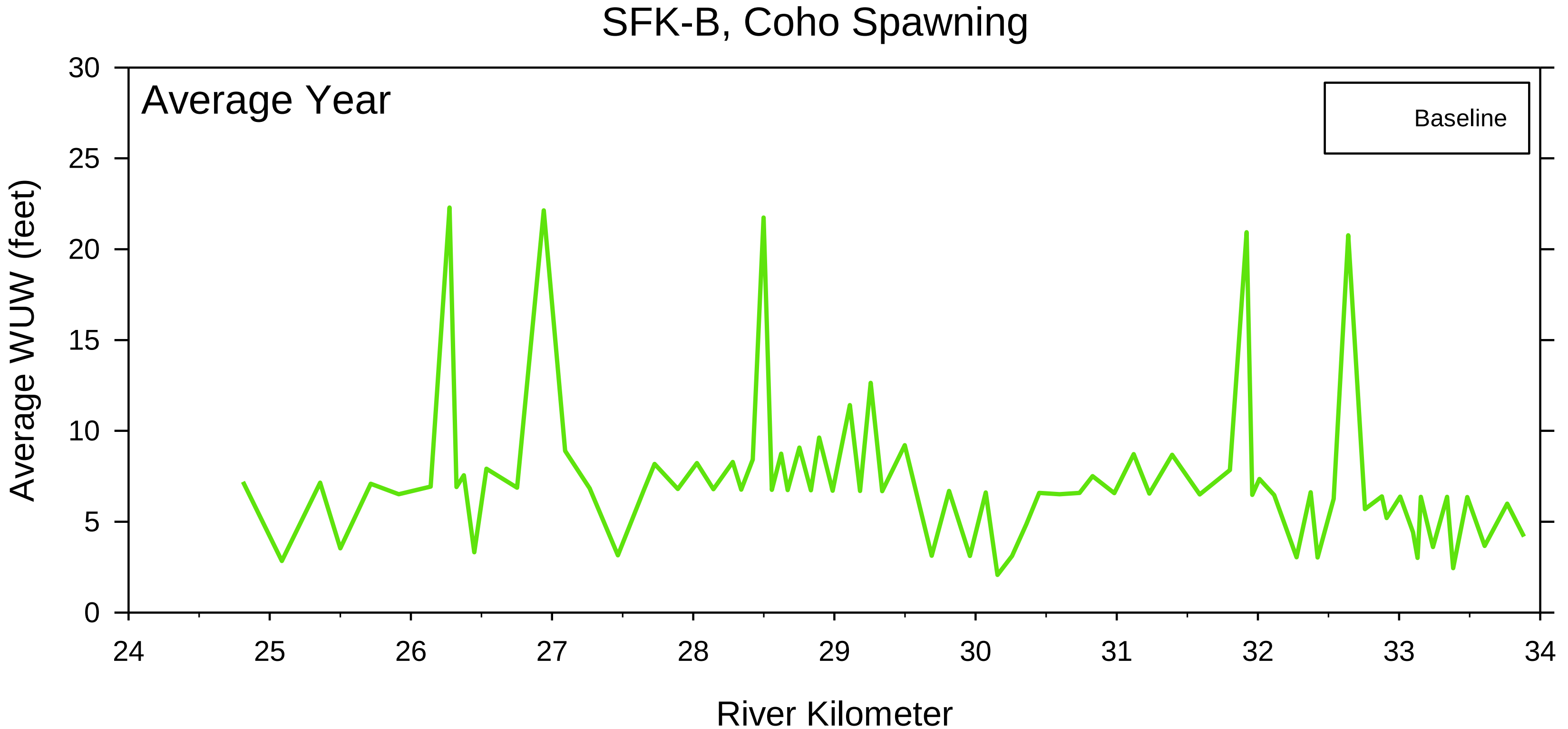


# RESULTS

- Hydrology and Habitat Area Comparisons
  - TEMPORAL VARIABILITY OF HABITAT: Stream/reach/species/lifestage for Wet, Average and Dry years
  - SPATIAL VARIABILITY OF HABITAT: Longitudinal distribution of Weighted Useable Width (WUW)
  - CUMULATIVE HABITAT : By species/lifestage/reach

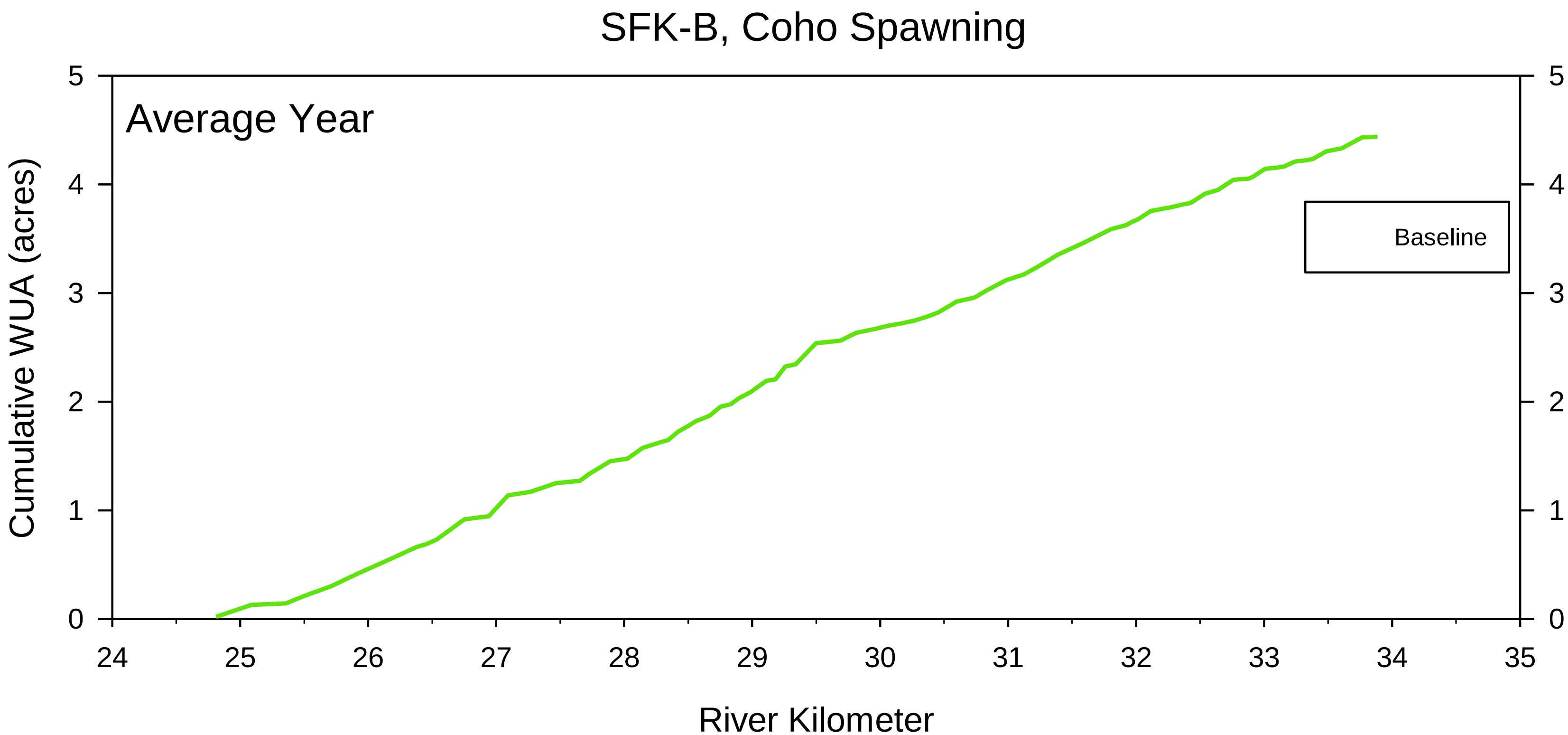
# Weighted Usable Width (WUW)

Weighted Usable Width (WUW) = habitat area divided by the length of the habitat unit. Area is dependent on the habitat unit length, but WUW is not.

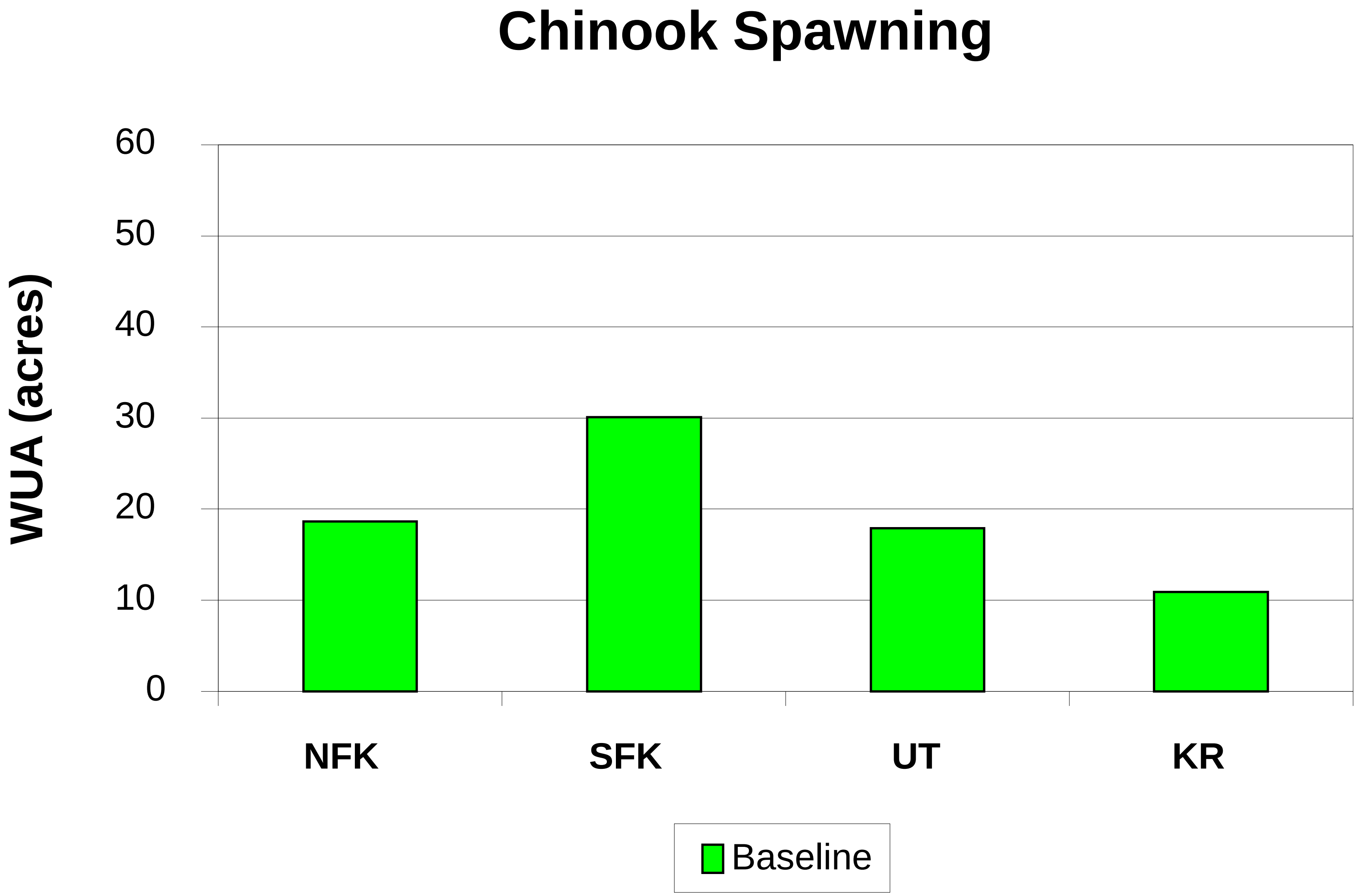


# Cumulative Habitat Area

Cumulative habitat areas along the stream reach can be calculated for Baseline Conditions and compared with conditions under differing project operations.

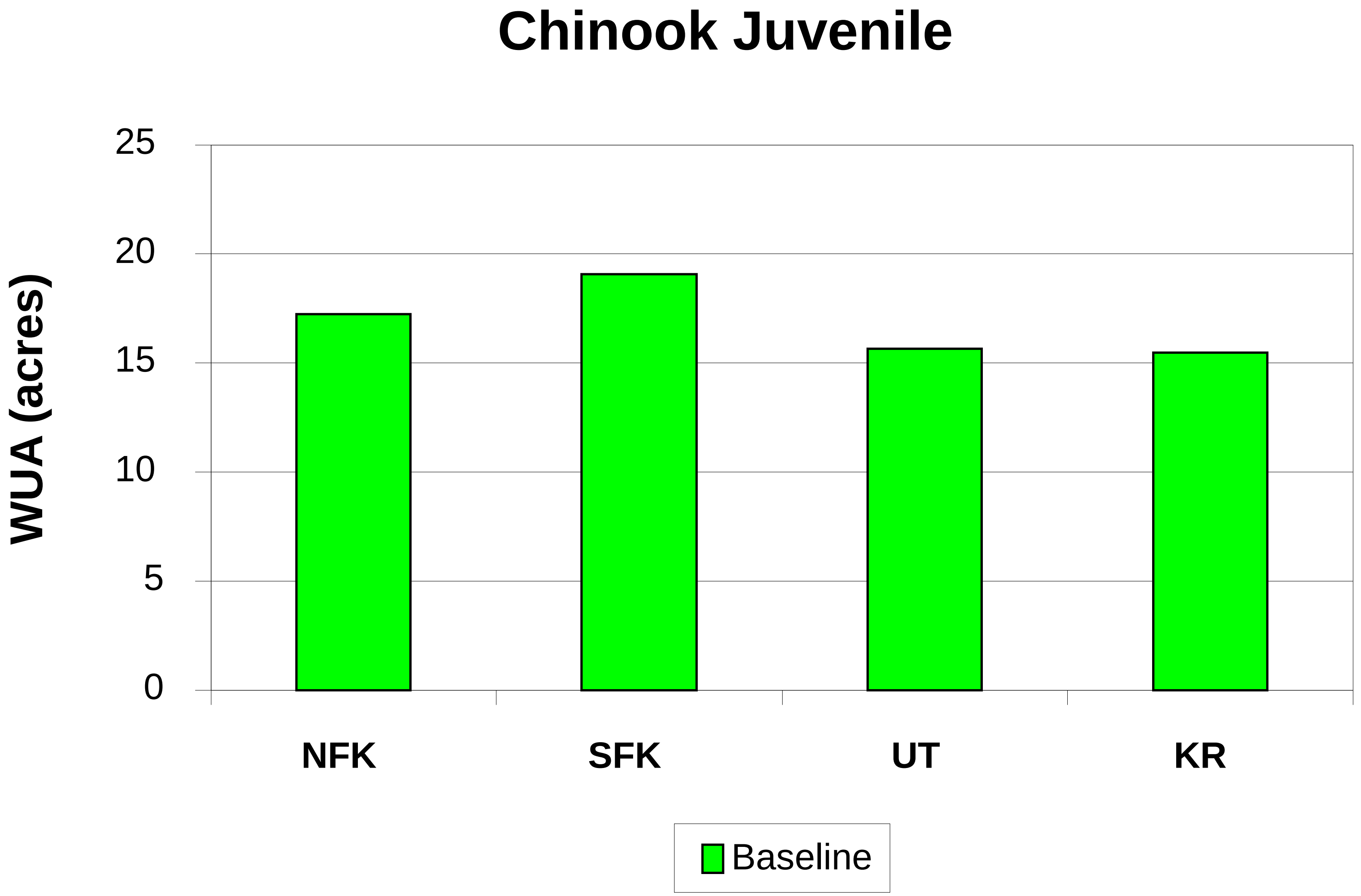


# Summary
## Average Year

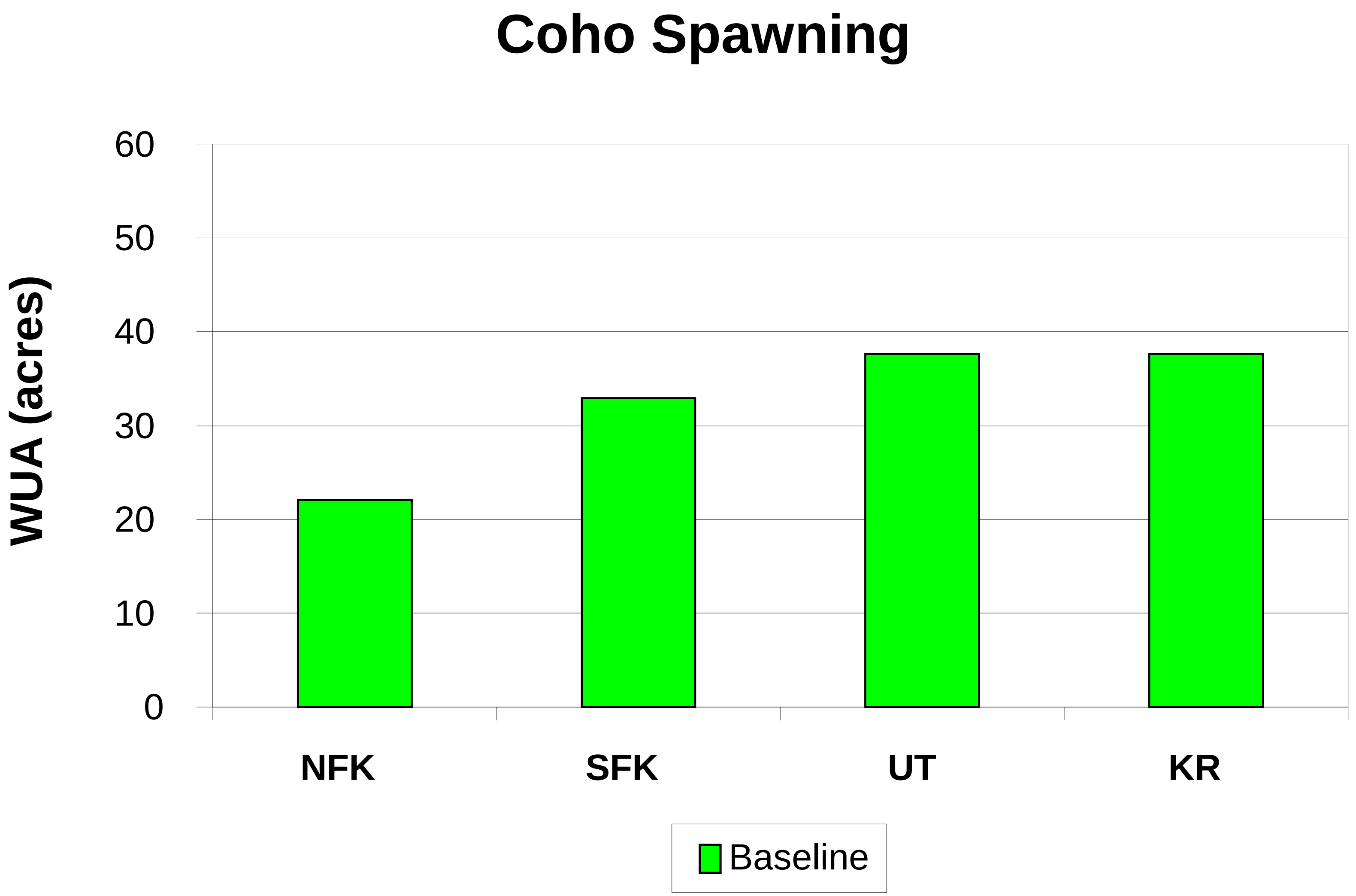


# Summary

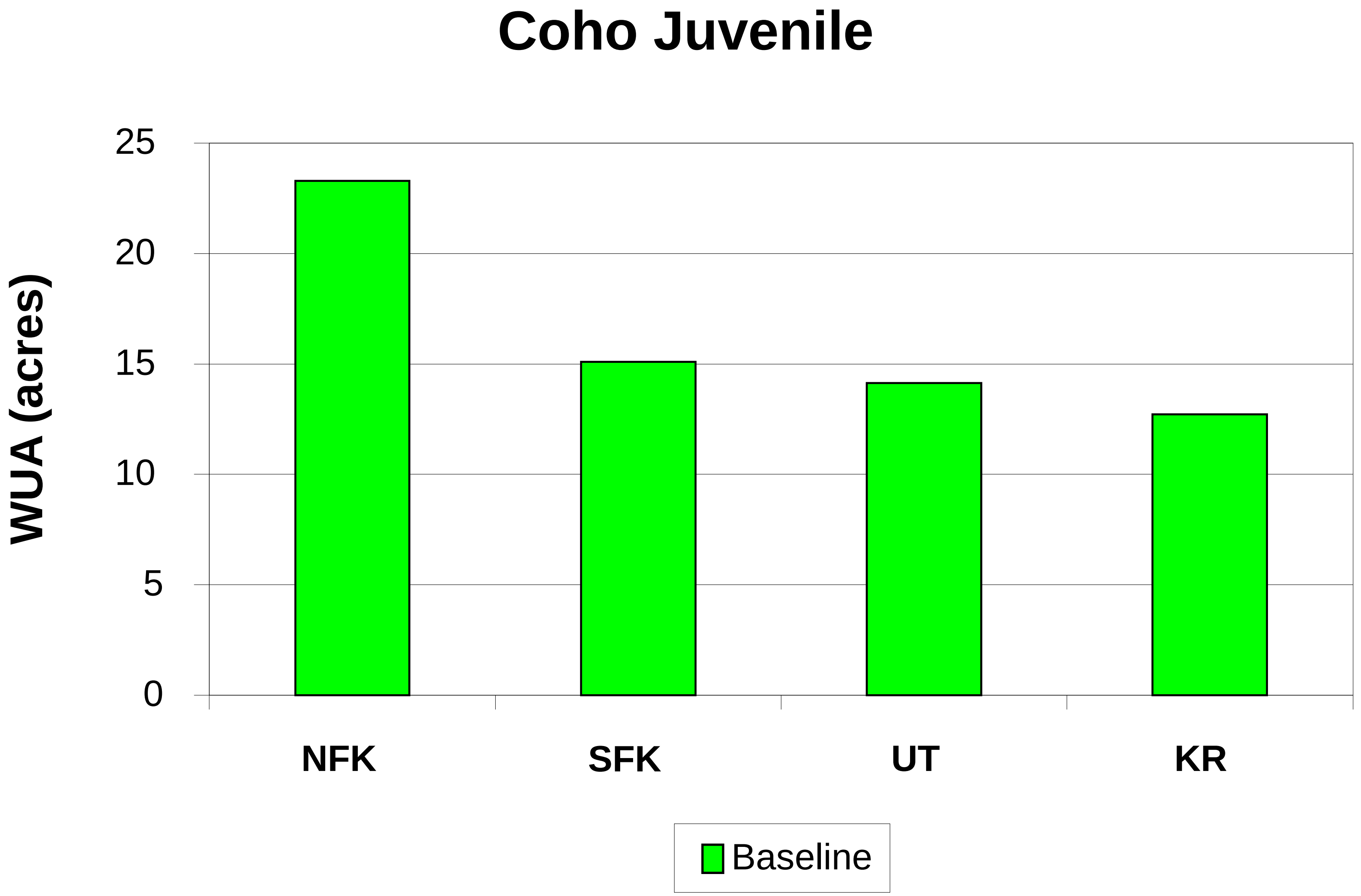
## Average Year



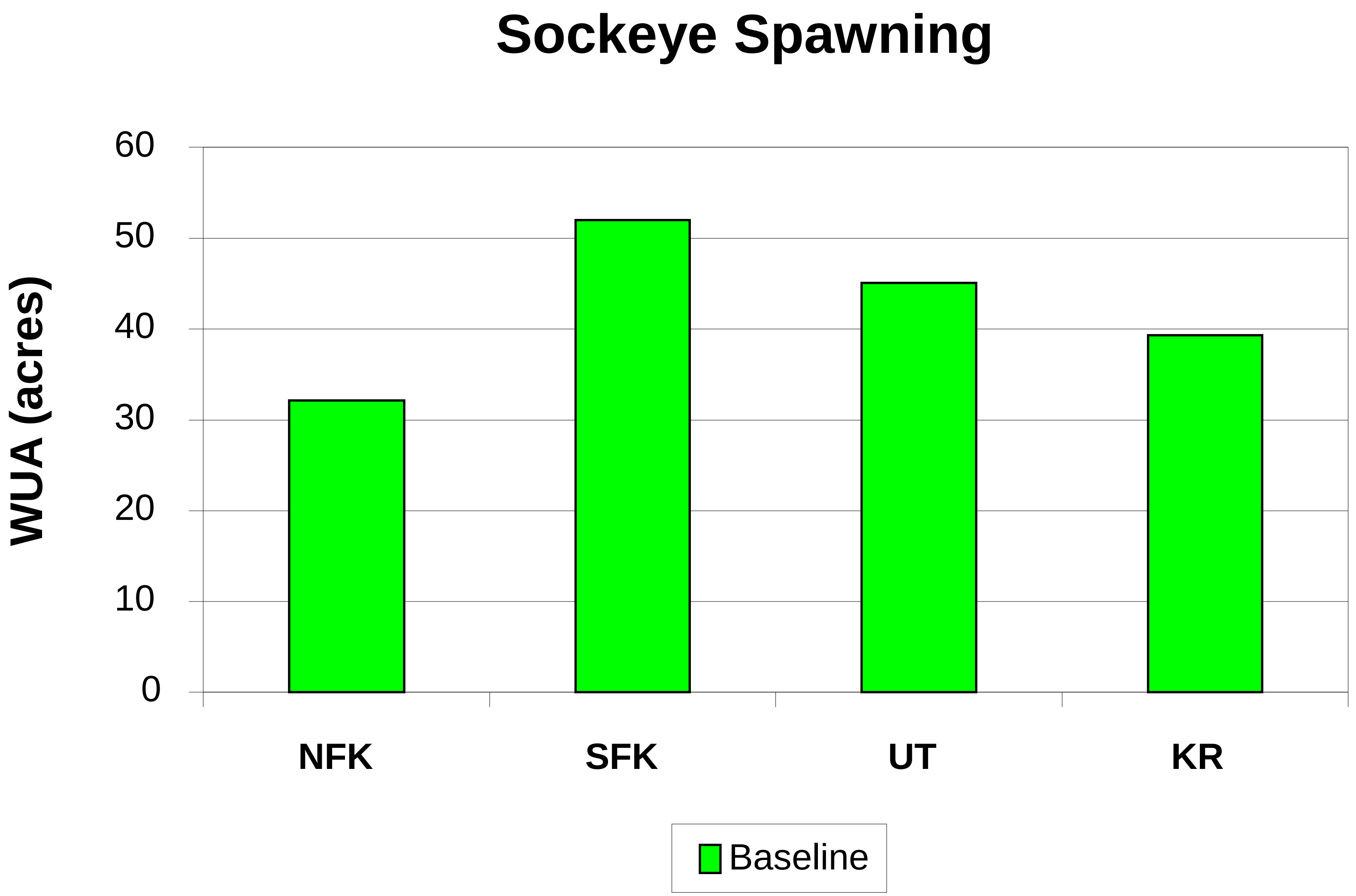
# Summary
## Average Year



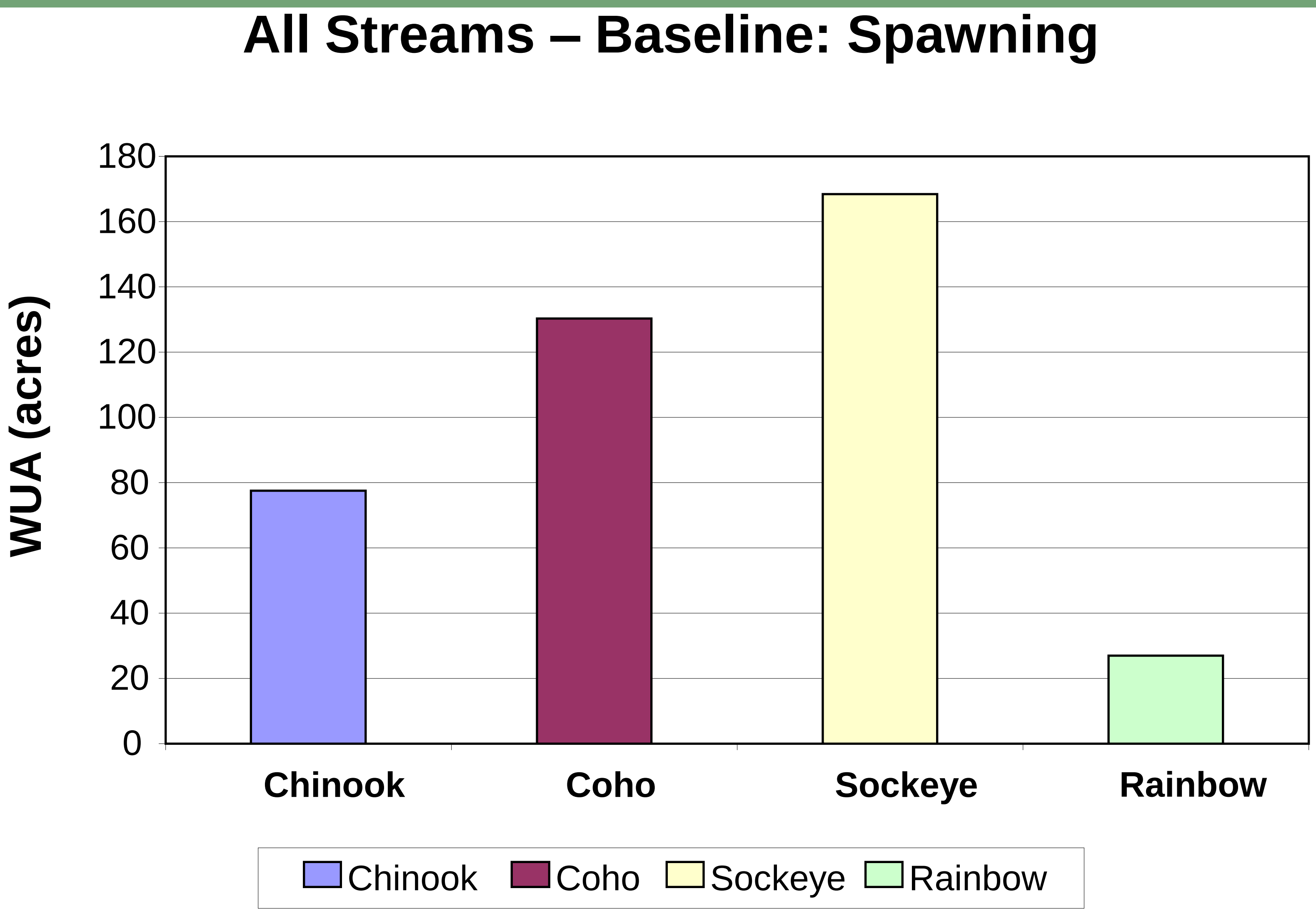
# Summary
## Average Year



# Summary
## Average Year

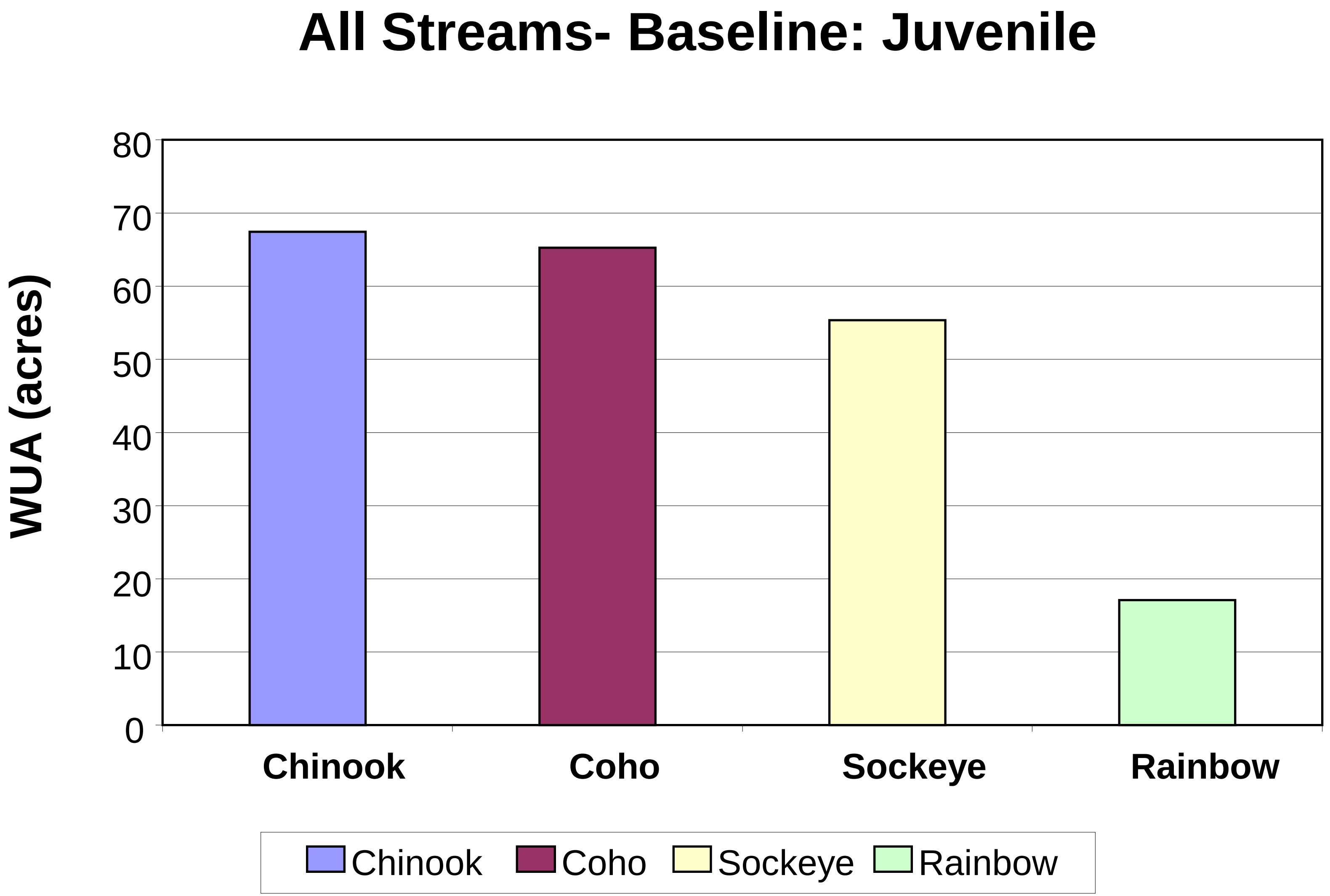


# Summary
## Average Year



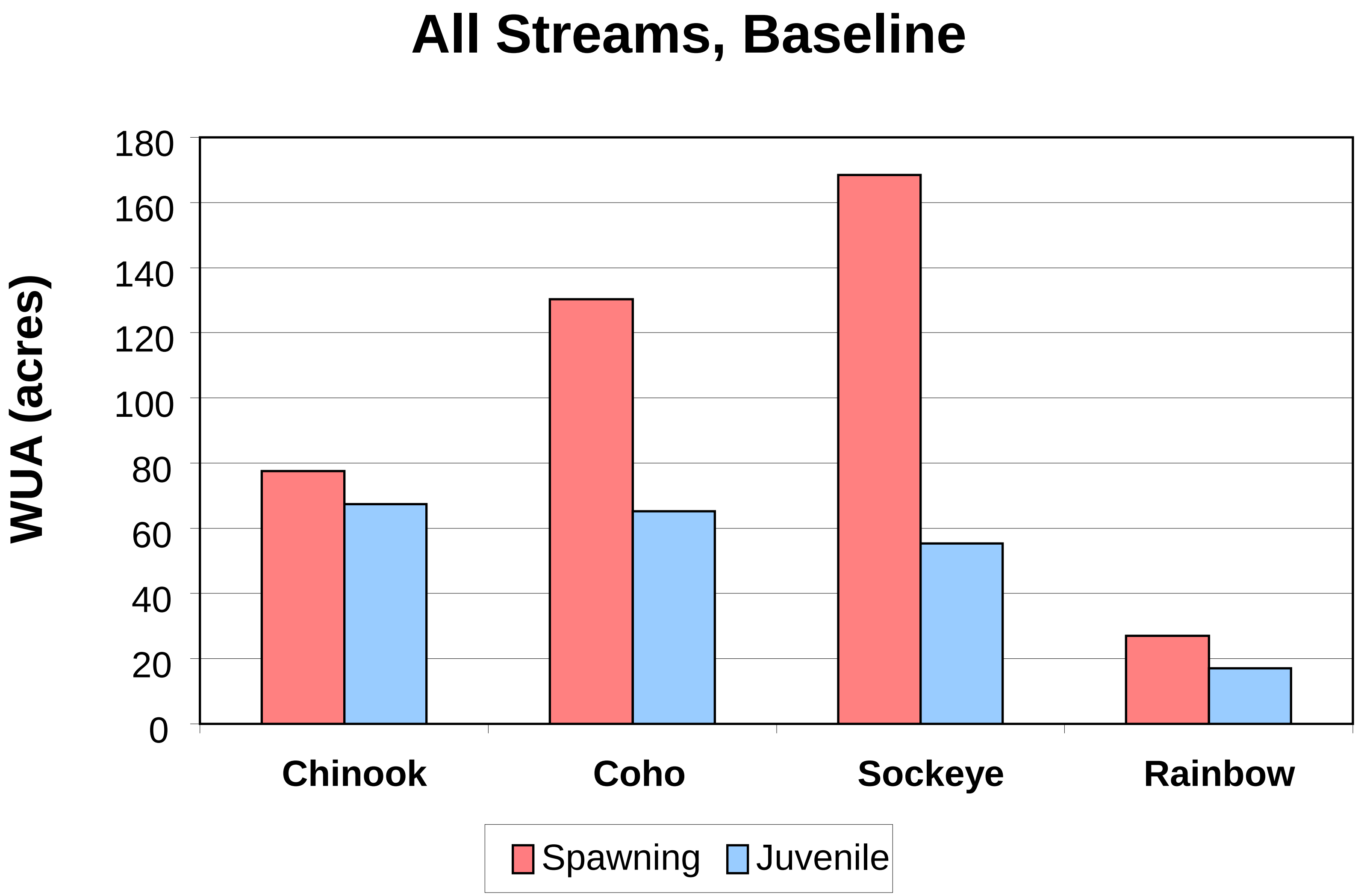
# Summary

## Average Year



# Summary

## Average Year



# Advantages of Approach Applied on Pebble Project

- WUA – flow relationships estimated for each of the nearly 2000 habitat units in the three basins.
- Each WUA is only used to represent the length of an individual habitat unit.
- Modeling allows for longitudinal assessment of flow changes on all available habitats by species and lifestage:
  - Able to assess flow influences at any location in the river
  - Able to compute habitat amounts at multiple scales: site, reach, entire stream, all streams combined.
- Model can be easily adapted to allow for effects analysis – i.e. with and without project influence.


Thank You!
Questions??