MORRISVILLE HYDROELECTRIC PROJECT
FERC Project No. 2629

Green River Flow Study (RSP 7.4)

Draft Study Report

Submitted to:
Village of Morrisville
857 Elmore Street
Morrisville, VT 05661-0460

Prepared by:
Gomez and Sullivan Engineers, P.C.
41 Liberty Hill Road, Building 1
Henniker, NH 03242

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Executive Summary

The Village of Morrisville (Morrisville) has initiated the relicensing process for its 5.1 MW Morrisville Project (Project) with the Federal Energy Regulatory Commission (FERC). The project consists of four developments: the Morrisville and Cadys Falls dams located on the Lamoille River main stem in Morrisville, the Lake Elmore dam located on Elmore Brook, a tributary to the Lamoille River, and the Green River development on the Green River, another tributary to the Lamoille River (Figure 1-1). The Project (FERC No. 2629) is owned and operated by the Village of Morrisville Water and Light Department (MW&L).

As part of the FERC relicensing process, MW&L's Revised Study Plan (RSP) includes a Green River flow study (RSP 7.4). The study goal is to quantitatively assess and characterize potential effects of the Green River development's existing flow regime on aquatic habitat and wetlands in the Green River. The purpose of this report is to provide the results of the Green River flow study and provide the information necessary for MW&L and resource agencies to determine an appropriate flow regime that will meet aquatic habitat management goals, while balancing power generation needs, at the Green River development.

As part of this study, habitat versus flow relationships were developed for eleven distinct target species and lifestages. The species include brook trout (spawning and incubation, late fry, juvenile, adult), all trout (early fry), rainbow trout (spawning and incubation, late fry, juvenile, adult), longnose sucker (spawning and incubation) and macroinvertebrates.

Results are presented in terms of individual transect analyses and a composite habitat analysis for a concise summary of the reach. Additionally, a dual-flow analysis was completed for several "immobile" life stages (all species' spawning and incubation, early fry and late fry life stages, plus macroinvertebrates).

The results of this study can be used to draw the following conclusions:

- Overall, spawning and incubation habitat in the Green River is relatively abundant. The individual transect results, however, show that there is considerable variability between the study transects.
- The early fry life stage for all trout species appeared to have limited amounts of habitat. This appears to be related to this life stage's heavy preference for shallow, slower moving waters, which were relatively rare in the Green River.
- The modeled life stages had a wide variety of preferred flow ranges, some of which shared little to no mutual overlap. There was a general split where lower flows were preferable for some species (trout early fry, brook trout spawning and incubation, brook trout juvenile, rainbow trout juvenile) while higher flows were more preferable for others (brook trout adult, rainbow trout spawning and incubation and juvenile and adult, longnose sucker spawning and incubation, macroinvertebrates).

- While there is no historic Green River flow data available, it appears that some of the life stages' flow preferences may be rather high given the watershed's small drainage area (14.6 mi^2 at the Green River Dam). This should be considered when determining any flow recommendations.

No specific flow will provide an optimum flow for all life stages and species, since there are multiple life stages existing simultaneously in a river. Setting instream flows requires ranking the importance of each fish species and life stage. This ranking requires considering long-term management plans for the fishery resources.

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1.0 Introduction

The Village of Morrisville (Morrisville) has initiated the relicensing process for its 5.1 MW Morrisville Project (Project) with the Federal Energy Regulatory Commission (FERC). The project consists of four developments: the Morrisville and Cadys Falls dams located on the Lamoille River main stem in Morrisville, the Lake Elmore dam located on Elmore Brook, a tributary to the Lamoille River, and the Green River development on the Green River, another tributary to the Lamoille River (Figure 1-1). The Project (FERC No. 2629) is owned and operated by the Village of Morrisville Water and Light Department (MW&L).

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On May 24 2012, MW&L conducted an on-site meeting with the Vermont Agency of Natural Resources (VANR). The purpose of the meeting was, in part, to walk the Green River and confirm the proposed study methodology was appropriate. At the conclusion of the meeting, MW&L and VANR confirmed that a transect-based Physical Habitat Simulation Model (PHABSIM) approach, would be an appropriate methodology for this study. The assessment was conducted at the Green River over several site visits between September 2012 and November 2012. The purpose of this report is to describe the habitat assessment results.

1.1 Project Description and Operation

The Green River development is located on the Green River, about 4.3 miles upstream of the Green River's confluence with the Lamoille River (Figure 1.1-1). The Green River dam has a watershed drainage area of 14.6 mi^2. The Green River dam is a 105-ft high and 360-ft long concrete arch dam, with a 60-ft long spillway.

The dam forms the Green River reservoir, a reservoir with a normal maximum surface area of 690 acres, a normal maximum water surface elevation of 1220 ft and a gross storage capacity of 17,400 acre-ft at the spillway crest. Based on historical bathymetric maps from VT DEC, the Green River Reservoir's maximum depth is approximately 80-100 ft.

The development has a maximum hydraulic capacity of approximately 283 cfs and a minimum hydraulic capacity of approximately 75 cfs. There are currently no USGS or other gages located anywhere on the Green River to measure flow, nor any historic flow data available.

The project maintains a 5.5 cfs minimum flow, with additional seasonal reservoir drawdown and maximum flow limits. The development's water quality certificate limits instantaneous releases year-round to 283 cfs or less except to prevent spill conditions, and further limits maximum outflows to 160 cfs between May and October except to prevent spill conditions. The project passes flow via a low-level outlet when it is not operating.

Figure 1-1: Morrisville Hydroelectric Project overview map.

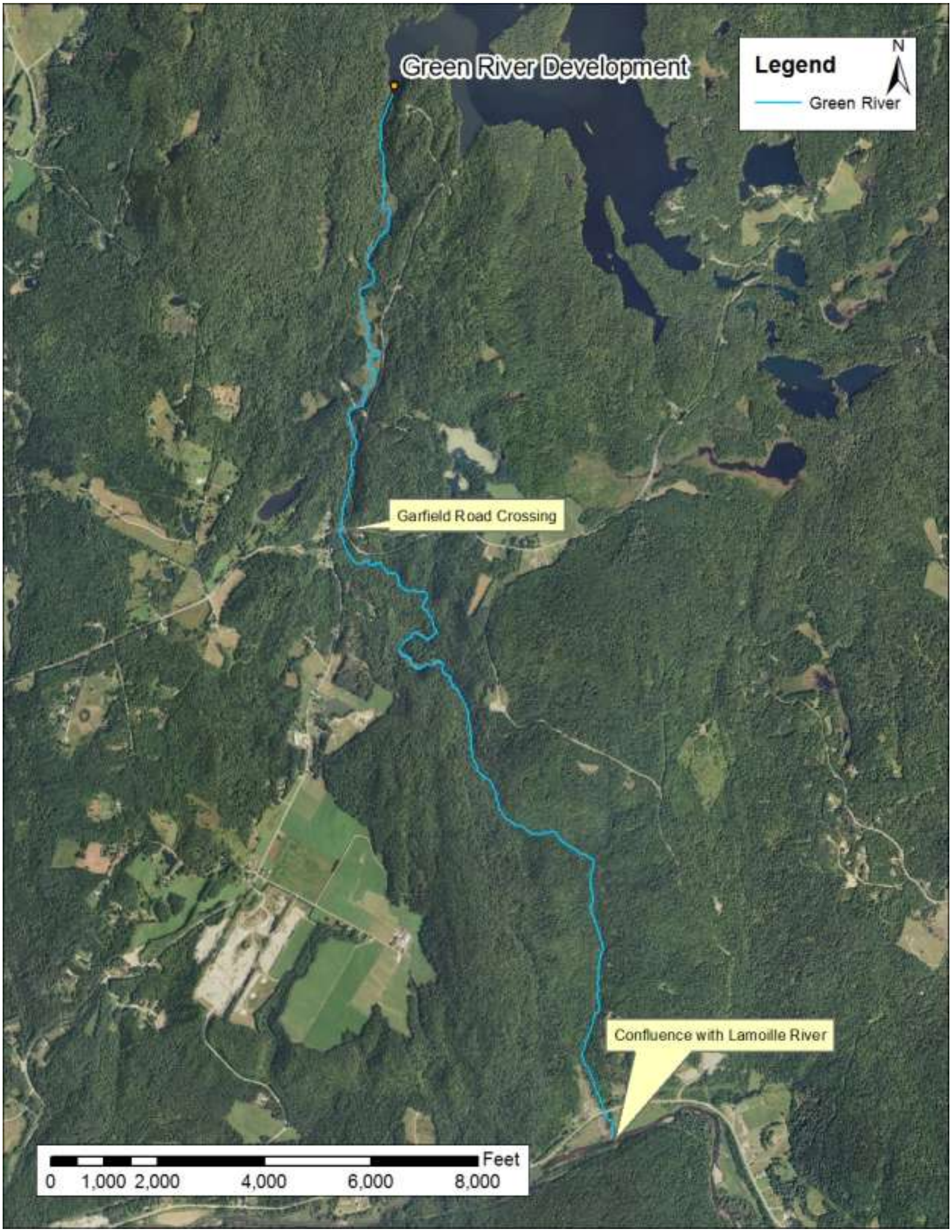

Figure 1.1-1: Green River development overview.

2.0 Assessment Methodology

The project's impact on aquatic habitat was assessed using two methods: an In-Stream Incremental Flow Incremental Methodology (IFIM) to quantitatively assess available aquatic habitat, and temperature loggers were used to assess the thermal regime throughout the Green River and track potential plant-related temperature impacts.

2.1 Habitat Assessment and PHABSIM Methodology

A one-dimensional a transect-based PHABSIM model was the specific IFIM implementation used. A PHABSIM methodology combines transect hydraulic information (depth, velocity, substrate) with aquatic habitat suitability index (HSI) curves to develop weighted usable area (WUA) (i.e., habitat) versus flow relationships at representative transects within the river. The PHABSIM methodology is based on the premise that aquatic organisms prefer a certain range of depths, velocities, substrates, and cover types, which are dependent upon the species and life stage, and that the availability of these preferred habitat conditions varies with stream flow. The PHABSIM methodology is designed to quantify potential physical habitat available for each evaluation species and life stage at various levels of stream flow, using a series of computer programs developed by the USFWS (Bovee 1982).

Streams consist of many different physical features in several combinations. One area, such as a riffle, may be shallow and fast-moving over a substrate of cobble and gravel with no cover while another area, such as a pool, may be deep and slow-moving over a substrate of silt, with a large root wad along the shore. One fish species may find the riffle desirable while another species may prefer the pool; a third species may not prefer either. It is also common for a fish species to prefer different habitats during its different life stages. For example, a species might prefer a riffle for spawning and another habitat, such as a pool with cover, for feeding, resting, or hiding. These different habitat types (e.g., pools, riffles, runs) are known as mesohabitats.

In general, a fish species or life stage prefers a particular mesohabitat type because of the microhabitat characteristics (i.e., depth, velocity, substrate, and cover) that make-up the mesohabitat are within its preferred range for the particular species/life stage. For example, brown trout prefer faster water with a rocky substrate, such as a boulder run, while common carp prefer slower water with silt or mud substrates, such as a pool. These microhabitat conditions of depth and velocity are not static; they vary with stream flow. Too much or too little flow through the riffle or pool may push the velocities and depths outside the preferred limits or tolerances of a particular species or life stage.

Using PHABSIM, the availability of preferred microhabitat conditions at any given flow can be modeled for instream flow decision making. In the field, microhabitat parameters of depth, velocity, substrate, and cover are measured at numerous points across the channel and at a number of locations along the length of the river. Each discrete location along the river where the measurements are collected are called transects. Each transect is located within a representative mesohabitat type and is used to characterize the microhabitat parameters that comprise each mesohabitat.

Depth, velocity, substrate, and cover measurements are made at close intervals along each transect, usually 1 to 3 feet apart. A group of transects is selected to represent a particular reach of river that is generally homogeneous in channel size, slope, and hydrology. All flow and water surface elevation measurements are usually taken at the same transect locations at selected low, medium, and high flow releases. The PHABSIM model uses these measurements to predict habitat availability at flows other than those measured in the field. The product of the PHABSIM model is a habitat versus flow relationship that is expressed as Weighted Usable Area (WUA) over the range of simulated stream flows.

A cross-section's WUA is calculated as the sum of WUA from several cells within a cross-section (Figure 2-1). WUA [ft/stream ft] within a cell is calculated as $WUA = w * SI_{depth} * SI_{velocity} * SI_{substrate}$, where SI_{depth} is the cell's depth suitability, $SI_{velocity}$ is the cell's velocity suitability and $SI_{substrate}$ is the cell's substrate suitability, for the target species. All three SI values are calculated by matching a cell's depth, velocity and substrate with a target's depth, velocity and suitability HSI curves.

2.1.1 Habitat Mapping

Habitat mapping was conducted along the Green River the week of May 21, 2012. The objective of the mapping was to assist in identifying appropriate cross-sections to create a PHABSIM model representing habitat in the Green River. The mapping consisted of identifying and delineating ecologically significant geomorphic features (e.g., riffle, run, pool) along the Green River with a sub-meter GPS, with supplemental attributes collected at each feature. The supplemental attributes included reach width, average depth, spot velocities, dominant and subdominant substrate, velocity refugia abundance and canopy coverage. Some supplemental attributes, such as depth or velocity, were not collected in areas which were considered hydraulically unmodelable (e.g., falls, cascades). Appendix A summarizes the habitat mapping results. As part of the habitat mapping, MW&L and ANR representatives walked the 4.3 miles of the Green River between the Green River Dam and the Green River's confluence with the Lamoille River. The habitat mapping and river walk was conducted at the typical minimum flow of 5.5 cfs. Habitat mapping results are shown in Figure 2.1.1-1 and Figure 2.1.1-2.

Supplemental characteristics of all three geomorphic types were used to assess any differences within the geomorphic units. In particular, differences in average depth, spot velocities (taken to approximate average velocity) and substrate were studied. Each of the geomorphic features had a relatively distinct range of depth, velocity and substrate characteristics (Figure 2.1.1-3). Table 2.1.1-1 summarizes the Green River's habitat types, including the percentage of the river that each habitat type represents.

Table 2.1.1-1: Summary of Green River habitat types

Habitat Type	Total Length (miles)	Cumulative % of Green River
Pool	1.22	25.1
Riffle	1.58	32.5
Run	0.79	16.3
Other	1.27	26.1
Total	4.86	100.0

2.1.2 Assessment Transects

The PHABSIM IFIM procedure requires the selection of transects that are representative of the habitat types within the bypass reach. Using the habitat mapping results as a guide, assessment transects were selected in consultation with ANR over the course of two follow-up site walks. The objective during transect selection was to identify cross-sections that were representative of the various habitat types identified during the habitat mapping. The sites were primarily identified as riffles as part of the habitat mapping. Riffles were preferentially chosen because they are typically more flow-sensitive than pool areas, and are thus better suited for identifying an appropriate flow regime. Some transects, however, were located in other non-riffle geomorphic features (e.g., run, pool). The Green River has a wide gradient range. To ensure that the gradient range was adequately represented in the study, some transects were chosen in the steeper upper river, while some transects were chosen in the less-steep lower river.

Transect-based habitat studies often do not intersect enough suitable spawning substrate to produce a reliable habitat-flow relationship for this life stage. In order to better understand the Green River development's impact on spawning and incubation habitat over a range of flows, several likely spawning areas were identified during the transect selection process. In particular, these areas contained considerable amounts of suitable substrate. These transects were included in the study specifically as "spawning transects." The identified spawning transects are intended to be representative of the greater river's overall spawning and incubation habitat. Thus, the spawning transects are considered as a supplement to transects that were selected to be representative of the overall river habitat. When discussing spawning and incubation habitat, this study therefore focuses on the spawning habitat located within the "spawning transects".

Nine total transects were selected for the study (Figure 2.1.2-1 and Figure 2.1.2-2). Five of the transects were designated as "spawning transects." Transects were marked with wooden stakes and survey flagging (Figure 2.1.2-3). A temporary staff gage was installed at each transect to allow water surface elevation changes between flows, as well as flow stability, to be measured.

Data were collected across each transect in one-foot increments (6" increments for transect 7) using a 150-ft long surveying tape. The tape was tied off in a consistent manner to the bank stakes. Substrate was mapped for each transect relative to the distance from the left bank pin, using the substrate coding in Table 2.1.2-1. Table 2.1.2-2 summarizes the habitat transect characteristics.

Transect 1 was located in a riffle that is approximately 3.2 miles downstream of the Green River Dam. This transect consisted primarily of gravel and cobble substrate with some small boulders. The banks are relatively steep and well vegetated. The water surface did not exceed the bank height at any of the measured flows. This transect was approximately 100 ft upstream of a steep 10-15 ft high falls section in the river that likely formed a year-round passage barrier. This transect is not designated as a spawning transect. Figure 2.1.2-4 illustrates the cross-section’s shape and shows the measured water surface elevations for the field-measured flows. The transect width was approximately 25 ft wide over the range of measured flows.

Transect 2 is located approximately 40 ft upstream of Transect 1 and is within the same riffle reach. Transect 2 is similar to Transect 1, though Transect 2 is wider (~35 ft) and contains slightly finer sediments consisting of small gravel, gravel and cobble. The banks are relatively steep and well vegetated. The water surface did not exceed the bank height at any of the measured flows. This transect is designated as a spawning transect. Figure 2.1.2-5 illustrates the cross-section’s shape and shows the measured water surface elevations for the field-measured flows.

Transect 3 is located approximately 50 ft upstream of Transect 2 and is within the same riffle reach. Transect 3 is similar to Transect 1 and Transect 2, though it is more similar to Transect 2. Transect 3 is approximately 40 ft wide and contains primarily finer sediments consisting of small gravel, gravel and cobble, with some small boulders. The banks are relatively steep and well vegetated. The water surface did not exceed the bank height at any of the measured flows. This transect is designated as a spawning transect. Figure 2.1.2-6 illustrates the cross-section’s shape and shows the measured water surface elevations for the field-measured flows.

Transect 4 is in a run located approximately 3.1 miles downstream of the Garfield Road crossing. Transect 4 is approximately 40 ft wide and contains sand, some gravel and cobble. The banks are relatively steep and well vegetated. The water surface did not exceed the bank height at any of the measured flows. This transect is not designated as a spawning transect. Figure 2.1.2-7 illustrates the cross-section’s shape and shows the measured water surface elevations for the field-measured flows.

Transect 5 is in a pool tailout located approximately 3.0 miles downstream of the Garfield Road crossing. Transect 5 is approximately 40 ft wide and is predominantly gravel substrate. The banks are steep and tall and consist of bedrock with minimal vegetation. The water surface did not exceed the bank height at any of the measured flows. This transect is designated as a spawning transect. Figure 2.1.2-8 illustrates the cross-section’s shape and shows the measured water surface elevations for the field-measured flows.

Transect 6 is in a run approximately 100 ft upstream of Transect 5. Transect 6 is approximately 35 ft wide and is predominantly gravel substrate with small amounts of cobble and boulder. The banks are steep and tall and consist of bedrock with minimal vegetation. The water surface did not exceed the bank height at any of the measured flows. This transect is designated as a spawning transect. Figure 2.1.2-9 illustrates the cross-section's shape and shows the measured water surface elevations for the field-measured flows.

Transect 7 is in a riffle located approximately 2.5 miles downstream of the Garfield Road crossing. Transect 7 is approximately 20 ft wide and is predominantly gravel substrate with small amounts of cobble and boulder. The banks are steep and tall and consist of bedrock with minimal vegetation. The water surface did not exceed the bank height at any of the measured flows. This transect is designated as a spawning transect. Figure 2.1.2-9 illustrates the cross-section's shape and shows the measured water surface elevations for the field-measured flows.

Transect 8 is in a riffle located approximately 4.6 miles downstream of the Garfield Road crossing, in the lower portion of the Green River. Transect 8 is approximately 40 ft wide and is predominantly gravel substrate with small amounts of cobble. The banks are somewhat steep and well vegetated. This transect is located at the confluence of an upstream split channel. The water surface did not exceed the bank height at any of the measured flows. This transect is designated as a spawning transect. Figure 2.1.2-10 illustrates the cross-section's shape and shows the measured water surface elevations for the field-measured flows.

Transect 9 is in a riffle located approximately 4.7 miles downstream of the Garfield Road crossing, in the lower portion of the Green River. Transect 9 is approximately 30 ft wide and is predominantly cobble substrate with some small boulders. The banks are somewhat steep and well vegetated, but contains a wide flood plain above the banks. The water surface did not exceed the bank height at any of the measured flows. This transect is not designated as a spawning transect. Figure 2.1.2-11 illustrates the cross-section's shape and shows the measured water surface elevations for the field-measured flows.

Appendix B includes photographs of the nine habitat transects.

Table 2.1.2-1: Substrate coding system

Substrate Description[1]	Substrate Code	Size
Roots, snags, undercut banks, overhead cover	1	N/A
Clay	2	N/A

[1] Typically embeddedness and cover (few or many velocity refugia) are also collected as part of substrate mapping. In consultation with ANR, it was determined, however, that the reach's irregular nature resulted in a categorization of many velocity refugia throughout the reach. It was also determined in consultation with ANR that since no spawning lifestages were being assessed in this reach that embeddedness data did not need to be collected.

Silt	3	N/A
Sand	4	N/A
Small Gravel	5	< 2”
Gravel	6	2”-4”
Cobble	7	4”-10”
Small Boulder	8	10”-2’
Large Boulder	9	>2’
Ledge/Bedrock	10	N/A
Detritus, Vegetation	11	N/A

Table 2.1.2-2: Habitat transect summary

Transect	Distance DS from Green River Dam (mi)	Spawning Transect?	Habitat Type	Habitat Mapping Unit
1	3.2	No	Riffle	79
2	3.2	Yes	Riffle	79
3	3.2	Yes	Riffle	79
4	3.1	No	Run	78
5	3.0	Yes	Pool	75[2]
6	3.0	Yes	Run	75
7	2.5	Yes	Riffle	61
8	4.6	Yes	Riffle	130
9	4.7	No	Riffle	131

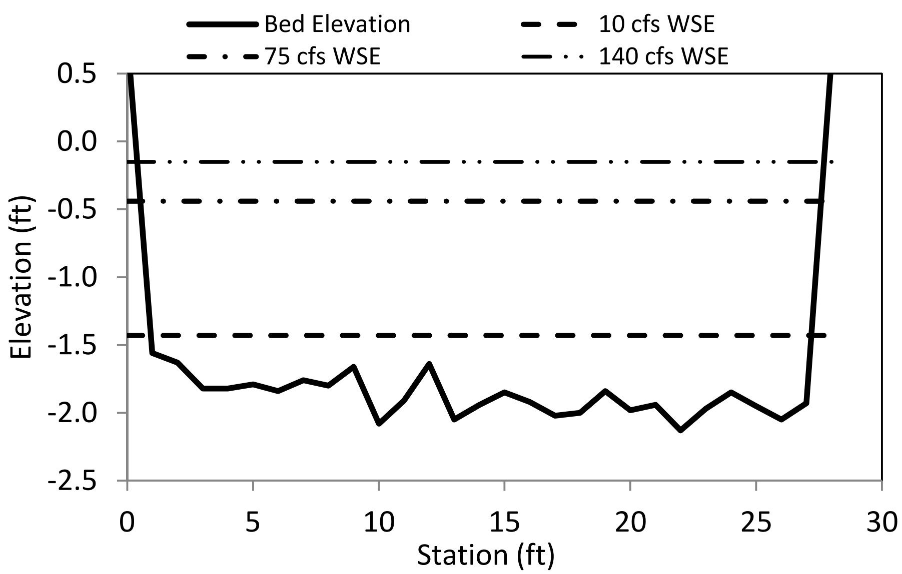

Figure 2.1.2-1: Transect 1 bed elevations and measured water surface elevations

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[2] Habitat unit 75 was initially mapped as a “deep run”, which exhibited characteristics typical of a pool and a run. Transects within this habitat unit have been assigned one specific type (pool or run) based on the local conditions.

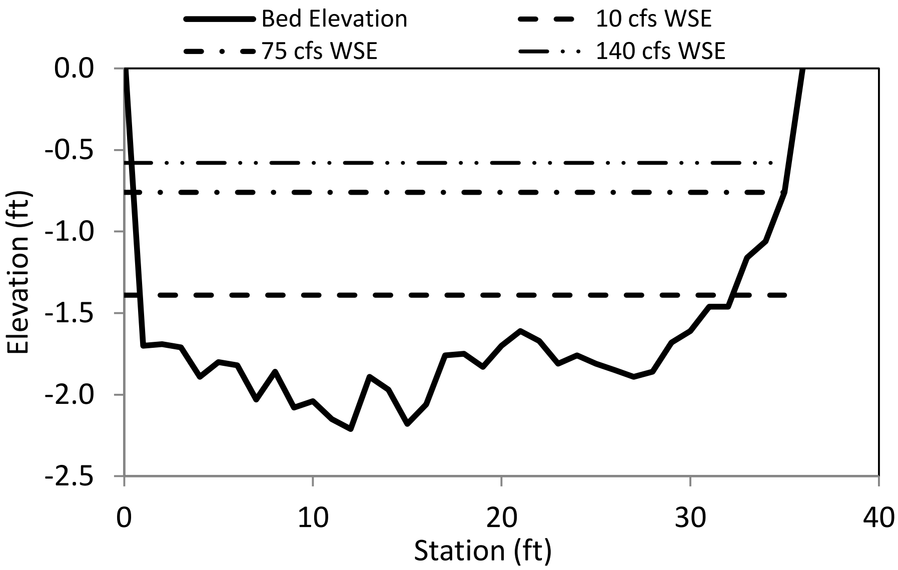


Figure 2.1.2-2: Transect 2 bed elevations and measured water surface elevations

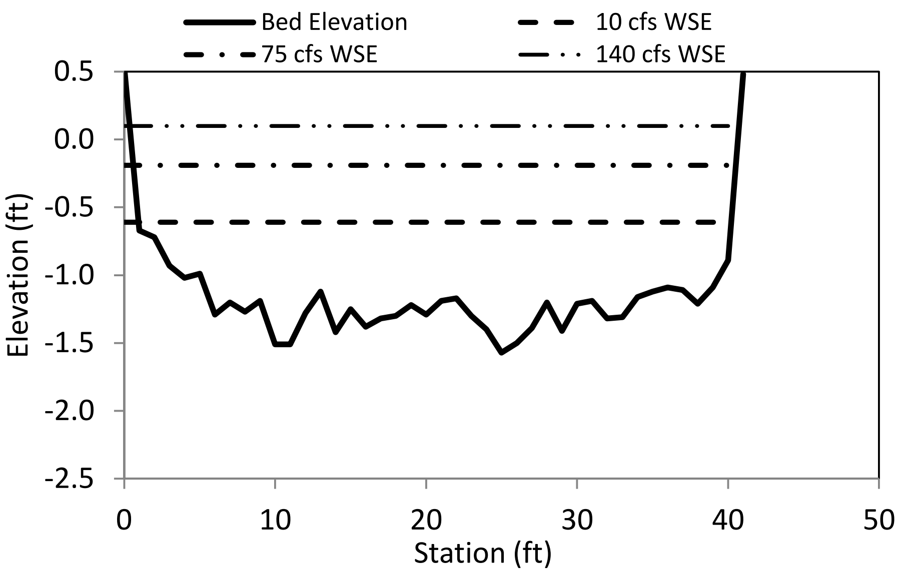


Figure 2.1.2-3: Transect 3 bed elevations and measured water surface elevations

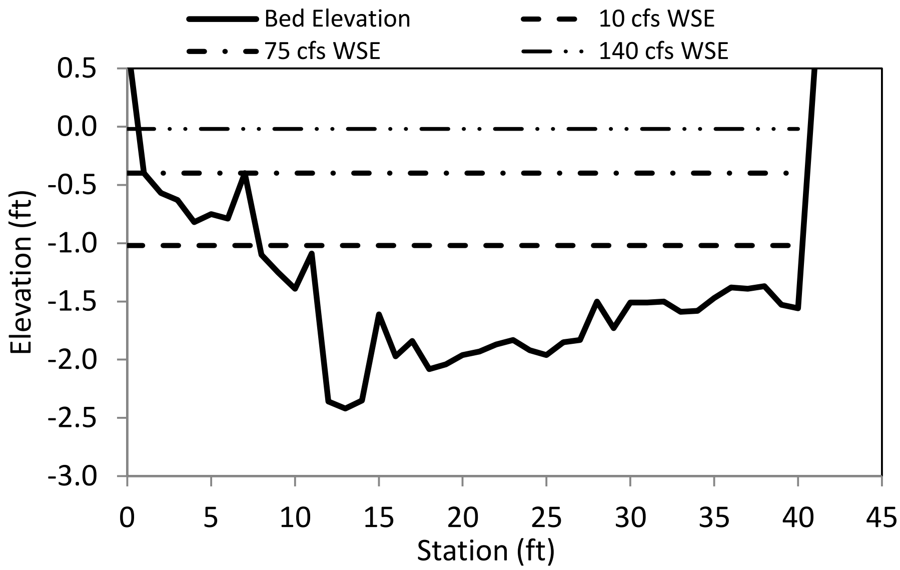


Figure 2.1.2-4: Transect 4 bed elevations and measured water surface elevations

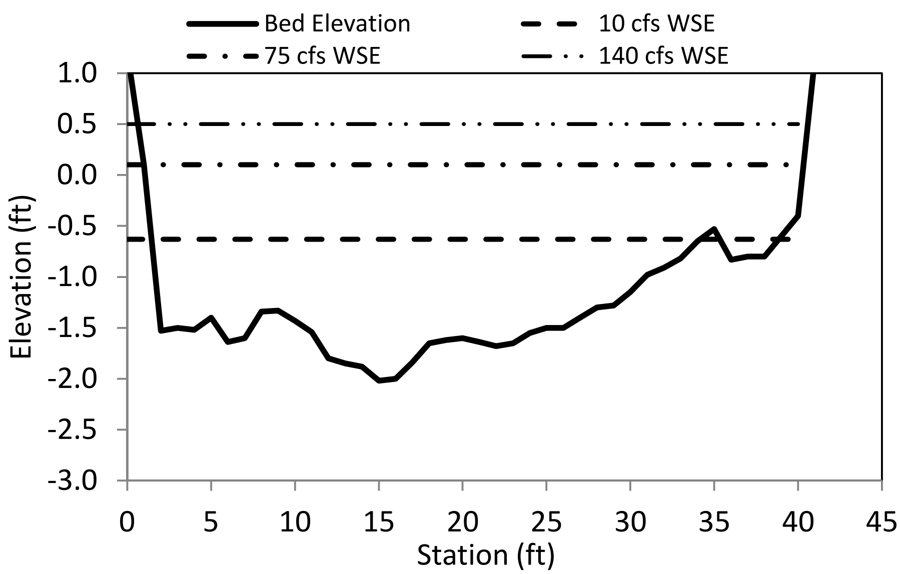


Figure 2.1.2-5: Transect 5 bed elevations and measured water surface elevations

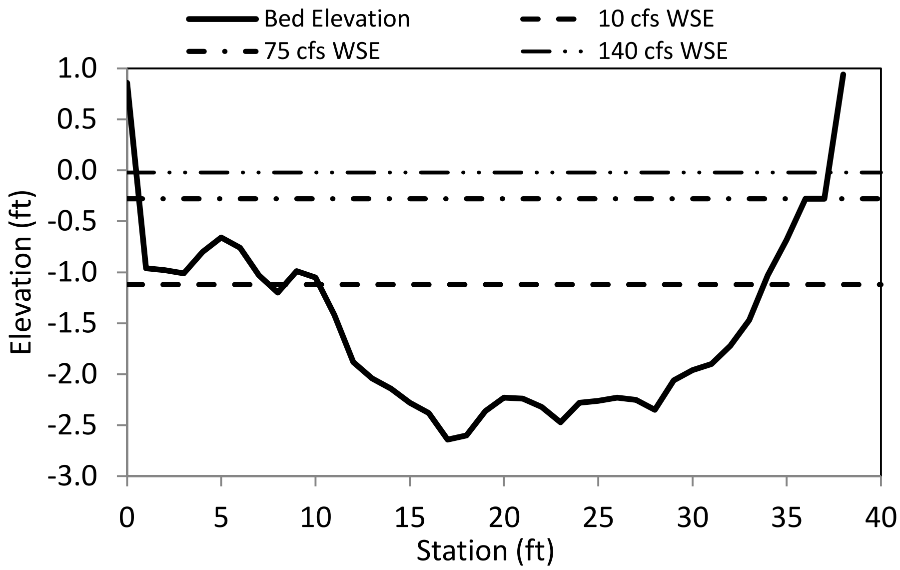


Figure 2.1.2-6: Transect 6 bed elevations and measured water surface elevations

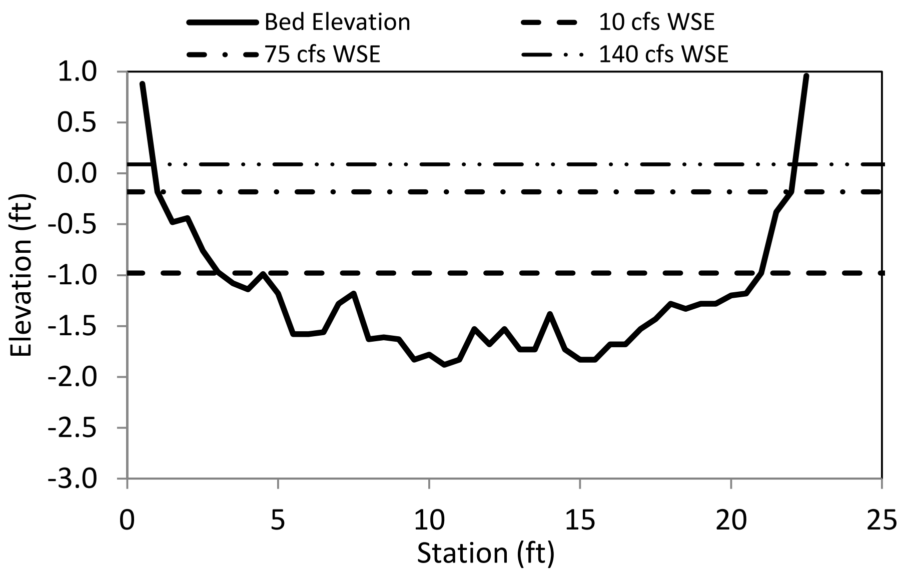


Figure 2.1.2-7: Transect 7 bed elevations and measured water surface elevations

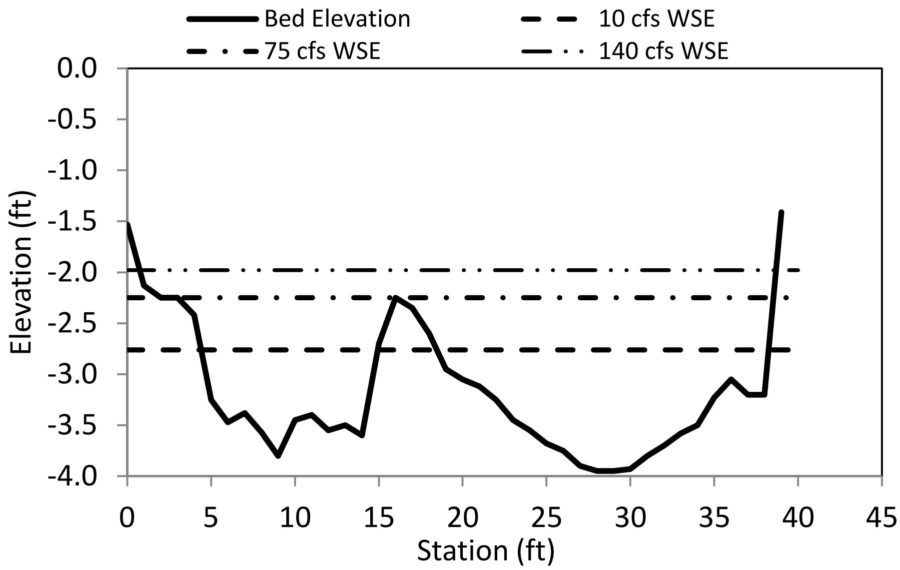


Figure 2.1.2-8: Transect 8 bed elevations and measured water surface elevations

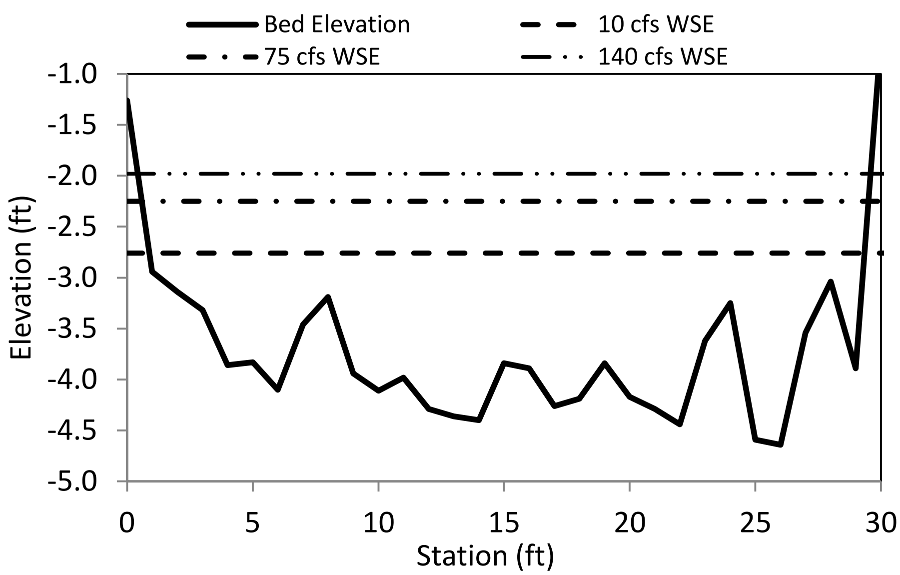


Figure 2.1.2-9: Transect 9 bed elevations and measured water surface elevations

2.1.3 Assessment Flows

The original study plan, as discussed with ANR, planned to involve collecting a full depth and velocity data set across all of the transects at three distinct flows (10 cfs, 40 cfs and 160 cfs). The 10 cfs velocity calibration set was collected without issue. Because of the powerhouse's minimum turbine flow limitations, achieving a 40 cfs flow within the river was not possible. Thus, velocities were taken at the powerhouse's minimum hydraulic capacity of 75 cfs. Finally, though data collection was attempted at a target flow of 160 cfs and water surface elevations were collected at that flow, the river was not wadeable at flows above 75 cfs (spot measurements indicated velocities > 6 ft/s in-channel). Thus, velocities were not collected at that flow. A flow measurement was made from a private bridge at an upstream location, and the actual flow was 140 cfs. Water surface elevation measurements were attempted at the plant's full capacity (285 cfs). While this flow was measured from the upstream bridge, the staff gages were not read because wading into the stream to read the staff gages was not possible. The flows were measured over several dates in September 2012 and November 2012.

During data collection, assessment flows were initially estimated utilizing station estimates. Actual flows were calculated using depth and velocity measurements at each transect. Each transect's staff gage was read prior to and following each measurement. Hydraulic data (depth, velocity) were collected at consistent stations for each flow, referenced as a distance from the left bank pin. Hydraulic data were collected using a Marsh-McBirney flow meter and staff rod.

2.1.4 Target Species and Habitat Suitability Indexes

Evaluation species were selected to be modeled in PHABSIM from a list of species known to be present in the general study area. Several aquatic species and lifestages were selected for the study reach in consultation with ANR. The species include:

a) Brook trout (*Salvelinus fontinalis*) with the following life stages: spawning and incubation, early fry, late fry, juvenile, adult;

b) Brown trout (*Salmo trutta*) with the following life stages: spawning and incubation, early fry, late fry, juvenile, adult;

c) Rainbow trout (*Oncorhynchus mykiss*) with the following life stages: spawning and incubation, early fry, late fry, juvenile, adult;

d) Longnose sucker spawning and incubation (*Catostomus catostumus*); and

e) Macroinvertebrates.

Brook and brown trout have similar habitat criteria. Thus, the brook trout HSI were used to represent both species. Additionally, all trout species have similar early fry habitat criteria, so one early fry HSI criteria set is used.

Aquatic habitat in a river is comprised of both microhabitat and macrohabitat parameters. Microhabitat represents a particular location's physical characteristics within a river, such as slope, width, substrate, cover and the variation of depth and velocity with flow. Macrohabitat refers to broader characteristics impacting fish survival and movement such as food supply, predation and water quality. The following analyses implicitly assume that macrohabitat is suitable throughout the study reach.

Referring to microhabitat characteristics, each species/life stage has a preference for a certain range of depth, velocity, substrate and cover conditions. For example, adult rainbow trout may prefer higher depths and lower velocities when compared to macroinvertebrates. Over the years, biologists have conducted studies to identify the depth, velocity, and substrate preferences for an array of species and life stages. Using the results of these studies, preference or HSI curves have been developed for depth, velocity, substrate, and in some cases, cover.

Suitability index curves describe the species/life stage preference using a 0 to 1 scale. A suitability index value of 0 indicates no habitat value, while a suitability index value of 1 indicates optimal habitat value. The HSI used in this study, compiled in consultation with ANR, are previously developed criteria from other Vermont aquatic habitat studies. Brook trout HSI were developed from the Deerfield River IFIM study (1990). Rainbow trout, longnose sucker and macroinvertebrate HSI were developed from the Lamoille River IFIM study (2000). Appendix C lists each species/life stage's HSI curves for depth, velocity and substrate.

2.2 Temperature Assessment

Temperature loggers were placed in three locations along the Green River (Figure 2.2-1). Temperatures were recorded on a continuous 15-min interval from May 1, 2012 through October 31, 2012. Supplemental water level and dissolved oxygen (DO) data were also collected at various points in August, September and October. The water level data provided insight on how fast and to what magnitude the river reacted hydraulically to peaking flows, and were collected in 5-min intervals from September 6 through October 31. The DO data provided insight into DO dynamics during generation cycles, and was collected in several one-week periods in August and September. This report briefly presents the temperature and water level data results. All three data sets are discussed in the Water Quality Report (RSP 7.6).

Continuous temperature monitoring data were primarily collected with Onset HOBO Pro v2 water temperature data loggers. Some temperature observations in September and October utilized Onset Hobo water level sensors. Onset documentation specifies that the Pro v2 loggers operate between a temperature range of -40°C to 50°C, with an accuracy of 0.2°C and a 0.02°C resolution, while the water level sensors operate between a temperature range of -20°C to 50°C, with an accuracy of 0.44°C and a 0.10°C resolution.

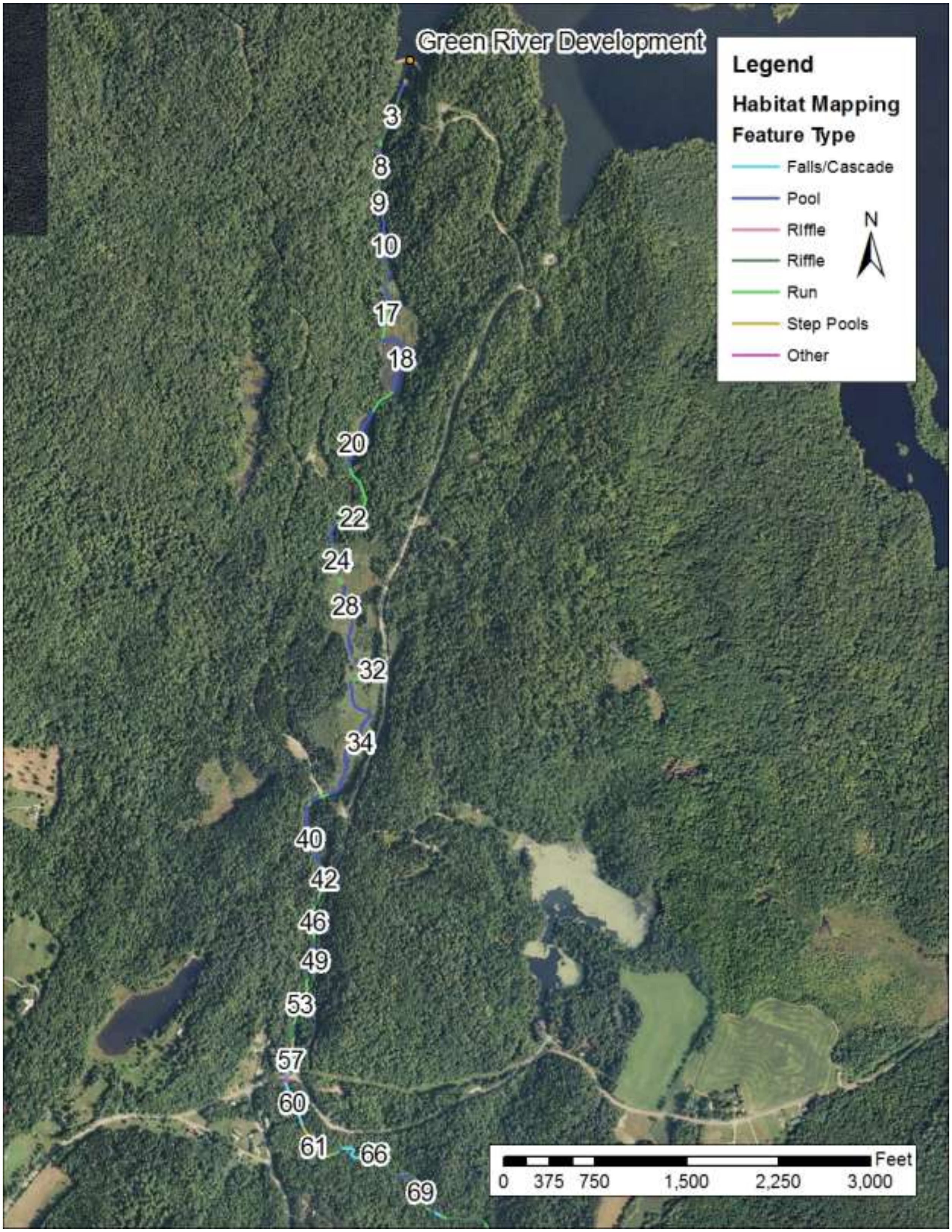


Figure 2.1.1-1: Upper Green River habitat mapping units.

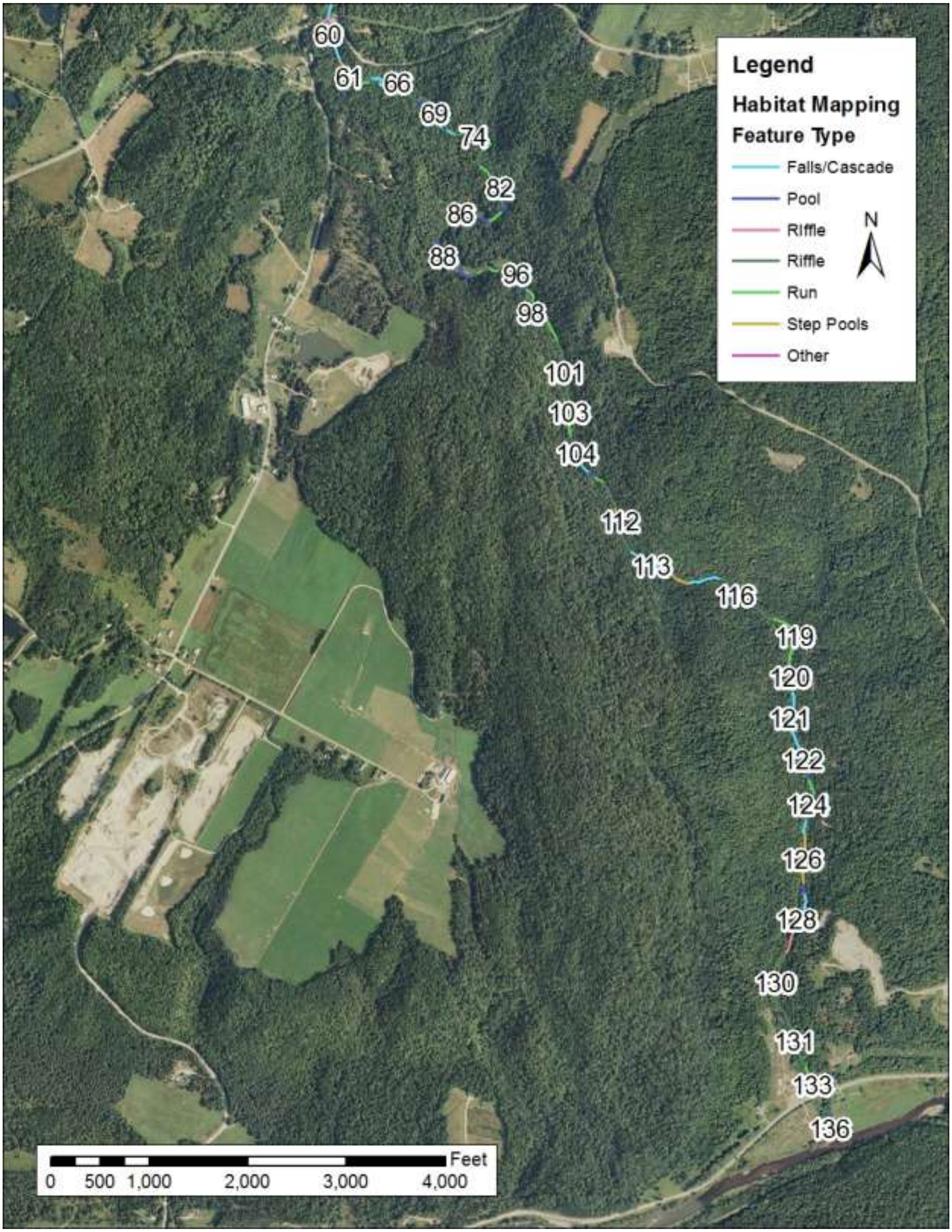


Figure 2.1.1-2: Lower Green River habitat mapping units.

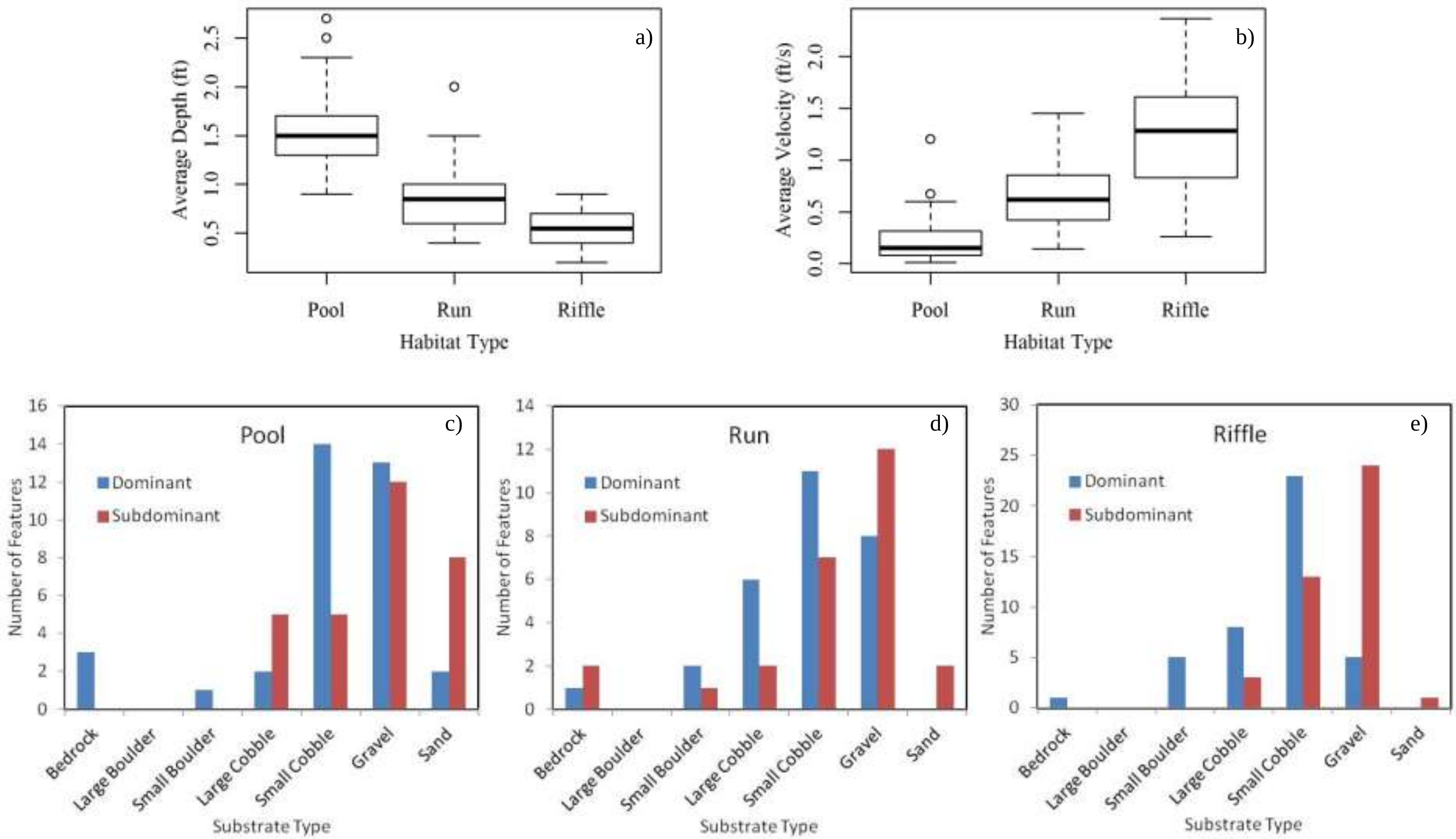


Figure 2.1.1-3: Geomorphic features' a) average depth; b) spot velocity; c) substrate type (pools); d) substrate type (runs); e) substrate type (riffles)

Figure 2.1.2-1: Habitat transects in the upper Green River

Figure 2.1.2-2: Habitat transects in the lower Green River

2.3 Hydraulic Modeling

A hydraulic model using the PHABSIM computer program was developed to simulate hydraulic conditions for each assessment transect using the field-collected data. The model predicts water surface elevations, water depths and mean water column velocities across each modeled transect as a function of flow.

The first step in the process involved using PHABSIM's STGQ component to simulate water surface elevations at each transect as a function of flow. STGQ predicts water surface elevations as a function of discharge by conducting independent log-linear regressions on field-collected water surface elevations at each assessment transect. The stage-discharge equation takes the form:

$$WSE = a^{*} Q^{b}$$

where: WSE = water surface elevation
a = constant derived from measured values of discharge and stage
Q = discharge
b = constant derived from measured values of discharge and stage

A linear regression was performed between the log of the discharge and the log of the water surface elevation to determine the constants in the above equation. Once the constants were known, the stage-discharge equation was used to predict water surface elevation for flows not measured in the field. Table 3.1-1 compares the field-collected water surface elevations with the STGQ modeled water surface elevations. All transects' modeled water surface elevations matched the observed water surface elevations within 0.1 ft.

The cellular velocities measured in the field were used to calculate the Manning's "n" roughness coefficient for each cell across the cross-sections. Manning's "n" is an empirical coefficient used to calculate head losses due to friction. Manning's "n" is higher for rough bed channels, and lower for smoother bed channels. For example, a Manning's "n" of .03 might represent a smooth natural channel with a sandy bed. Alternatively, a Manning's "n" of .10 might represent a small boulder strewn channel.

PHABSIM's VELSIM component was used to simulate velocities across each cross-section for all simulated flows. VELSIM estimates cellular velocities based on a cellular manning's "n" roughness coefficient. Manning's "n" is an empirical coefficient used to calculate head losses due to friction. Manning's "n" is higher for rough bed channels, and lower for smoother bed channels. For example, a Manning's "n" of .03 might represent a smooth natural channel with a sandy bed. Alternatively, a Manning's "n" of .10 might represent a small boulder strewn channel.

The cellular velocities measured in the field were used to calculate the Manning's "n" roughness coefficient for each cell across the cross-sections. VELSIM allows different velocity calibration sets, and thus manning's "n" values, to be utilized for different simulation flows, since channel velocity distributions may change as flows rise or fall in a river. The velocity set collected at the lower calibration flow (10 cfs) was used to calibrate each transect for flows between 4 cfs and 20 cfs. The velocity set collected at 75 cfs was used to calibrate each transect for flows between 30 cfs and 300 cfs.

During the calibration process, an initial solution of Manning's equation to obtain an estimated Manning's n at each vertical along a cross section was completed. This approach treats the velocities measured in the field as a template for describing velocities for other flows. Since channel slope, water surface elevation, and cellular velocity are known as part of the calibration flow data collection, Manning's equation can be solved for "n" at each vertical:

$$n = [1.486 * Se^{1/2} * d^{2/3}]/v$$

where: n = estimated Manning's n value at vertical
Se = energy slope for transect
d = depth at vertical
v = measured velocity at vertical

Note in this equation, that depth at the vertical has been substituted for the hydraulic radius. Once the individual Manning's n values are computed at each vertical, cellular velocities can be computed at any other flow by solving Manning's equation for velocity and using the initial Manning's n value derived from the equation above:

$$v = [1.486/n] * d^{2/3} * Se^{1/2}$$

The purpose of the model calibration process is to accurately simulate the measured water surface elevations and cellular velocities at the calibration flows using VELSIM, while at the same time provide reasonable predictions of water surface elevation and cellular velocities at the range of simulated flows. The calibration of a model is judged by the comparison of predicted and measured water surface elevations and velocities. Normal acceptance standards are to have the predicted water surface elevation within +/- 0.1 ft of the measured. Generally, if the predicted cell velocity at the calibration flow was within 0.2 feet per second of the measured cell velocity, the predicted velocity was considered adequate. Interpolation and extrapolation with the regression equations allowed modeling of flows between and beyond the measured calibration flows.

2.4 Habitat Modeling

2.4.1 Steady-state Habitat Modeling

The calibrated hydraulic model, which predicts velocities and depths over a range of flows, was then combined with a habitat model. The amount of aquatic habitat for a given species/life stage of fish is calculated using the habitat program (the program is called HABTAE), which is part of the PHABSIM library of computer programs. Each habitat cell is evaluated for its habitat suitability for a particular species/life stage based on the fixed characteristics (substrate and cover) and the variable characteristics of the cell (depth and velocity).

Fish habitat, as used in IFIM procedures, is quantified in terms of a variable known as Weighted Usable Area (WUA). A unit of WUA represents a unit of optimum habitat for the life stage evaluated. The following equation is used to calculate WUA, within a cross-section:

$$WUA = \sum_{i=1}^{n} WUA(I) \times n$$

where: WUA(I) = Weighted Usable Area in cell (I);
n = Total number of cells in the reach;

The individual cell WUA(I) is calculated as follows:

WUA(I) = CF(I) x Area(I)

where: Area(I) = Surface area of cell(I); and
CF(I) = Compound Function Index for cell(I)

The Compound Function Index, CF(I), is calculated as follows:

$CF(I) = SI_V \text{ x } SI_D \text{ x } SI_S$

where: SI_V = Suitability Index for Velocity;
SI_D = Suitability Index for Depth; and
SI_S = Suitability Index for Substrate/Cover.

The WUA is then computed for each cell and summed for each transect. In a given study section or reach, the WUA(I) for all the cells are summed, divided by the study reach length, and expressed in units of square feet per foot of stream.

In addition to presenting individual transect habitat results, a composite habitat curve was created. The composite habitat curve represents the weighted average of all nine modeled cross-sections for all life stages. Transect weighting is calculated based on the habitat type that it represents and how many other transects are representing that habitat type. The sum of all transect weights adds up to one. For example, the Green River consisted of 25.1% pools, 32.5% riffles, 16.3% runs and 26.1% “other” (e.g., cascades, falls, step pools, etc.) unmodeled types. Thus, 73.9% of the river’s habitat types are represented in the habitat model. Since six transects were located along a riffle, the weight for any riffle would be $\frac{0.325}{0.739} \times \frac{1}{6} = 0.0733$. The composite weighting is summarized for all nine transects in Table 2.4-1. The composite habitat curves, representing the overall habitat in the modeled portion of the river, is the sum of the individual habitat curves (WUA vs flow) multiplied by the individual transects’ weighting factor.

Table 2.4.1-1: Habitat transect weighting factors

Transect	Habitat Type	Weighting Factor
1	Riffle	0.0733
2	Riffle	0.0733
3	Riffle	0.0733
4	Run	0.1103
5	Pool	0.3396
6	Run	0.1103
7	Riffle	0.0733
8	Riffle	0.0733
9	Riffle	0.0733

2.4.2 Dual Flow Analysis

When streamflow varies, habitat quality may decrease in some habitat cells, while increasing in others. A dual flow analysis is commonly used to calculate the quantity of habitat that is present over a flow range, such as those that may be expected during a minimum flow/peaking flow hydroelectric operation. For immobile aquatic biota, a dual flow analysis assumes that a transect's available habitat is equal to the sum of the individual cells' minimum habitat for a given flow pair. In other words, a cell's the effective habitat is the minimum cellular WUA during a minimum/generation flow pair. The dual-flow analysis was conducted for the "immobile" target life stages. All spawning/incubation and fry life stages, as well as macroinvertebrates, were considered immobile for the purposes of this study. Dual flow analysis results are typically focused on riffle areas, as they are the habitat most affected by changes in flow. For completeness, dual flow results have been compiled for all modeled transects. Additionally, a "composite" dual-flow analysis is presented for each immobile species/life stage that includes a weighting factor derived using the same process as the steady-state WUA analysis results, but using only transects designated as "spawning" transects. The weighting factors are listed in Table 2.4.2-1.

The following species and life stages were included in the dual flow analysis:

- Brook/Brown trout: spawning and incubation; late fry
- Rainbow trout: spawning and incubation; late fry
- Early fry: all trout species
- Longnose sucker: spawning and incubation
- Macroinvertebrates

Table 2.4.2-1: Habitat transect weighting factors, spawning transects

Transect	Habitat Type	Weighting Factor
2	Riffle	0.1466
3	Riffle	0.1466

5	Pool	0.3396
6	Run	0.2206
9	Riffle	0.1466

3.0 Results and Discussion

This section describes the hydraulic model performance as well as habitat preferences for each target species/life stage. Habitat modeling results are presented in terms of WUA (i.e., habitat) versus flow relationships. Results were computed for each transect individually. Results were also combined into a compound habitat versus flow curve representing habitat along the entire river. Dual flow results are also presented.

3.1 Hydraulic Model Calibration

The predicted water surface elevations computed by the STGQ model corresponded well with the field measured water surface elevations at the four calibration lows. Table 3.1-1 illustrates the measured and predicted water surface elevations for the calibration flows. The result of the calibration at all transects was found to be very good, as the difference between the predicted and measured water surface elevations was within the normal acceptance standard of ±0.1 ft.

Table 3.1-1: Measured and predicted water surface elevations for calibration flows. Water surface elevations are relative to the local bank pins.

	T1	T2	T3	T4	T5	T6	T7	T8	T9
Calibration Flow = 10 cfs									
Observed WSE (ft)	-1.43	-1.39	-0.61	-1.02	-0.63	-1.12	-0.98	-2.76	-3.65
Predicted WSE (ft)	-1.42	-1.39	-0.62	-1.02	-0.63	-1.12	-0.98	-2.76	-3.65
Difference (ft)	0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
Calibration Flow = 75 cfs									
Observed WSE (ft)	-0.44	-0.76	-0.19	-0.40	0.10	-0.28	-0.18	-2.25	-2.94
Predicted WSE (ft)	-0.53	-0.81	-0.15	-0.38	0.12	-0.36	-0.24	-2.23	-3.01
Difference (ft)	-0.09	-0.05	0.04	0.02	0.02	-0.08	-0.06	0.02	-0.07
Calibration Flow = 140 cfs									
Observed WSE (ft)	-0.15	-0.58	0.10	-0.02	0.50	-0.02	0.09	-1.98	-2.77
Predicted WSE (ft)	-0.05	-0.53	0.06	-0.04	0.48	0.06	0.16	-2.00	-2.70
Difference (ft)	0.10	0.05	-0.04	-0.02	-0.02	0.08	0.07	-0.02	0.07

The cell velocities predicted by the VELSIM hydraulic model at the calibration flow were generally within 0.2 feet per second of the measured cell velocities. In addition, the hydraulic model simulations' velocity adjustment factors increased with increasing discharge, and were close to 1.0 at the calibration discharge. This is indicative of a properly calibrated VELSIM hydraulic model.

3.2 Steady State Habitat Analysis

Habitat within the Green River was modeled using a PHABSIM hydraulic and habitat model. A transect's WUA was calculated using the Habtae component of the PHABSIM program.

Appendix D contains WUA vs flow plots for all target species/life stages at all flows and transects. For conciseness, only compound habitat versus flow curves representing habitat along the entire river are shown, rather than individual transects' curves for each species/life stage.

3.2.1 Brook and Brown Trout

As previously stated, the habitat suitability criteria for brook and brown trout are similar. Following ANR's recommendation, brook trout HSI were used to develop results for both species. Brook trout composite habitat results are shown in Figure 3.2-1. The early fry curve represents the generic early fry curve used for all trout species in this study.

Spawning and Incubation: The brook trout spawning and incubation curve indicates that spawning habitat is most prevalent at flows between approximately 10 and 40 cfs. Habitat is relatively low (< 50% of maximum WUA) at flows at or below 5.5 cfs, but rapidly increases between 4 and 20 cfs because of an increase in overall depths and velocities. Habitat reaches a local peak at 15 cfs before slightly declining at 20 cfs and then rising again at 30 cfs. This "double peak" appears to primarily be an effect of the composite curve, as the riffles tended to have greater habitat at lower flows (resulting in the local peak) that rapidly fell off, while the pools and runs tended to have more habitat at higher flows. As in-channel velocities increased with higher flows, habitat decreased moderately between 30 and 75 cfs before beginning to level off at higher flows. A small amount of habitat remained at higher flows.

Early Fry: The early fry curve indicated that there is not much early fry habitat available for any flows, relative to the other brook trout life stages, and the available habitat is primarily available at low flows. The maximum habitat was provided at 4 cfs, the lowest modeled flow. Habitat decreased smoothly between 4 and 20 cfs, before a slight increase occurred between 20 and 30 cfs. Habitat continues to gradually decline at flows above 30 cfs.

Late Fry: Brook trout late fry habitat is moderately abundant throughout the modeled flow range, but is most abundant at flows below 40 cfs. The maximum habitat was provided at 10 cfs. Habitat decreases moderately as flows increase between 10 cfs and 40 cfs, and then continue to decrease more gradually through the rest of the modeled flow range. A moderate amount of habitat was still available at the highest modeled flows, even though it was a low percentage of the maximum habitat.

Juvenile: The brook trout juvenile habitat vs. flow curve features a sharp increase in habitat between 4 and 30 cfs, with the maximum habitat available at 40 cfs. Habitat decreases moderately as flows increase between 40 cfs and 100 cfs, and decrease in an increasingly more gradual manner as flows increase beyond 100 cfs, similar to the late fry habitat curve.

Adult: The brook trout adult habitat vs. flow curve is similar to the juvenile curve, but with a lower amount of maximum habitat and a preference for slightly higher flows in general (habitat peaks at a higher flow and falls off less at higher flows). Habitat increases relatively quickly between 4 cfs and 70 cfs, with the maximum habitat provided at 70 cfs. Habitat then gradually decreases as flows increase, primarily because velocities become less suitable (though not intolerable) at higher flows. Adult brook trout prefer slightly deeper water and are more tolerant of higher velocities than the juvenile brook trout, which explains this life stage's generally higher flow preferences.

3.2.2 Rainbow Trout

The rainbow trout composite habitat results are shown in Figure 3.2-2. The early fry curve represents the generic early fry curve used for all trout species in this study.

Spawning and Incubation: The rainbow trout spawning and incubation curve indicates that spawning habitat is most prevalent at flows between 60 cfs and 150 cfs. Habitat is sparse at lower flows, but rapidly increases between 20 cfs and 90 cfs. Spawning and incubation habitat reaches its maximum value at 90 cfs. Habitat gradually declines with increasing flows between 90 cfs and 180 cfs. Habitat rapidly decreases at flows above 180 cfs as channel velocities exceed the suitable velocity range.

Early Fry: The early fry curve indicated that there is not much early fry habitat available for any flows, relative to the other brook trout life stages, and the available habitat is primarily available at low flows. The maximum habitat was provided at 4 cfs, the lowest modeled flow. Habitat decreased smoothly between 4 and 20 cfs, before a slight increase occurred between 20 and 30 cfs. Habitat continues to gradually decline at flows above 30 cfs.

Late Fry: Rainbow trout late fry habitat somewhat abundant throughout the modeled flow range, but is heavily skewed toward flows below 50 cfs. The maximum habitat is provided at 30 cfs. Habitat decreases moderately as flows increase between 4 cfs and 10 cfs, is relatively level between 10 cfs and 30 cfs, and then rapidly declines at flows above 30 cfs. Habitat decreases are more gradual at flows above 70 cfs.

Juvenile: The rainbow trout juvenile habitat vs. flow curve features a sharp habitat increase between 4 cfs and 30 cfs, with the maximum habitat available at 60 cfs. Habitat decreases moderately at flows above 60 cfs through the rest of the modeled flow range as velocities begin to exceed the optimal range.

Adult: The rainbow trout adult habitat vs. flow curve is similar to the juvenile curve, but with a lower amount of maximum habitat and a preference for slightly higher flows, similar to the juvenile-adult relationship for brook trout. Habitat increases quickly between 4 cfs and 50 cfs. 80 cfs provides the maximum available habitat. Habitat gradually decreases at flows above 90 cfs as velocities exceed the preferred range.

3.2.3 Longnose Sucker

Longnose sucker were only modeled for the spawning and incubation life stage. Figure 3.2-3 shows the composite habitat vs. flow curve.

Spawning and Incubation: Longnose sucker spawning and incubation habitat increased sharply between 4 cfs and 40 cfs. The maximum habitat available was at 40 cfs. Habitat then gradually declined as flows increased for the rest of the modeled flow range. Both depths and velocities were beginning to exceed the preferred ranges at the higher modeled flows.

3.2.4 Macroinvertebrates

Macroinvertebrates were modeled as one overall unit using composite suitability indices. The composite habitat vs. flow curve is shown in Figure 3.2-4. Macroinvertebrate habitat increased rapidly between 4 cfs and 60 cfs, after which gains became more gradual. 100 cfs provided the maximum habitat. Habitat at flows above 100 cfs only gradually decreases, since the macroinvertebrate suitability curves are fairly tolerant of higher depths and velocities.

3.2.5 Summary

Table 3.2-1 shows which flows provide the maximum WUA for each species and life stage. It also includes the flow range that provides 95%, 90%, 80% and 70% of the maximum WUA. For life stages that peak at the minimum or maximum modeled flow (4 cfs and 300 cfs, respectively), this is assumed to be the maximum WUA even though habitat may continue to increase at higher flows. Figure 3.2-5 graphically compares the flow preferences for each life stage described in Table 3.2-1.

Table 3.2-2 shows what percentage of the maximum available habitat is provided at select flows. The purpose of this table is to allow an easy numerical comparison of various life stages' flow preferences.

Table 3.2-1: Flow versus percentage of the maximum weighted usable area (WUA), using the composite habitat results.

Species/Life Stage	Maximum WUA Flow (cfs)	Range of Flows providing 95% of Maximum WUA (cfs)	Range of Flows providing 90% of Maximum WUA (cfs)	Range of Flows providing 80% of Maximum WUA (cfs)	Range of Flows providing 70% of Maximum WUA (cfs)
Brook/Brown Trout:					
Spawning & Inc.		26.3-32.4	22.6-34.7	10.8-39.4	8.9-44.3
Early Fry		4.0-4.4	4.0-4.8	4.0-5.5	4.0-7.2
Late Fry		4.0-15.7	4.0-19.9	4.0-34.0	4.0-42.5
Juvenile		26.9-56.2	22.7-65.6	16.0-79.9	12.0-94.0
Adult		49.9-105.2	41.4-124.8	29.8-159.5	23.0-196.9
Rainbow Trout:					
Spawning & Inc.		68.6-109.8	64.9-122.0	58.2-152.0	52.5-182.3
Early Fry		4.0-4.4	4.0-4.8	4.0-5.5	4.0-7.2
Late Fry		11.1-34.0	9.0-38.0	6.2-45.2	4.4-52.5
Juvenile		43.1-89.0	35.3-102.5	26.5-128.0	20.4-154.5
Adult		63.3-113.6	54.8-131.0	42.7-167.5	33.5-202.1
Longnose Sucker:					
Spawning & Inc.		29.1-63.9	25.8-77.5	19.1-102.1	13.4-127.0
Macroinvertebrates:					
All		68.2-141.7	58.8-167.8	47.0-223.8	38.3-275.3

Table 4-2: Percentage of the maximum weighted usable area (WUA) for various flows, using the composite habitat results.

Species/Life Stage	Maximum WUA Flow (cfs)	4 cfs	5.5 cfs	10 cfs	20 cfs	50 cfs	75 cfs	100 cfs	140 cfs	200 cfs	285 cfs
Brook/Brown Trout											
Spawning & Inc.	30	25.4	42.6	78.4	86.5	58.1	26.1	17	14.1	13.1	10.4
Early Fry	4	100	80.3	53.1	29.9	35.8	30.7	23.3	11.2	4.3	2.7
Late Fry	10	97.8	99.8	100	89.9	62.6	48.3	39.5	31.2	24.1	20.5
Juvenile	40	39.5	46.7	64.3	86.8	97.6	83.7	66	50.4	37.9	31.2
Adult	70	27.9	32.9	45.5	65.6	95.0	99.9	96.2	85.6	69.3	55.1
Rainbow Trout											
Spawning & Inc.	90	0.0	0.0	0.7	9.4	65.6	99.2	96	84.7	52.5	20.1
Early Fry	4	100	80.3	53.1	29.9	35.8	30.7	23.3	11.2	4.3	2.7
Late Fry	30	67.4	77.4	93.8	99.2	73.1	47.3	33.5	21.9	15.8	11.9
Juvenile	60	27.2	33.0	47.9	69.3	98.1	99.1	91.0	75.5	53.4	32.4
Adult	80	10.9	15.1	27.1	47.9	86.7	99.3	98.5	87.2	70.7	43.2
Longnose Sucker											
Spawning & Inc.	40	32.8	41.7	60.9	81.3	98.9	91	80.9	64.8	43.3	22.4
Macroinvertebrates											
All	100	2.9	5.5	16.4	40.1	83.1	97.4	100	95.3	84.1	68.0

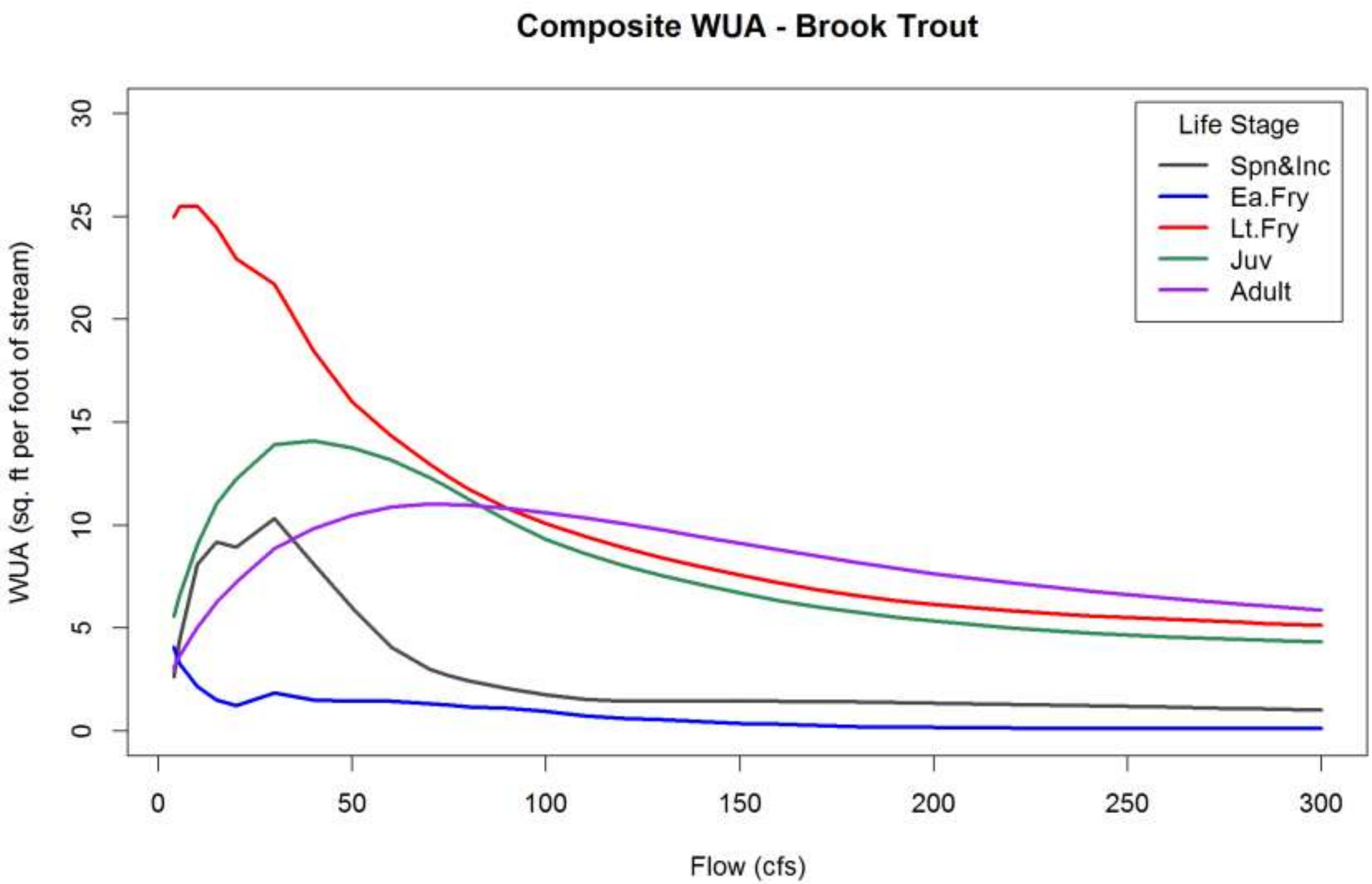


Figure 3.2-1: Brook trout composite habitat vs. flow curve.

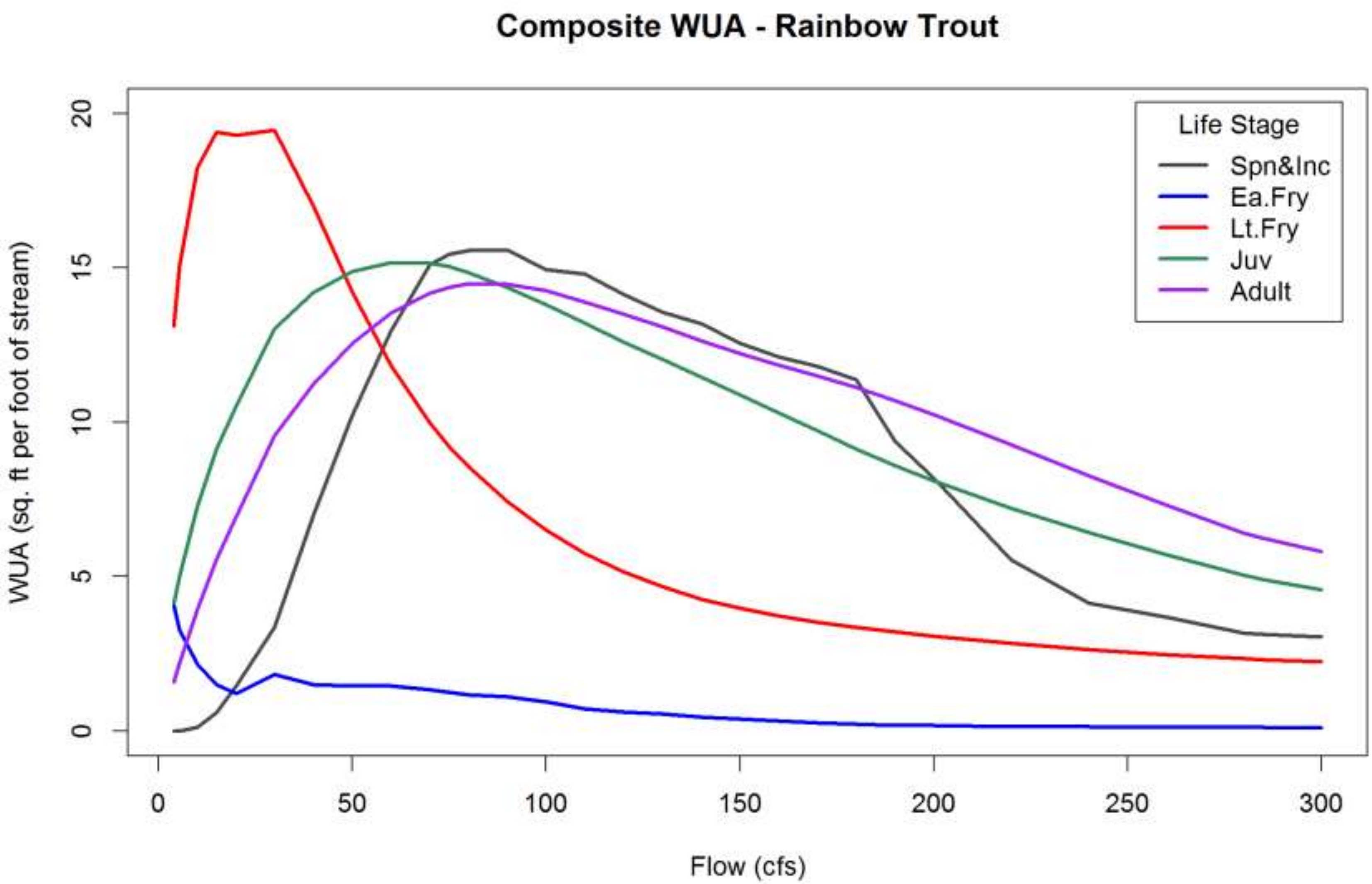


Figure 3.2-2: Rainbow trout composite habitat vs. flow curve.

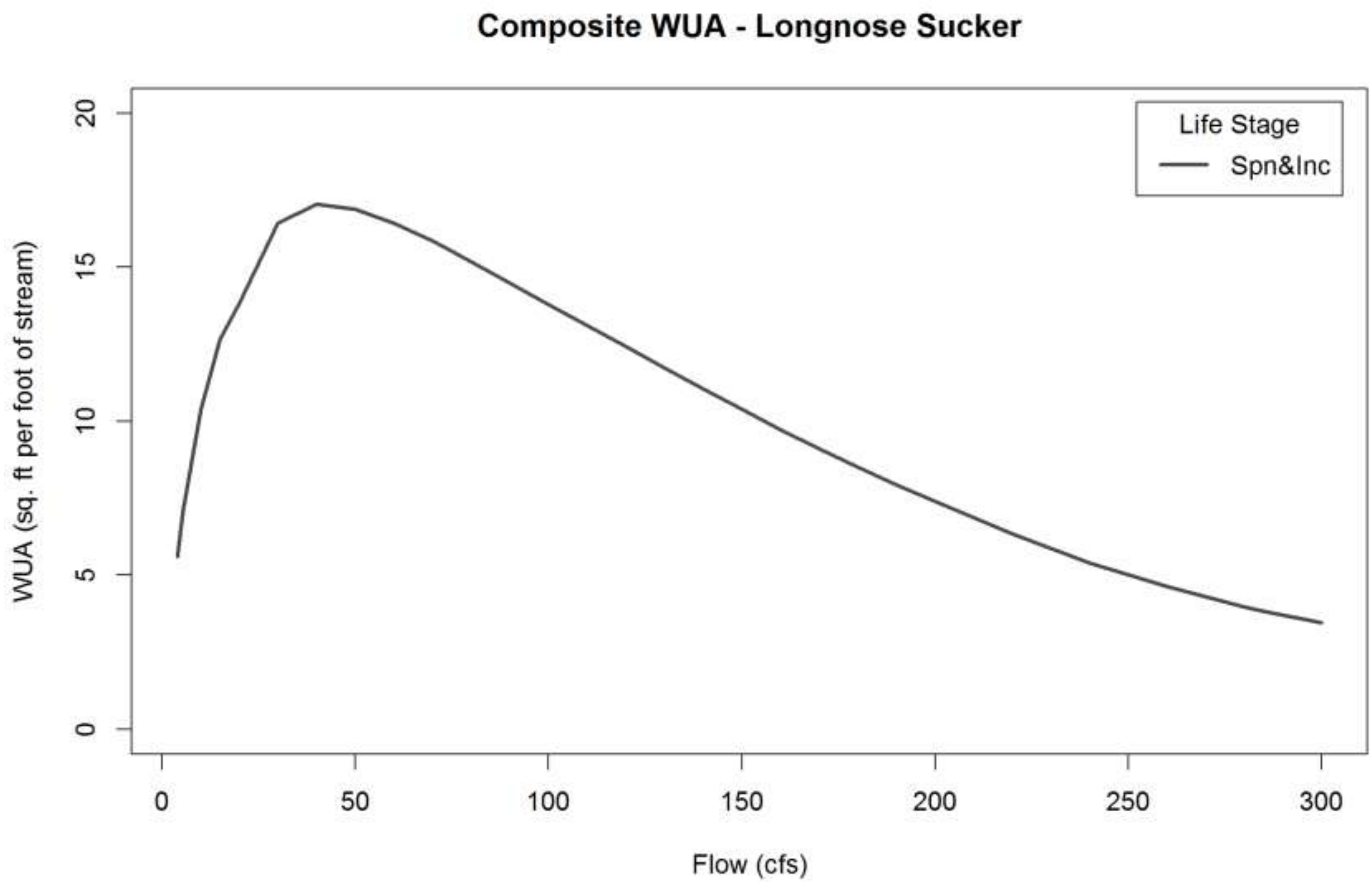


Figure 3.2-3: Longnose sucker spawning and incubation composite habitat vs. flow curve.

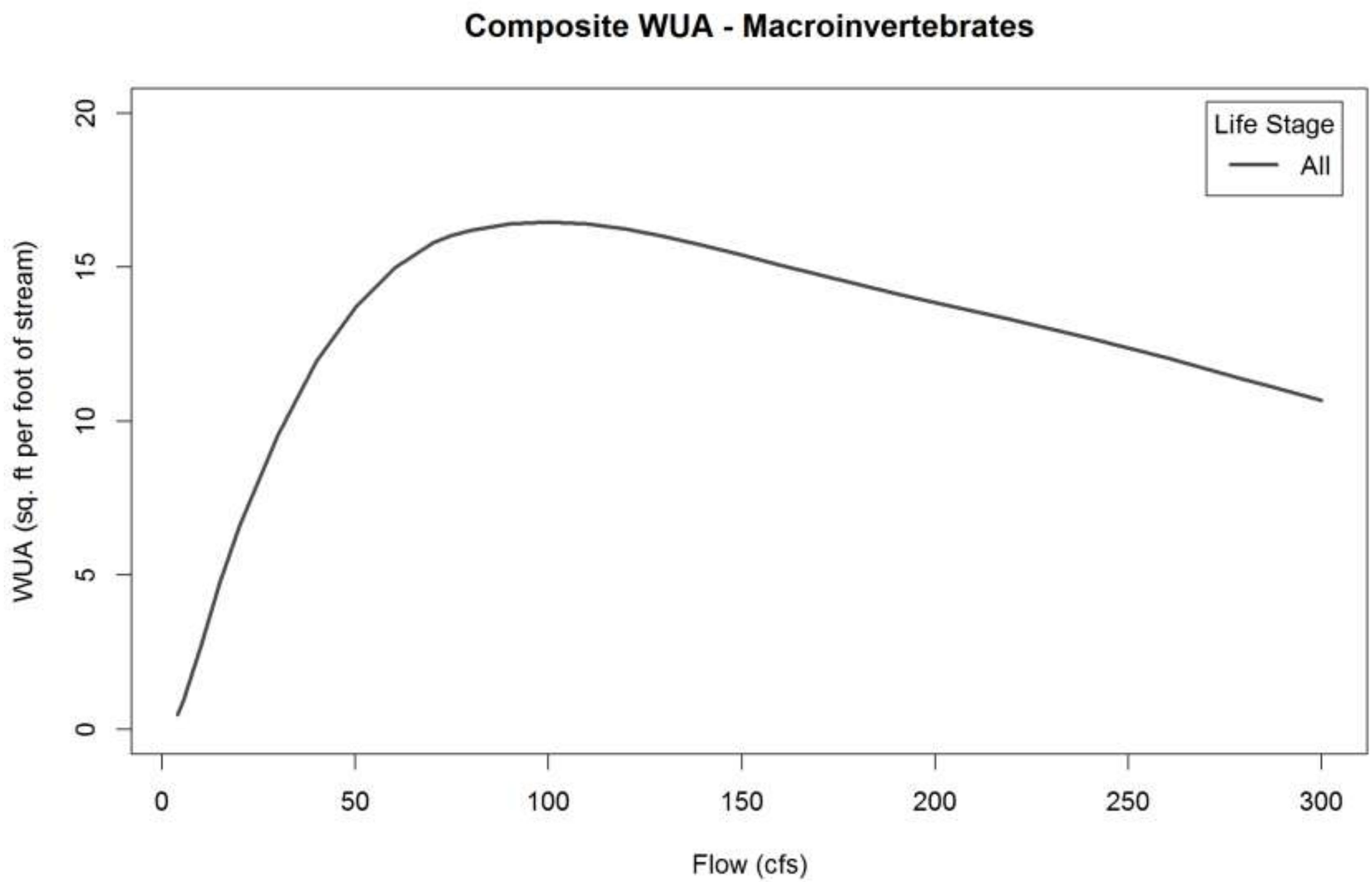


Figure 3.2-4: Macroinvertebrates composite habitat vs. flow curve.

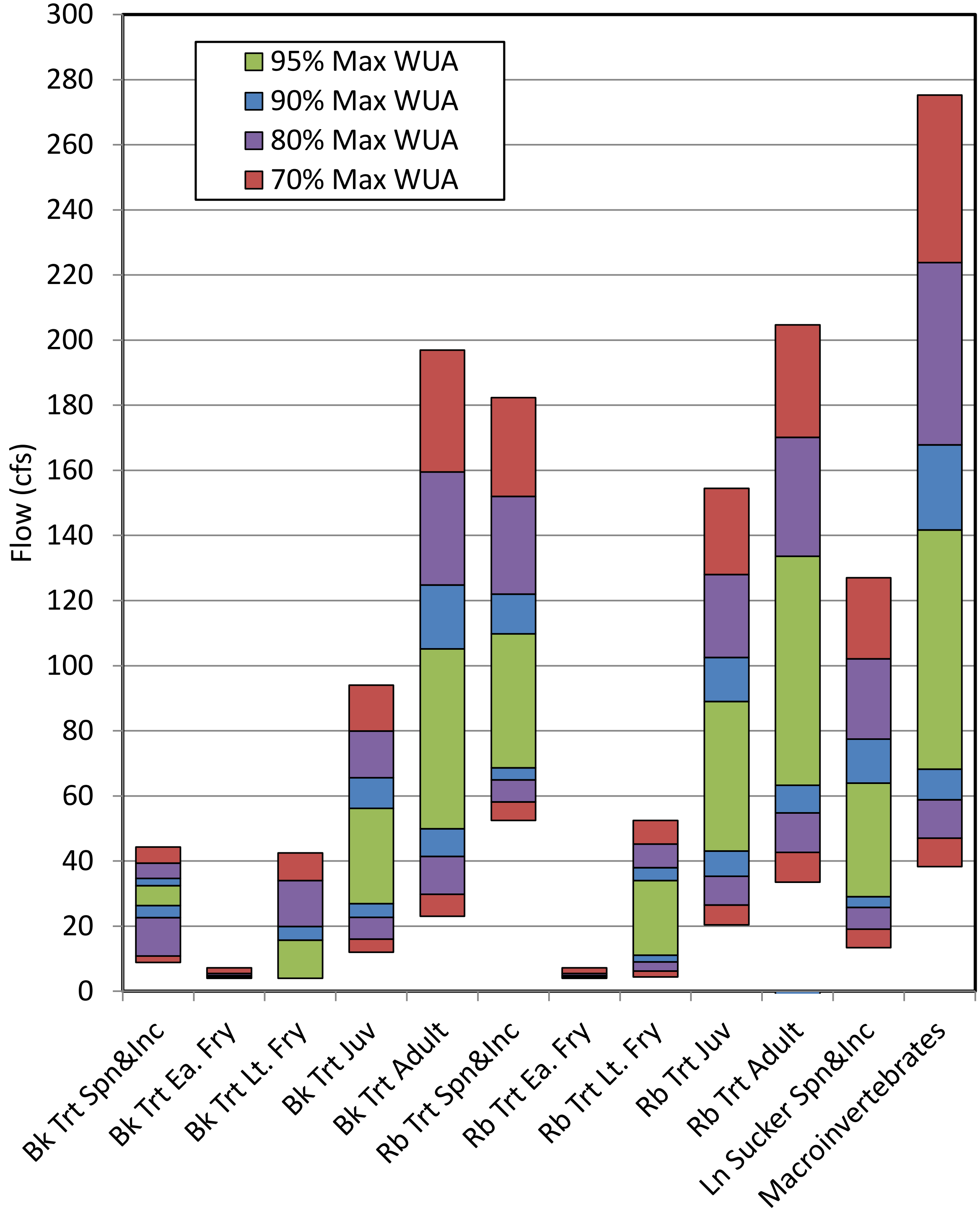


Figure 3.2-5: Comparison of all modeled life stages' flow preferences, as a percentage of maximum WUA.

3.3 Dual Flow Analysis

The results of the dual flow analysis are described in this section. The dual flow results were developed on a transect-by-transect scale, using the PHABSIM hydraulic and habitat model outputs. Appendix E contains dual flow result for all immobile target species/life stages at all flows and transects. For conciseness, only composite dual flow results representing habitat along the entire river are shown, rather than individual transects' results for each species/life stage. To reiterate, the composite results presented in this section only consider the transects designated as "spawning" transects.

3.3.1 Brook and Brown Trout

Three brook trout life stages were considered immobile for this analysis: spawning and incubation, early fry and late fry. The early fry life stage uses the generic early fry trout results.

Figure 3.3-1 shows the composite brook trout spawning and incubation dual flow results. The plot shows that the majority of the dual flow habitat is available when flows remain under 50 cfs, and that the habitat declines moderately quickly as flow pairs with 50 cfs or larger divergences are paired.

Figure 3.3-2 shows the composite brook trout early fry dual flow results. The plot shows that the majority of the habitat is available only at very low flows (< 10 cfs) and any dual flow habitat is minimal once flows exceed 100 cfs.

Figure 3.3-3 shows the composite brook trout late fry dual flow results. The plot shows that while the majority of the dual flow habitat occurs when flows stay between 4 cfs and 50 cfs, there is a small amount available at flows of up to 150-250 cfs, depending on the paired low flow.

3.3.2 Rainbow Trout

Three rainbow trout life stages were considered immobile for this analysis: spawning and incubation, early fry and late fry. The early fry life stage uses the generic early fry trout results.

Figure 3.3-4 shows the composite rainbow trout spawning and incubation dual flow results. The plot shows that minimum flows must be over approximately 40-50 cfs with maximum flows less than approximately 200 cfs in order to maintain the highest amounts of dual flow habitat.

Figure 3.3-5 shows the composite brook trout early fry dual flow results. The plot shows that the majority of the habitat is available only at very low flows (< 10 cfs) and any dual flow habitat is minimal once flows exceed 100 cfs.

Figure 3.3-6 shows the composite rainbow trout late fry dual flow results. The plot shows that high amounts of dual flow habitat are maintained when maximum flows are kept below 50 cfs, though modest amounts are still available when flows stay below 100 cfs.

3.3.3 Longnose Sucker

Longnose sucker were only modeled for the spawning and incubation life stage. This life stage was considered immobile for this analysis.

Figure 3.3-7 shows the composite longnose sucker spawning and incubation life stage results. The plot shows that small to modest amounts of dual flow habitat are available for nearly any minimum/maximum flow pair. The most amount of habitat, however, was maintained when minimum flows were kept above approximately 20 cfs and maximum flows stayed below approximately 100-150 cfs.

3.3.4 Macroinvertebrates

Macroinvertebrates only had one composite life stage modeled for habitat in this study. Macroinvertebrates were considered immobile for this analysis.

Figure 3.3-8 shows the composite macroinvertebrate dual flow results. The plot shows that moderate amounts of dual flow habitat are available when minimum flows are maintained above 20-30 cfs. The maximum amount of dual flow habitat is available when flows are between 50 and 150 cfs.

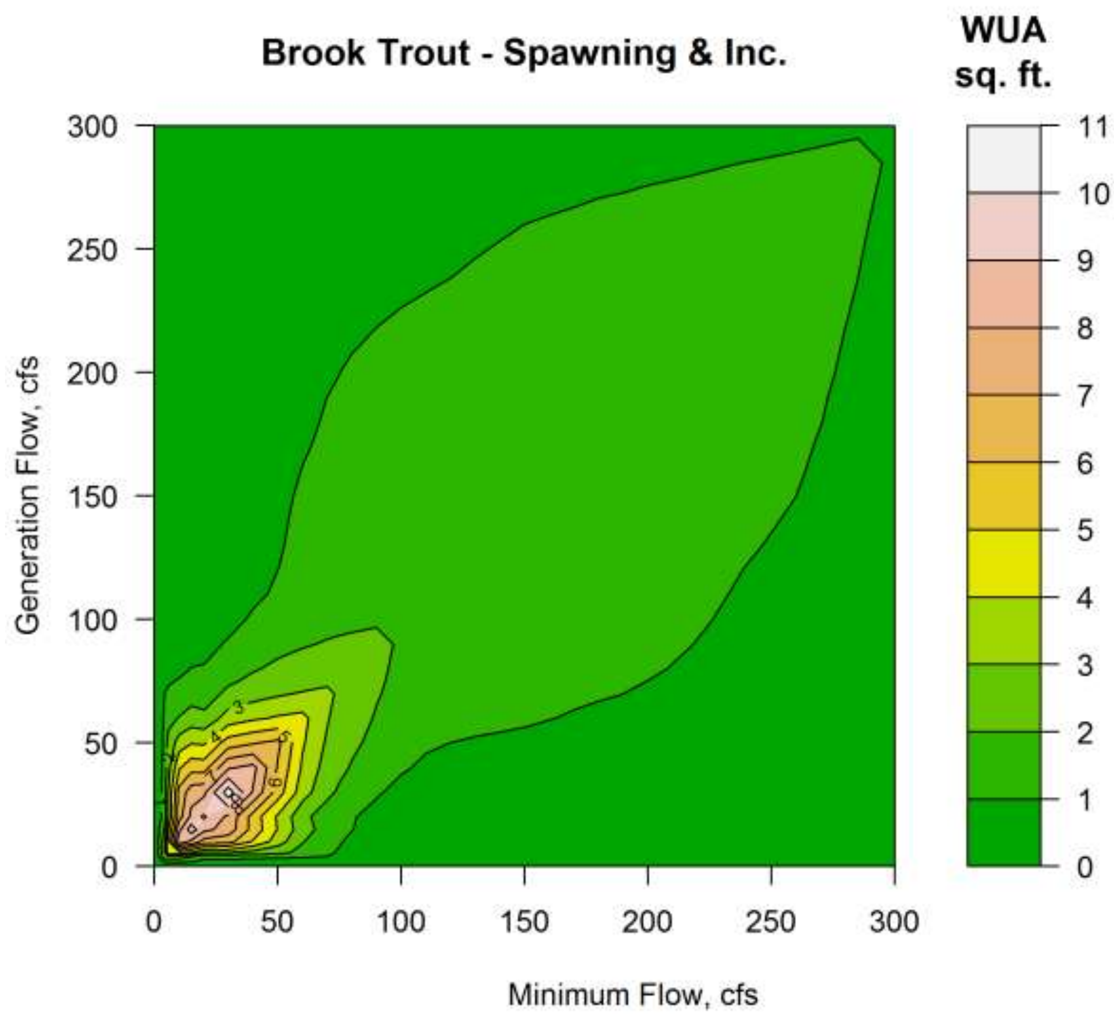


Figure 3.3-1: Brook and brown trout spawning and incubation composite dual flow habitat results. WUA results are in terms of square feet of dual flow habitat per linear foot of stream.

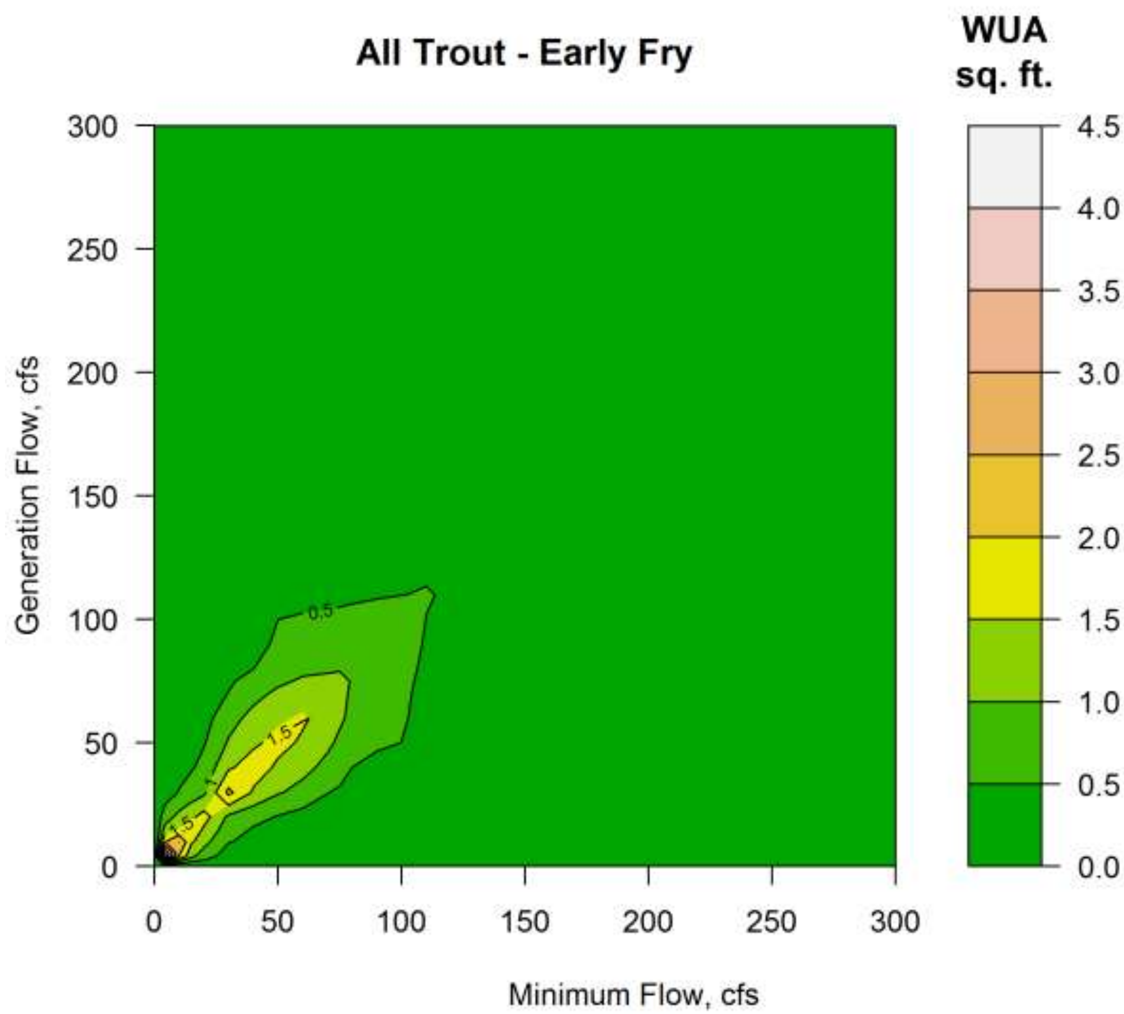


Figure 3.3-2: Brook and brown trout early fry composite dual flow habitat results. WUA results are in terms of square feet of dual flow habitat per linear foot of stream.

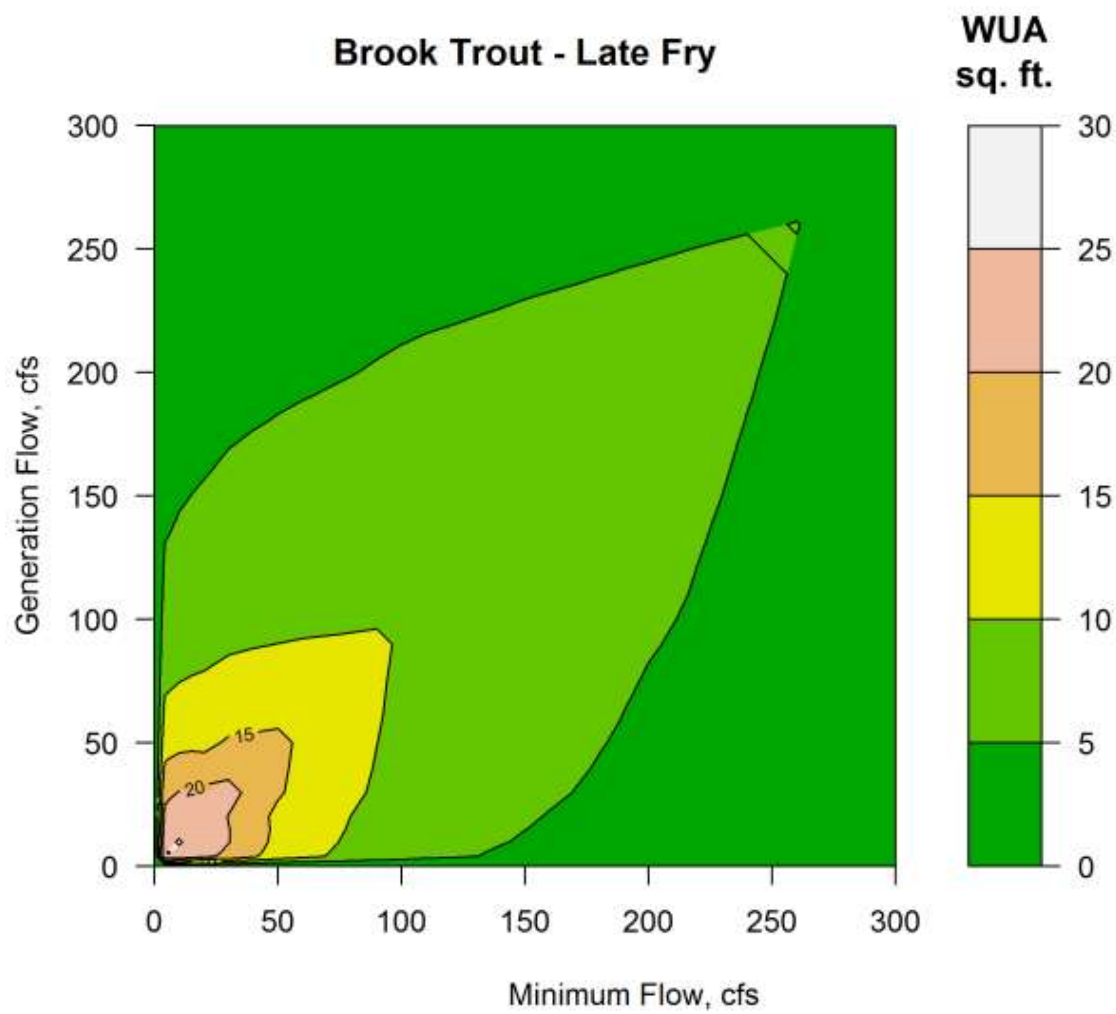


Figure 3.3-3: Brook and brown trout late fry composite dual flow habitat results. WUA results are in terms of square feet of dual flow habitat per linear foot of stream.

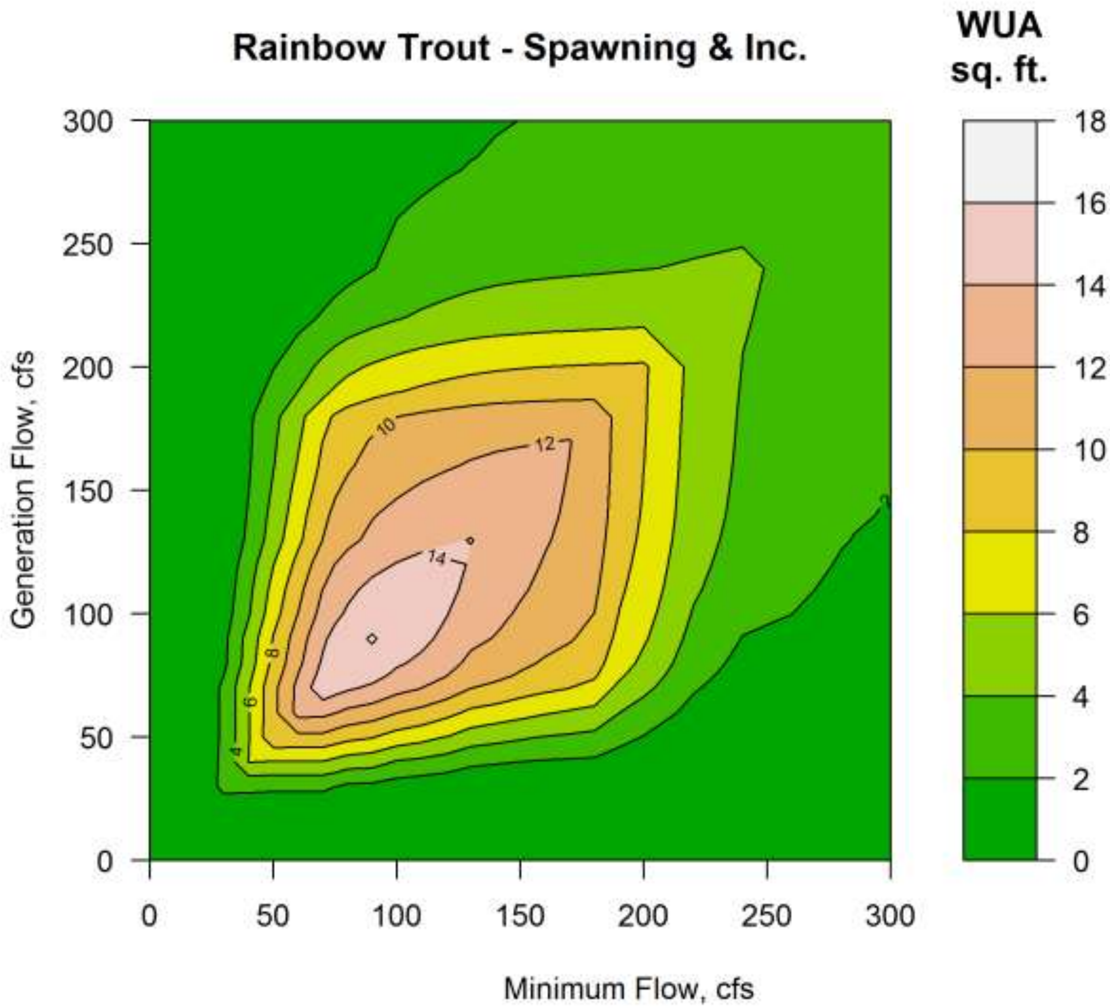


Figure 3.3-4: Rainbow trout spawning and incubation composite dual flow habitat results. WUA results are in terms of square feet of dual flow habitat per linear foot of stream.

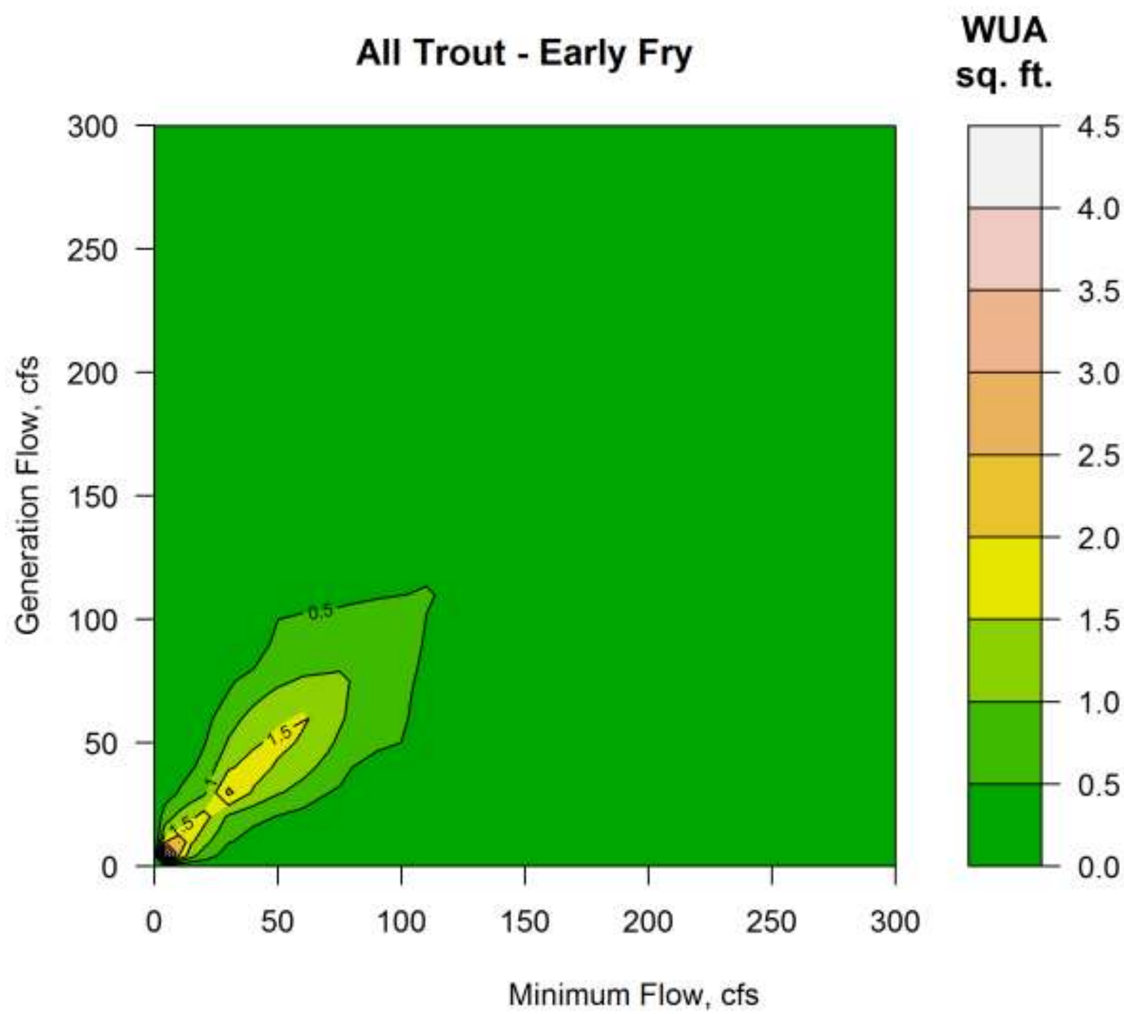


Figure 3.3-5: Rainbow trout early fry composite dual flow habitat results. WUA results are in terms of square feet of dual flow habitat per linear foot of stream.

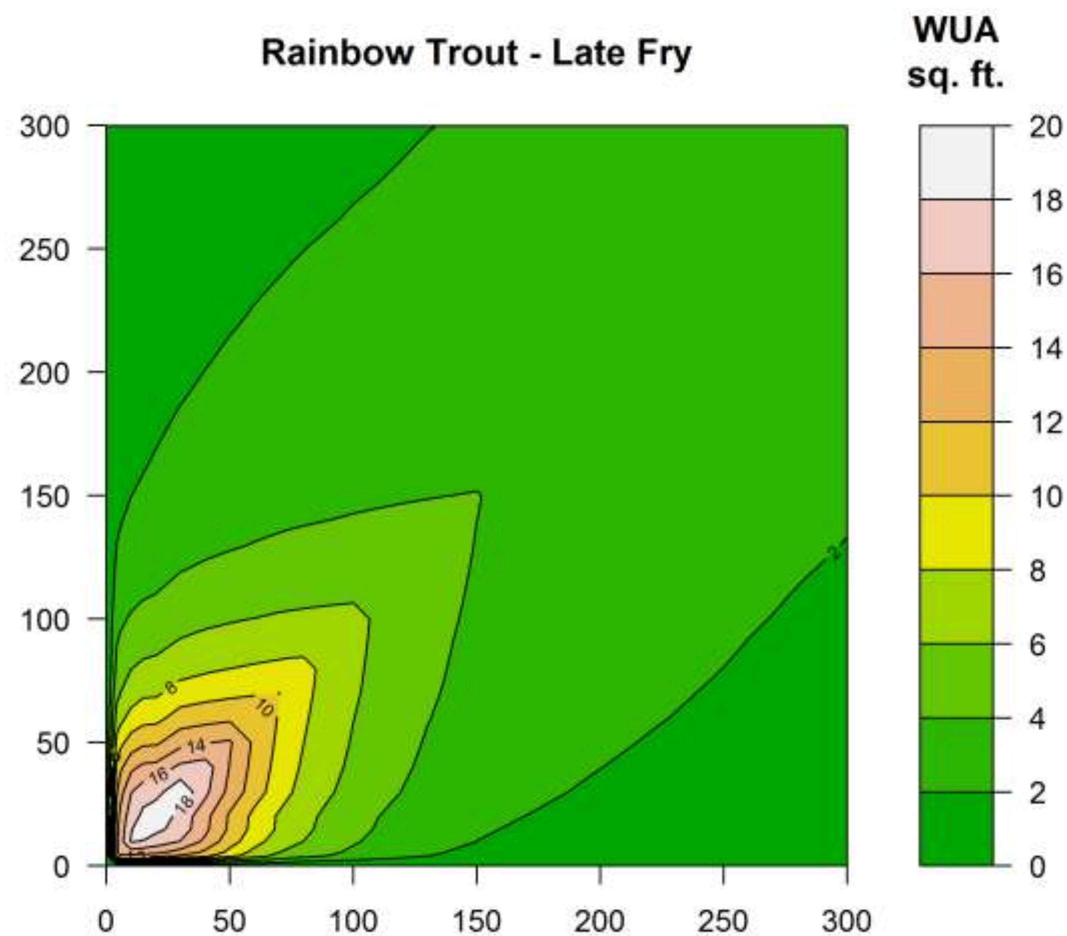


Figure 3.3-6: Rainbow trout late fry composite dual flow habitat results. WUA results are in terms of square feet of dual flow habitat per linear foot of stream.

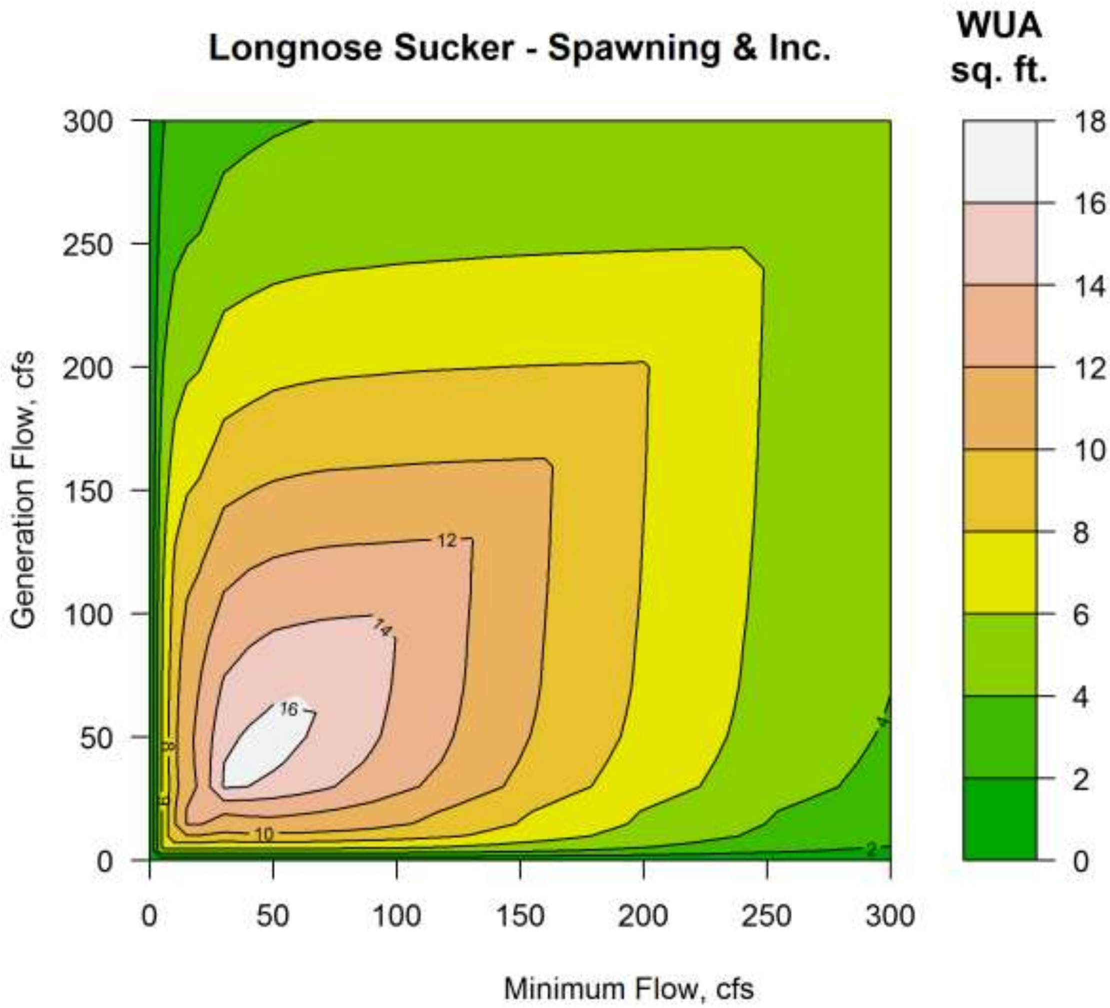


Figure 3.3-7: Longnose sucker spawning and incubation composite dual flow habitat results. WUA results are in terms of square feet of dual flow habitat per linear foot of stream.

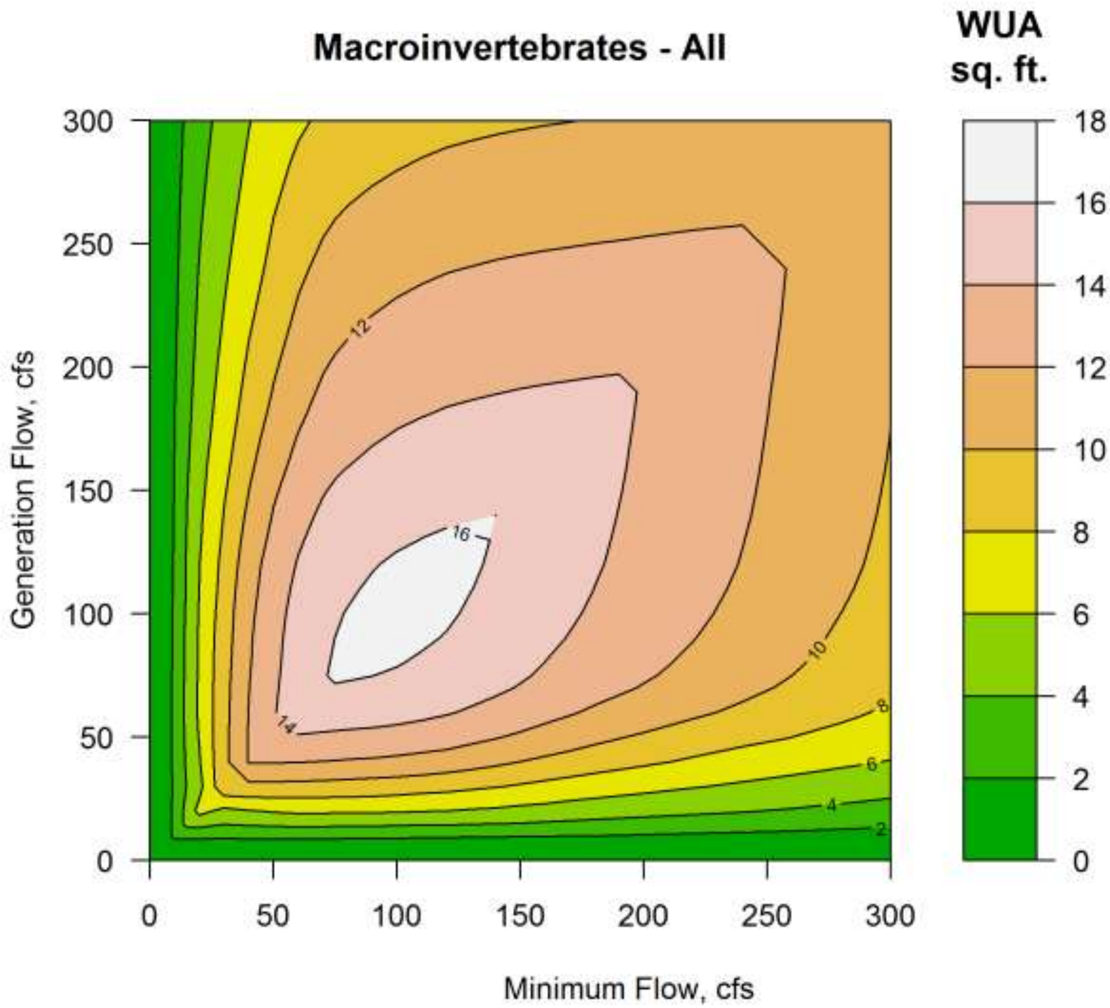


Figure 3.3-7: Macroinvertebrate composite dual flow habitat results. WUA results are in terms of square feet of dual flow habitat per linear foot of stream

4.0 Conclusions

Determining instream flows requires more than choosing the peak WUA flow for one life stage of one species from the IFIM study. No specific flow will provide an optimum flow for all life stages and species, since there are multiple life stages existing simultaneously in a river. Setting instream flows requires ranking the importance of each fish species and life stage. This ranking requires considering long-term management plans for the fishery resources.

The results of this study can be used to draw the following conclusions:

- Overall, spawning and incubation habitat in the Green River is relatively abundant. The individual transect results, however, show that there is considerable variability between the study transects.
- The early fry life stage for all trout species appeared to have limited amounts of habitat. This appears to be related to this life stage's heavy preference for shallow, slower moving waters, which were relatively rare in the Green River.
- The modeled life stages had a wide variety of preferred flow ranges, some of which shared little to no mutual overlap. There was a general split where lower flows were preferable for some species (trout early fry, brook trout spawning and incubation, brook trout juvenile, rainbow trout juvenile) while higher flows were more preferable for others (brook trout adult, rainbow trout spawning and incubation and juvenile and adult, longnose sucker spawning and incubation, macroinvertebrates).
- While there is no historic Green River flow data available, it appears that some of the life stages' flow preferences may be rather high given the watershed's small drainage area (14.6 mi^2 at the Green River Dam). This should be considered when determining any flow recommendations.

Appendix A: Habitat Mapping Data for the Green River

Reach Number	Feature Type	Dominant Substrate	Subdominant Substrate	Average Depth (ft)	Average Velocity (ft)	Velocity Refugia	Approx. Width (ft)	Reach Length (ft)	Max. Depth (ft)	Canopy Cover (%)	Notes
1	Pool	Bedrock	Small Cobble	0.9	0.05	None	18	80		0-25	Dam tailrace pool
2	Riffle	Small Cobble	Gravel	0.3	0.74	None	18	67		0-25	0
3	Riffle	Large Cobble	Small Cobble	0.4	0.54	Few	20	351		0-25	0
4	Run	Small Cobble	Gravel	0.6	0.43	Few	15	49		25-50	0
5	Pool	Small Cobble	Large Cobble	1.3	0.12	Few	25	78		25-50	0
6	Riffle	Small Cobble	Large Cobble	0.3	0.61	Few	35	29		25-50	0
7	Pool	Small Cobble	Large Cobble	1.3	0.12	Few	35	93		25-50	0
8	Riffle	Small Cobble	Large Cobble	0.3	0.61	Few	35	136		25-50	0
9	Run	Small Cobble	Bedrock	0.6	0.38	Few	20	231		25-50	0
10	Pool	Small Cobble		1.3	0.03	Few	25	158		0-25	0
11	Run	Small Cobble		0.5	0.14	Few	25	109		25-50	0
12	Pool	Small Cobble	Large Cobble	1.4	0.12	Few	25-30	126		0-25	0
13	Riffle	Gravel	Small Cobble	0.5	0.99	Few	20	82		0-25	0
14	Pool	Small Cobble	Gravel	1.5	0.16	Few	15	69		0-25	0
15	Riffle	Small Cobble	Gravel	0.3	0.55	None	15	55		0-25	0
16	Pool	Small Cobble	Gravel	1.5	0.09	Few	25	125		0-25	0
17	Run	Small Cobble	Gravel	0.5	0.38	None	8	305		0-25	0
18	Pool	Gravel	Sand	1.4	0.09	Few	20	567		0-25	0
19	Run	Large Cobble	Small Boulder	0.7	0.41	Moderate	35	244		50-75	0
20	Pool	Small Boulder	Small Cobble	1.1	0.16	Few	45	512	10	0-25	0
21	Run	Gravel	Sand	0.7	0.15	Moderate	35	305		25-50	0
22	Shallow Run	Large Cobble	Small Boulder	0.6	1.32	Moderate	18	329		50-75	0
23	Pool	Small Cobble	Gravel	2.5	0.27	Few	35	190		50-75	0
24	Riffle	Large Cobble	Small Cobble	0.3	1.39	Moderate	45	118		0-25	0
25	Pool	Sand	Gravel	1.6	0.08	Few	40	77	3.5	0-25	0
26	Riffle	Small Cobble	Gravel	0.3	1.34	None	20	94		0-25	0

Reach Number	Feature Type	Dominant Substrate	Subdominant Substrate	Average Depth (ft)	Average Velocity (ft)	Velocity Refugia	Approx. Width (ft)	Reach Length (ft)	Max. Depth (ft)	Canopy Cover (%)	Notes
27	Run	Small Cobble	Gravel	0.6	0.17	None	20	69		0-25	0
28	Pool	Gravel		1.5	0.04	Few	25	279	4	0-25	0
29	Riffle	Small Cobble	Gravel	0.5	0.49	Few	15	81		0-25	0
30	Pool	Gravel		1.5	0.04	Few	25	264	4	0-25	0
31	Braided Riffle	Gravel		0.4	2.14	None	7	41		0-25	0
32	Pool	Gravel		1.5	0.04	Few	25	387	4	0-25	0
33	Run	Gravel		0.7	0.86	Few	14	72		0-25	0
34	Pool	Gravel	Sand	1.4	0.30	Few	20	1176	5	0-25	Mid-reach beaver dam
35	Run	Small Cobble	Gravel	0.6	0.59	Few	15-20	66		0-25	0
36	Pool	Sand	Large Cobble	1.7	0.12	Few	25	81	3.1	0-25	0
37	Run	Gravel	Sand	0.6	0.65	Few	20	57		0-25	0
38	Pool	Gravel	Sand	1.7	0.18	None	20	38	2	0-25	0
39	Riffle	Small Cobble	Gravel	0.8	1.85	Few	20	28		0-25	0
40	Pool	Gravel	Sand	1.5	0.01	None	30	415	2	0-25	Small (<10' long) riffle in middle, ecologically insignificant
41	Riffle	Gravel		0.6	0.55	Few	25	41		0-25	0
42	Run	Gravel	Small Cobble	0.7	0.32	Few	20	119		0-25	0
43	Riffle	Small Cobble	Gravel	0.3	0.83	None	20	25		0-25	0
44	Shallow Run	Small Cobble	Gravel	0.5	0.67	Few	250	126		0-25	0
45	Riffle	Gravel	Small Cobble	0.2	0.88	Few	15	75		0-25	0
46	Shallow Run	Small Cobble	Gravel	0.5	1.31	Few	15	213		50-75	0
47	Run	Small Cobble	Gravel	0.7	0.51	Few	20	65		0-25	0
48	Riffle	Small Cobble	Sand	0.5	0.74	Few	15	35		50-75	0
49	Pool	Small Cobble	Sand	1.3	0.13	Few	30	130		0-25	0
50	Riffle	Small Boulder	Large Cobble	0.5	1.47	Few	20	115		50-75	0
51	Pool	Large Cobble	Small Cobble	1.0	0.23	Moderate	30	26		25-50	
52	Riffle	Large Cobble	Small Cobble	0.4	1.57	Few	15-20	26		0-25	0

Reach Number	Feature Type	Dominant Substrate	Subdominant Substrate	Average Depth (ft)	Average Velocity (ft)	Velocity Refugia	Approx. Width (ft)	Reach Length (ft)	Max. Depth (ft)	Canopy Cover (%)	Notes
53	Shallow Run	Large Cobble	Small Cobble	0.6	0.62	Moderate	20	404		25-50	0
54	Riffle	Small Cobble	Gravel	0.4	1.18	Few	12	97		25-50	0
55	Shallow Run	Large Cobble	Small Cobble	0.7	0.55	Few	25	64		0-25	0
56	Steep Riffle	Small Boulder	Large Cobble	0.5	0.58	Few	15-20	92		75-100	0
57	Cascade	Bedrock	Small Boulder	0.5	N/A	Few	6-12	174		75-100	Ends at culvert
58	Culvert	None		N/A	N/A	None	N/A	64		0	6' diameter culvert, perched, corrugated metal
59	Falls	Large Boulder	Large Cobble	N/A	N/A	N/A	20	46		0-25	0
60	Cascade	Large Cobble	Small Boulder	0.6	0.75	Moderate	35	338		50-75	0
61	Step Pools	Gravel	Small Boulder	0.8	1.34	Moderate	25	344		50-75	Short <10' riffles with braids interspersed
62	Run	Large Cobble	Gravel	0.8	0.95	Moderate	15	84		50-75	0
63	Pool	Small Cobble	Gravel	1.6	0.08	Few	25	19		25-50	Splits into falls reach
64	Falls w/ Pools	Bedrock	Large Cobble	0.6	1.66	Moderate	10-30	151	8	25-50	Variable width and braided channels
65	Cascade	Small Boulder	Small Cobble	0.7	0.90	Moderate	15-20	100		75-100	Split channel
66	Step Pools	Large Boulder	Gravel	0.9	0.47	Moderate	12	290		75-100	0
67	Riffle	Small Cobble	Gravel	0.8	0.26	Moderate	15-25	151		75-100	0
68	Pool	Small Cobble	Gravel	1.1	0.33	Few	15-20	85		75-100	0
69	Riffle	Large Cobble	Small Cobble	0.4	1.37	Moderate	15	341		50-75	0
70	Run	Small Boulder	Large Cobble	1.0	0.48	Moderate	10	34		75-100	
71	Pool	Small Cobble	Gravel	1.9	0.16	Few	12	30		75-100	Slight embeddedness
72	Cascade	Large Boulder		1.0	1.67	Few	10-15	70		50-75	0
73	Run	Small Cobble	Gravel	1.2	0.46	Few	15-20	52		25-50	0
74	Riffle	Small Cobble	Gravel	0.6	1.61	Moderate	15	327		50-75	0
75	Deep Run	Small Boulder	Bedrock	2.0	1.32	Few	15	62		50-75	3-4' falls at end of reach (Jud - seasonal barrier, Tom - full barrier)

Reach Number	Feature Type	Dominant Substrate	Subdominant Substrate	Average Depth (ft)	Average Velocity (ft)	Velocity Refugia	Approx. Width (ft)	Reach Length (ft)	Max. Depth (ft)	Canopy Cover (%)	Notes
76	Run	Large Cobble	Small Cobble	1.0	0.44	Few	20	20		50-75	Small deep (>4') side pool
77	Run	Small Boulder	Bedrock	2.0	1.32	Few	15	60		50-75	0
78	Riffle	Small Cobble	Gravel	0.7	1.32	Few	15-20	189		75-100	0
79	Run	Small Cobble	Gravel	1.0	0.84	Few	18-20	167		75-100	Some embeddedness
80	Cascade	Large Boulder	Small Cobble	N/A	N/A	Moderate	15	43		50-75	0
81	Pool	Gravel	Sand	2.3	0.01	Few	30	100	6	25-50	0
82	Riffle	Small Cobble	Gravel	0.7	1.37	Few	15	200		0-25	Split channel
83	Pool	Gravel	Large Cobble	1.5	0.36	Few	30-35	67	5	0-25	0
84	Run	Large Cobble	Small Cobble	0.9	0.89	Few	20	181		0-25	0
85	Pool	Gravel	Sand	2.0	0.01	Few	20	105		0-25	0
86	Riffle	Gravel	Small Cobble	0.7	1.01	Few	18-20	378		0-25	0
87	Debris Jam Riffle	Small Cobble	Gravel	0.8	1.66	Many	10, 2 channels	208		0-25	Braided b/c of debris jam
88	Pool	Small Cobble	Gravel	1.3	0.67	None	20-25	341		0-25	0
89	Riffle	Small Cobble	Gravel	0.6	0.75	Few	25	83		0-25	0
90	Pool	Gravel	Small Cobble	0.9	0.41	Few	20	165		0-25	Observed 6" brook trout
91	Debris Jam Riffle	Gravel	Sand	0.6	2.11	Many	10, 2 channels	79		0-25	Split channel
92	Run	Gravel	Small Cobble	0.9	0.73	None	15-18	77		0-25	0
93	Riffle	Small Cobble	Gravel	0.6	2.08	None	10-15	57		0-25	0
94	Run	Gravel	Small Cobble	1.0	0.51	Few	15-20	126		25-50	0
95	Riffle	Small Cobble	Gravel	0.8	1.03	Few	15-20	132		0-25	0
96	Run	Small Cobble	Gravel	1.2	1.03	Few	15-25	276		0-25	0
97	Pool	Small Cobble	Sand	1.7	0.50	Moderate	20	96		25-50	0
98	Run	Gravel	Small Cobble	1.5	0.69	Moderate	20-25	223		0-25	0
99	Riffle	Small Cobble	Gravel	0.7	2.04	Moderate	20-25	199		25-50	0
100	Run	Gravel	Small Cobble	1.4	0.79	Few	25	219		50-75	0

Reach Number	Feature Type	Dominant Substrate	Subdominant Substrate	Average Depth (ft)	Average Velocity (ft)	Velocity Refugia	Approx. Width (ft)	Reach Length (ft)	Max. Depth (ft)	Canopy Cover (%)	Notes
101	Riffle	Small Boulder	Gravel	0.9	0.99	Moderate	25	615		0-25	Debris jams
102	Riffle	Small Cobble	Gravel	0.5	1.39	Few	30	99		25-50	0
103	Deep Run	Small Cobble	Gravel	1.3	0.67	Few	30	272		0-25	
104	Riffle	Gravel	Small Cobble	0.4	1.03	Moderate	35	324		50-75	0
105	Falls	Bedrock		N/A	N/A	N/A	N/A	95		50-75	Variable width, full passage barrier
106	Pool	Bedrock	Gravel	1.6	0.60	Moderate	50	81		25-50	0
107	Run	Small Cobble	Gravel	1.0	0.84	Moderate	30	88		25-50	0
108	Riffle	Large Cobble	Gravel	0.5	2.03	Few	25	157		50-75	0
109	Riffle	Small Boulder	Small Cobble	0.7	1.25	Many	25	149		25-50	
110	Step Pools	Large Cobble	Gravel	0.8	1.08	Moderate	25	72		50-75	0
111	Pool	Gravel		1.1	1.20	Few	30	50	4	0-25	0
112	Riffle	Small Boulder	Small Cobble	0.7	1.25	Many	25	362		25-50	0
113	Falls/Cascade	Bedrock		N/A	N/A	N/A	25-40	395		25-50	20' falls, with 10-20' deep plunge pool, with a second 10' falls
114	Step Pools	Gravel	Large Boulders	N/A	N/A	Moderate	25	285		50-75	0
115	Cascade	Bedrock		N/A	N/A	N/A	N/A	320		25-50	Several seasonal barriers throughout reach
116	Riffle	Large Cobble	Small Cobble	0.6	1.90	Moderate	30	424		25-50	0
117	Pool	Large Cobble	Gravel	2.7	0.17	Few	35	61	4	0-25	0
118	Riffle	Large Cobble	Small Cobble	0.6	1.90	Moderate	30	204		25-50	0
119	Run	Bedrock	Large Cobble	1.1	1.09	Few	25	631		25-50	0
120	Riffle	Large Cobble	Small Cobble	0.6	1.9	Moderate	30	261		25-50	0
121	Cascade	Bedrock		N/A	N/A	Moderate	15-35	694		50-75	15' falls in middle, full passage barrier
122	Pool	Bedrock	Gravel	1.9	0.15	Few	35	226		75-100	0

Reach Number	Feature Type	Dominant Substrate	Subdominant Substrate	Average Depth (ft)	Average Velocity (ft)	Velocity Refugia	Approx. Width (ft)	Reach Length (ft)	Max. Depth (ft)	Canopy Cover (%)	Notes
123	Run	Large Cobble	Gravel	0.4	0.85	Few	30	150		25-50	0
124	Riffle	Small Cobble	Gravel	0.7	0.85	Moderate	35	299		25-50	0
125	Cascade	Bedrock		N/A	N/A	Moderate	25-35	142		25-50	0
126	Step Pools	Large Boulder	Small Cobble	N/A	N/A	Moderate	30	518		25-50	0
127	Pool	Gravel	Small Cobble	1.9	0.58	Few	25	110		0-25	0
128	Cascade	Bedrock	Gravel	N/A	N/A	Moderate	40	401		25-50	0
129	Steep Riffle	Bedrock	Gravel	1.0	1.00	Few	30	254		50-75	0
130	Riffle	Bedrock	Gravel	0.7	1.59	Few	35-40	600		25-50	0
131	Riffle	Small Boulder	Gravel	0.7	1.73	Moderate	40	645		0-25	0
132	Run	Large Cobble	Gravel	1.0	1.45	Few	35	92		25-50	0
133	Riffle	Small Cobble	Gravel	0.6	2.37	Few	35-40	221		25-50	0
134	Riffle	Small Cobble	Gravel	0.5	1.61	Few	35	221		0-25	0
135	Pool	Small Cobble	Gravel	2.7	0.48	Few	30	60		0-25	0
136	Riffle	Small Cobble	Gravel	0.5	1.56	Few	35	229		0-25	0

Appendix B: Green River Habitat Transect Photographs

Transect 1 at approximately 10 cfs, looking upstream from the left bank.

Transect 2 at approximately 10 cfs, looking upstream from the center of the river.

Transect 3 at approximately 10 cfs, looking upstream from the center of the river.

Transect 4 at approximately 10 cfs, looking upstream from the center of the river.

Transect 5 at approximately 10 cfs, looking downstream from the left bank.

Transect 6 at approximately 10 cfs, looking downstream from left bank.

Transect 7 at approximately 10 cfs, looking downstream.

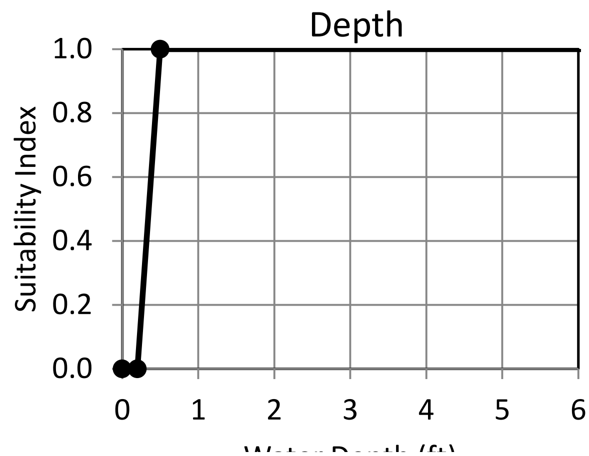
Transect 8 at approximately 10 cfs, looking upstream at the right channel from the center of the river.

Transect 9 at approximately 10 cfs, looking upstream from the left bank.

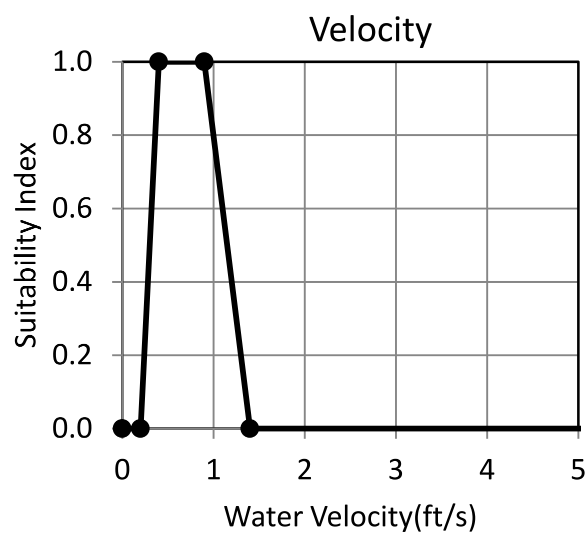
Appendix C: Habitat Suitability Index Curves

Brook/brown trout spawning and incubation HSI curves

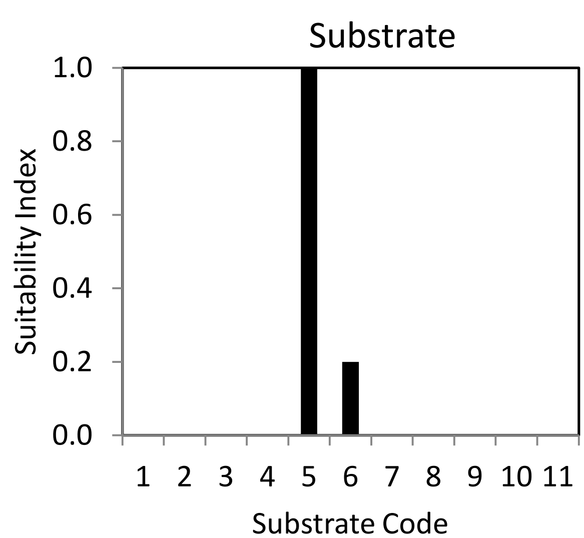
Depth (ft/s)	SI
0	0
0.2	0
0.5	1
100	1



Velocity (ft/s)	SI
0	0
0.2	0
0.4	1
0.9	1
1.4	0
100	0

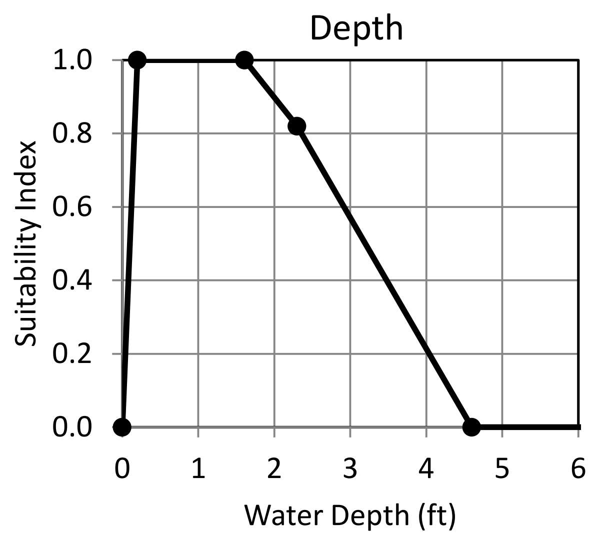


Substrate	Code	SI
Roots, snags, banks, etc.	1	0.0
Clay	2	0.0
Silt	3	0.0
Sand	4	0.0
Small Gravel (<2")	5	1.0
Gravel (2"-4")	6	0.2
Cobble (4"-10")	7	0.0
Small Boulder(10"-2')	8	0.0
Large Boulder (>2')	9	0.0
Ledge/Bedrock	10	0.0
Detritus/vegetation	11	0.0

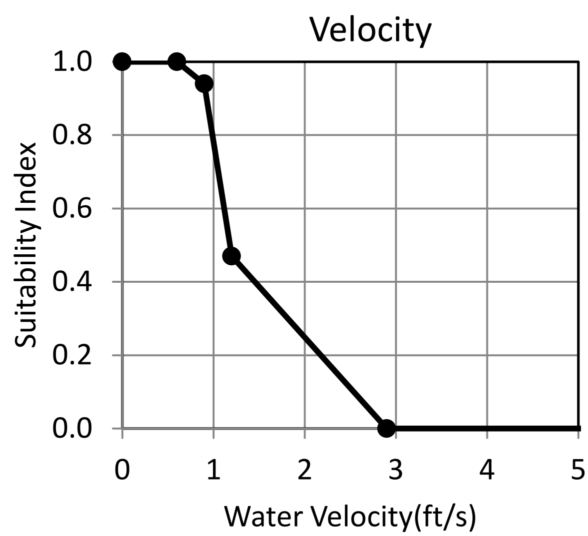


Brook/brown trout late fry HSI curves

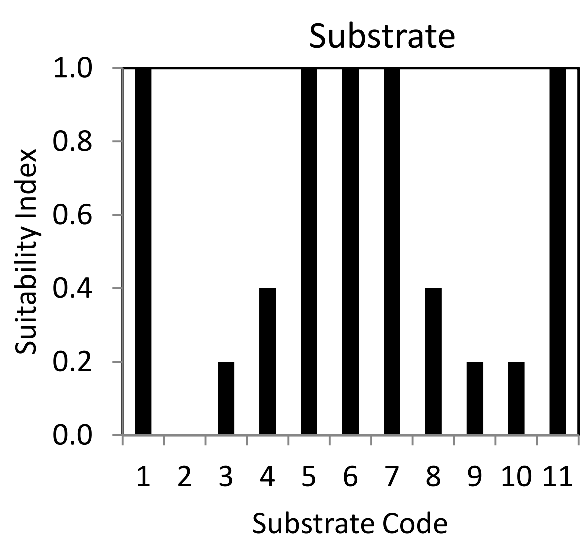
Depth (ft/s)	SI
0	0
0.2	1
1.61	1
2.3	0.82
4.6	0
100	0



Velocity (ft/s)	SI
0	1
0.6	1
0.9	0.94
1.2	0.47
2.9	0
100	0

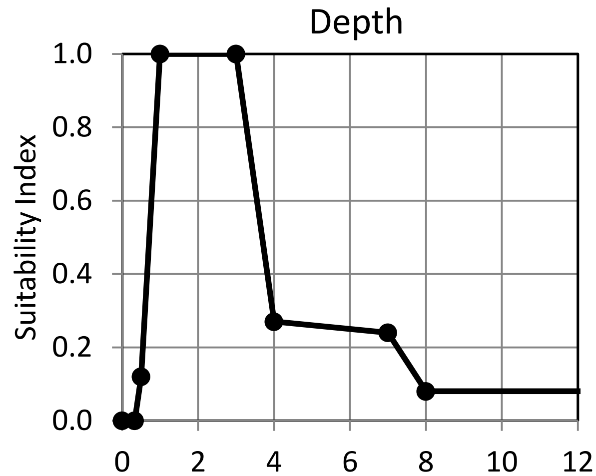


Substrate	Code	SI
Roots, snags, banks, etc.	1	1
Clay	2	0
Silt	3	0.2
Sand	4	0.4
Small Gravel (<2")	5	1
Gravel (2"-4")	6	1
Cobble (4"-10")	7	1
Small Boulder(10"-2')	8	0.4
Large Boulder (>2')	9	0.2
Ledge/Bedrock	10	0.2
Detritus/vegetation	11	1

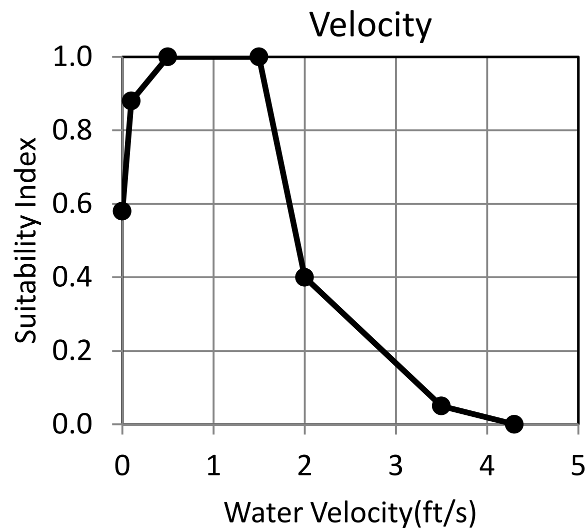


Brook/brown trout juvenile HSI curves

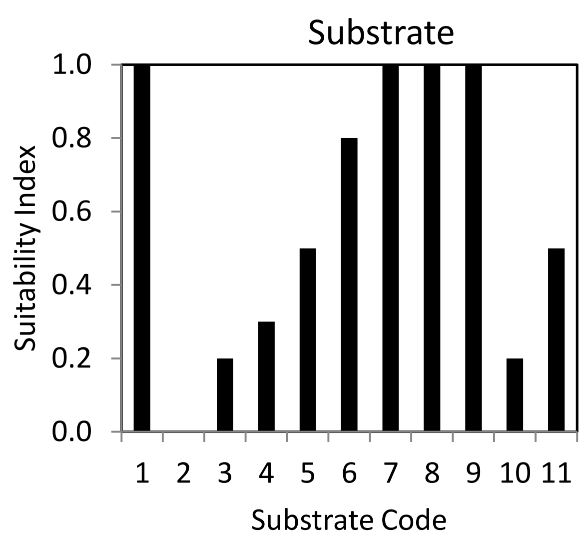
Depth (ft/s)	SI
0.00	0.00
0.33	0.00
0.50	0.12
1.00	1.00
3.00	1.00
4.00	0.27
7.00	0.24
8.00	0.08
100.00	0.08



Velocity (ft/s)	SI
0	0.58
0.1	0.88
0.5	1
1.5	1
2	0.4
3.5	0.05
4.3	0

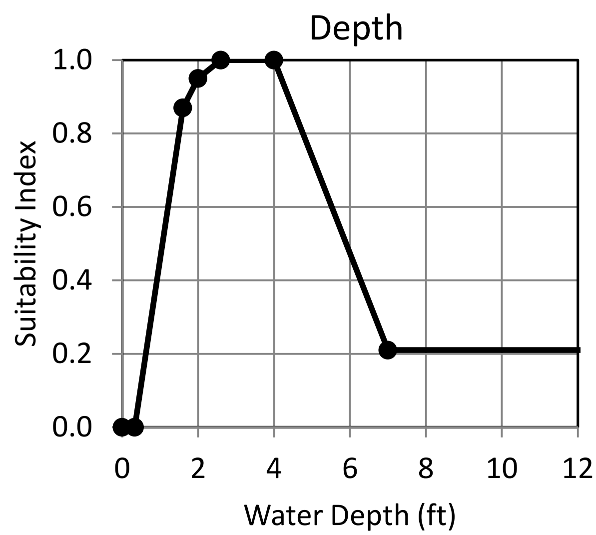


Substrate	Code	SI
Roots, snags, banks, etc.	1	1
Clay	2	0
Silt	3	0.2
Sand	4	0.3
Small Gravel (<2")	5	0.5
Gravel (2"-4")	6	0.8
Cobble (4"-10")	7	1
Small Boulder(10"-2')	8	1
Large Boulder (>2')	9	1
Ledge/Bedrock	10	0.2
Detritus/vegetation	11	0.5

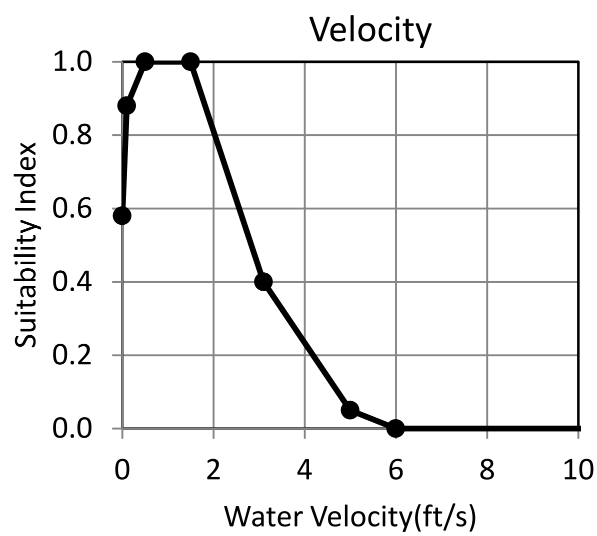


Brook/brown trout adult HSI curves

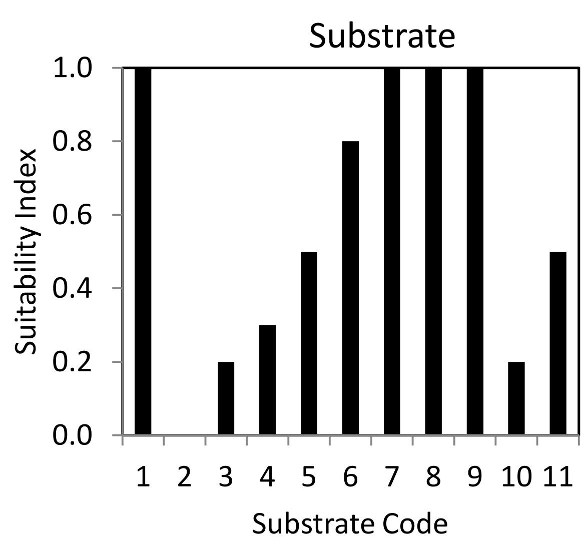
Depth (ft/s)	SI
0	0.00
0.33	0.00
1.6	0.87
2	0.95
2.6	1.00
4	1.00
7	0.21
100	0.21



Velocity (ft/s)	SI
0	0.58
0.1	0.88
0.5	1.00
1.5	1.00
3.1	0.40
5	0.05
6	0.00
100	0.00

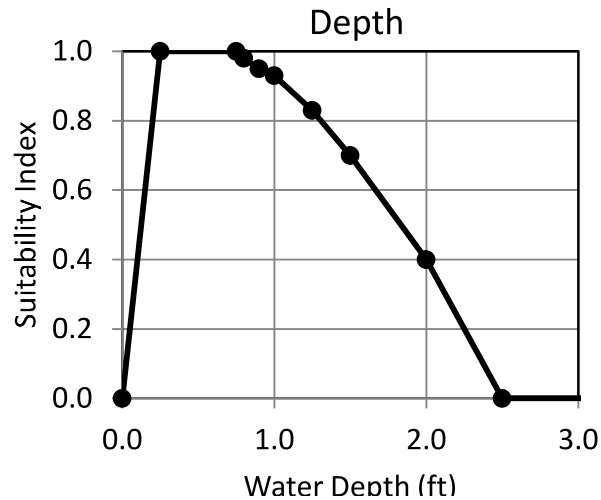


Substrate	Code	SI
Roots, snags, banks, etc.	1	1.00
Clay	2	0.00
Silt	3	0.20
Sand	4	0.30
Small Gravel (<2")	5	0.50
Gravel (2"-4")	6	0.80
Cobble (4"-10")	7	1.00
Small Boulder(10"-2')	8	1.00
Large Boulder (>2')	9	1.00
Ledge/Bedrock	10	0.20
Detritus/vegetation	11	0.50

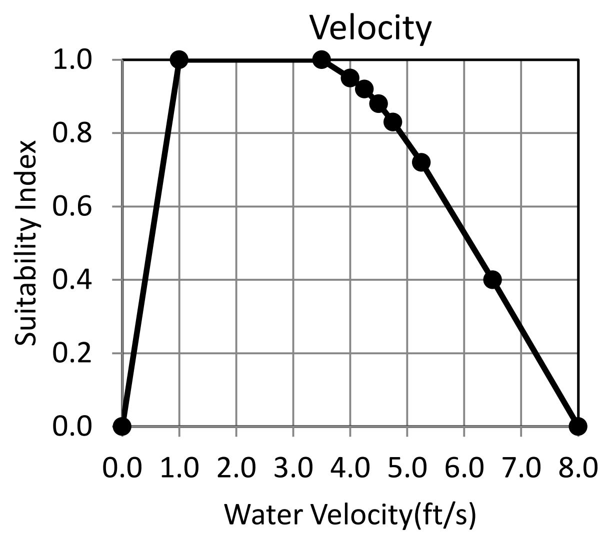


Longnose Sucker spawning and incubation HSI curves

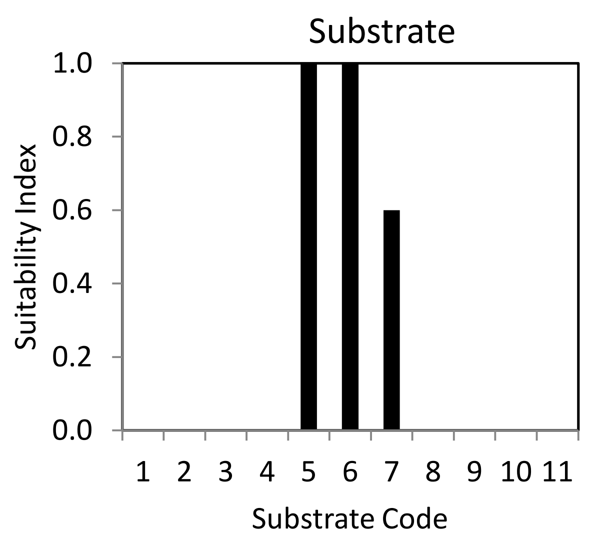
Depth (ft/s)	SI
0	0.00
0.25	1.00
0.75	1.00
0.8	0.98
0.9	0.95
1	0.93
1.25	0.83
1.5	0.70
2	0.40
2.5	0.00
100	0.00



Velocity (ft/s)	SI
0	0
1	1
3.5	1
4	0.95
4.25	0.92
4.5	0.88
4.75	0.83
5.25	0.72
6.5	0.4
8	0
100	0

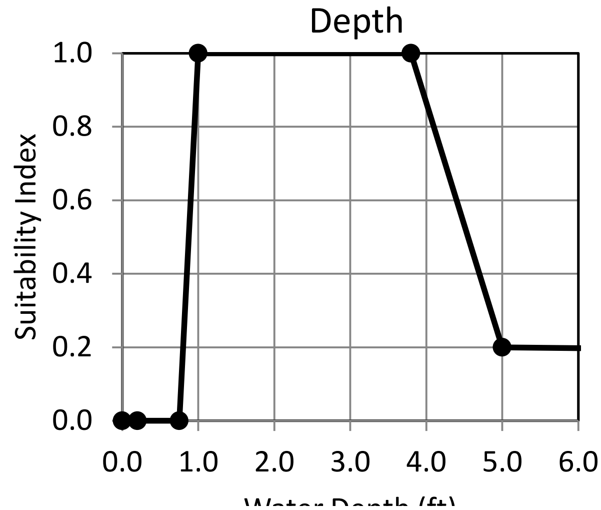


Substrate	Code	SI
Roots, snags, banks, etc.	1	0
Clay	2	0
Silt	3	0
Sand	4	0
Small Gravel (<2")	5	1
Gravel (2"-4")	6	1
Cobble (4"-10")	7	0.6
Small Boulder(10"-2')	8	0
Large Boulder (>2')	9	0
Ledge/Bedrock	10	0
Detritus/vegetation	11	0

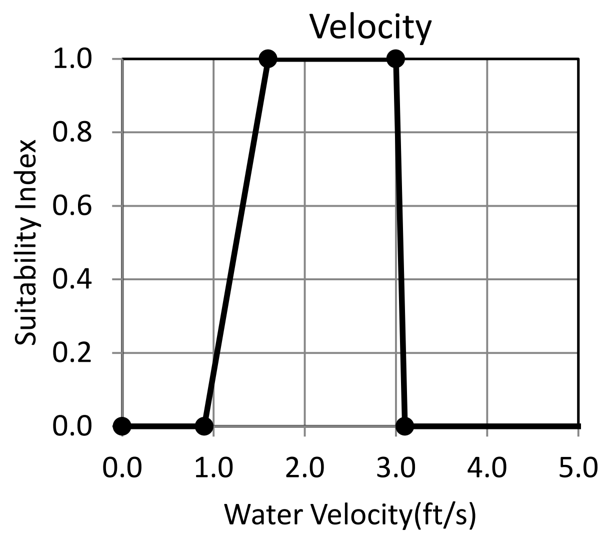


Rainbow trout spawning and incubation HSI curves

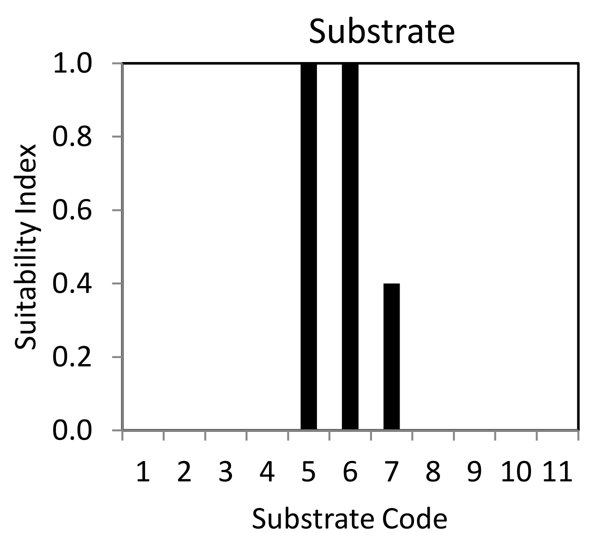
Depth (ft/s)	SI
0	0.0
0.2	0.0
0.75	0.0
1	1.0
3.8	1.0
5	0.2
100	0.0



Velocity (ft/s)	SI
0	0
0.9	0
1.6	1
3	1
3.1	0
100	0

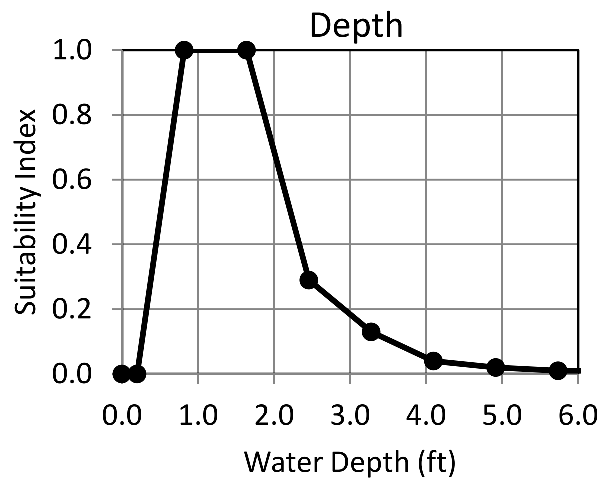


Substrate	Code	SI
Roots, snags, banks, etc.	1	0
Clay	2	0
Silt	3	0
Sand	4	0
Small Gravel (<2")	5	1
Gravel (2"-4")	6	1
Cobble (4"-10")	7	0.4
Small Boulder(10"-2')	8	0
Large Boulder (>2')	9	0
Ledge/Bedrock	10	0
Detritus/vegetation	11	0

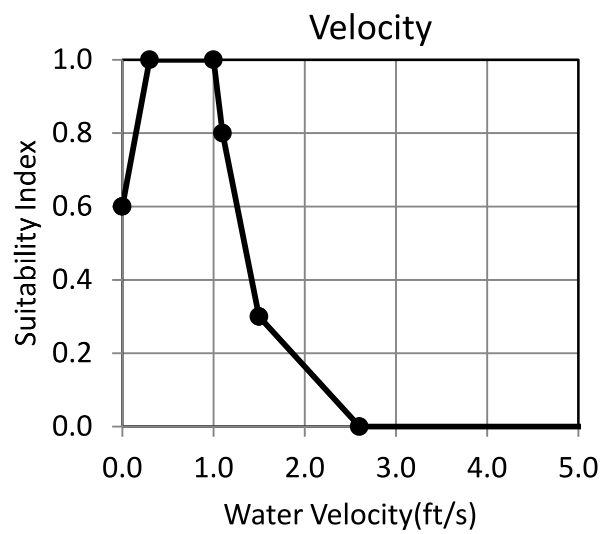


Rainbow trout late fry HSI curve

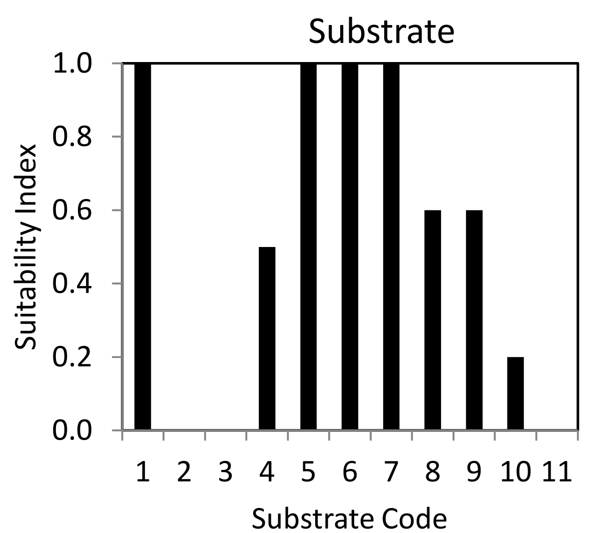
Depth (ft/s)	SI
0	0
0.2	0
0.82	1
1.64	1
2.46	0.29
3.28	0.13
4.1	0.04
4.92	0.02
5.74	0.01
7.38	0.01
8.2	0
100	0



Velocity (ft/s)	SI
0	0.6
0.3	1
1	1
1.1	0.8
1.5	0.3
2.6	0
100	0

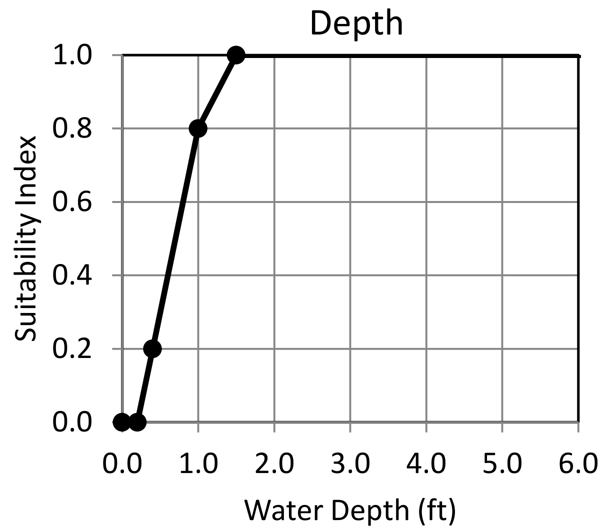


Substrate	Code	SI
Roots, snags, banks, etc.	1	1.0
Clay	2	0.0
Silt	3	0.0
Sand	4	0.5
Small Gravel (<2")	5	1.0
Gravel (2"-4")	6	1.0
Cobble (4"-10")	7	1.0
Small Boulder(10"-2')	8	0.6
Large Boulder (>2')	9	0.6
Ledge/Bedrock	10	0.2
Detritus/vegetation	11	0.0

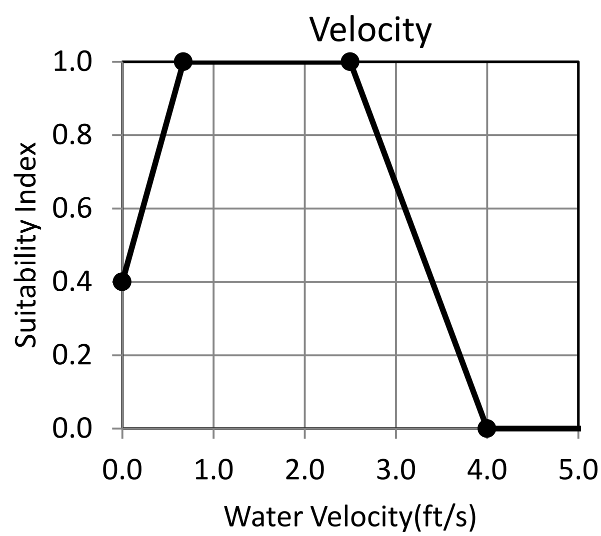


Rainbow trout juvenile HSI curves

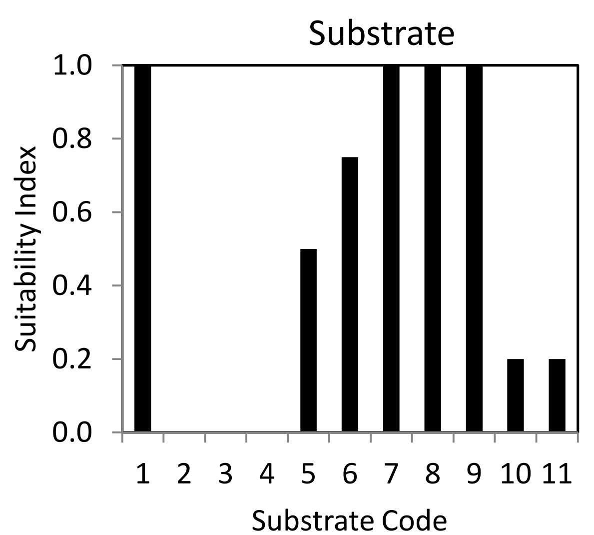
Depth (ft/s)	SI
0	0.00
0.2	0.00
0.4	0.20
1	0.80
1.5	1.00
100	1.00



Velocity (ft/s)	SI
0	0.40
0.67	1.00
2.5	1.00
4	0.00
100	0.00

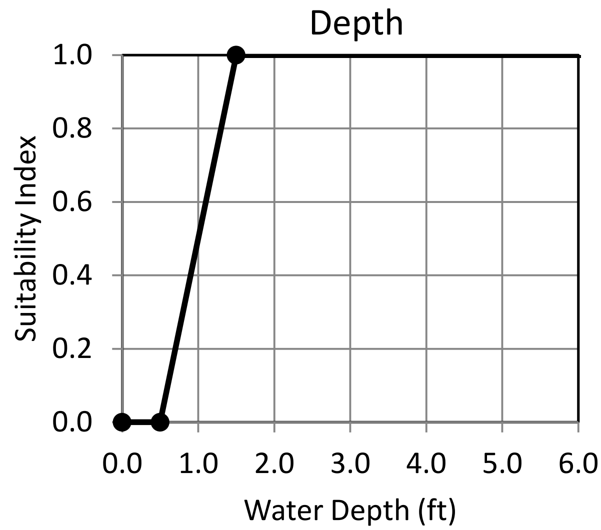


Substrate	Code	SI
Roots, snags, banks, etc.	1	1.00
Clay	2	0.00
Silt	3	0.00
Sand	4	0.00
Small Gravel (<2")	5	0.50
Gravel (2"-4")	6	0.75
Cobble (4"-10")	7	1.00
Small Boulder(10"-2')	8	1.00
Large Boulder (>2')	9	1.00
Ledge/Bedrock	10	0.20
Detritus/vegetation	11	0.20

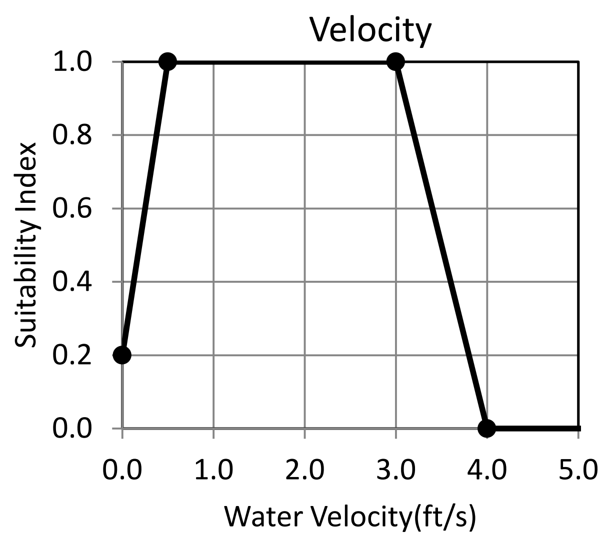


Rainbow trout adult HSI curves

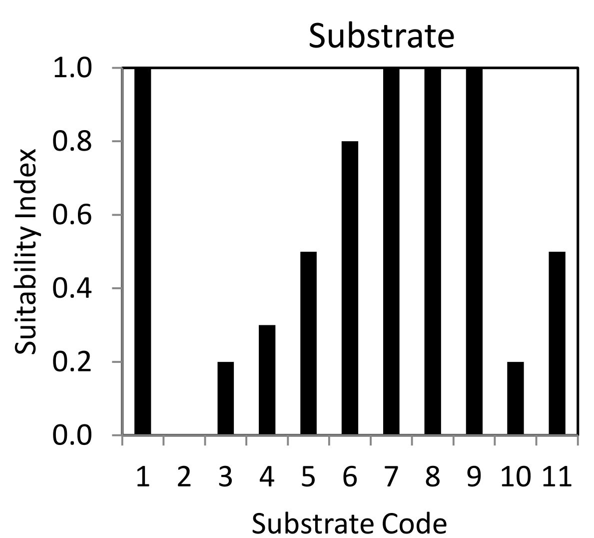
Depth (ft/s)	SI
0.00	0.00
0.50	0.00
1.50	1.00
100.00	1.00



Velocity (ft/s)	SI
0.00	0.20
0.50	1.00
3.00	1.00
4.00	0.00
100.00	0.00

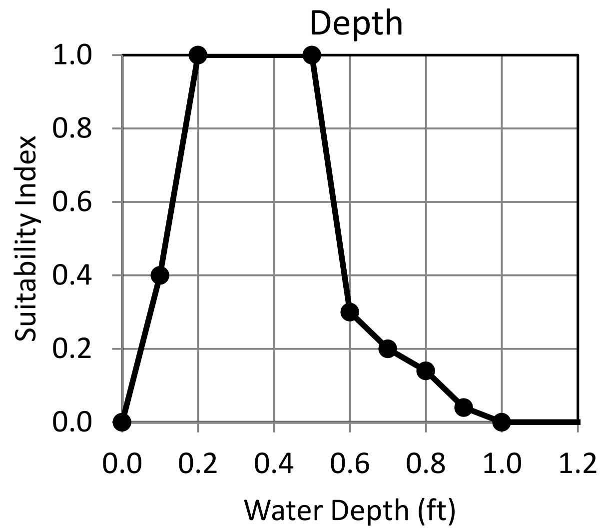


Substrate	Code	SI
Roots, snags, banks, etc.	1	1.00
Clay	2	0.00
Silt	3	0.20
Sand	4	0.30
Small Gravel (<2")	5	0.50
Gravel (2"-4")	6	0.80
Cobble (4"-10")	7	1.00
Small Boulder(10"-2')	8	1.00
Large Boulder (>2')	9	1.00
Ledge/Bedrock	10	0.20
Detritus/vegetation	11	0.50

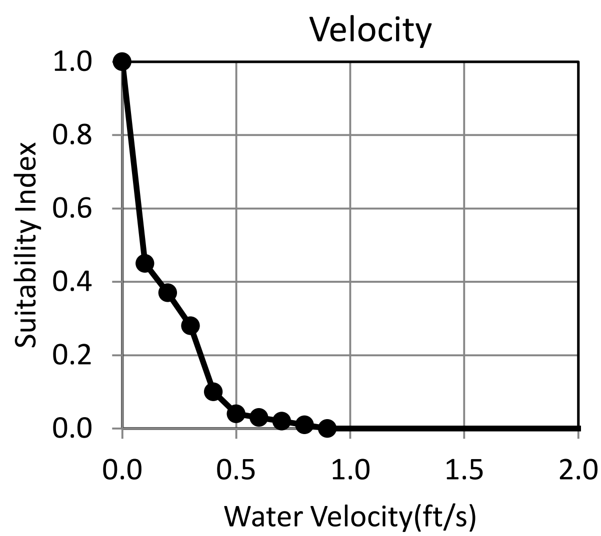


All Trout – Early Fry Life Stage HSI

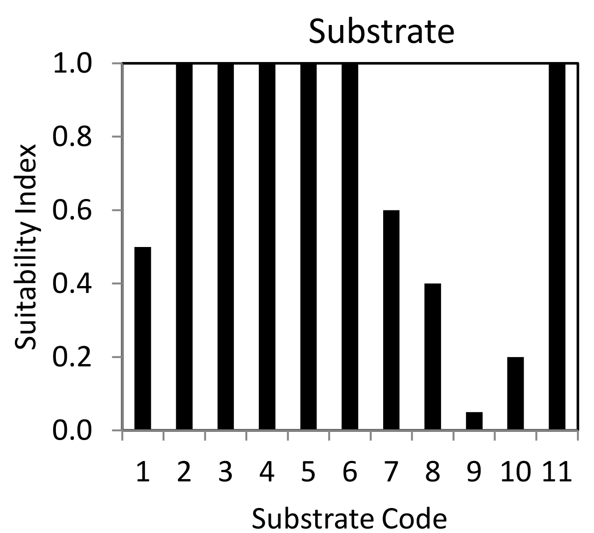
Depth (ft/s)	SI
0	0.00
0.1	0.40
0.2	1.00
0.5	1.00
0.6	0.30
0.7	0.20
0.8	0.14
0.9	0.04
1	0.00
100	0.00



Velocity (ft/s)	SI
0	1.00
0.1	0.45
0.2	0.37
0.3	0.28
0.4	0.10
0.5	0.04
0.6	0.03
0.7	0.02
0.8	0.01
0.9	0.00
100	0.00

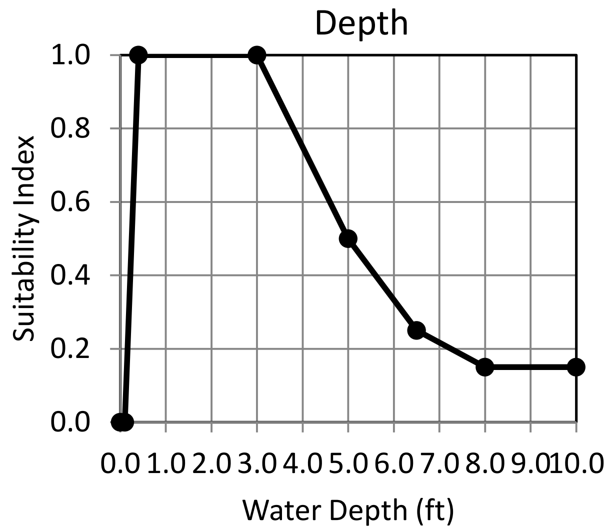


Substrate	Code	SI
Roots, snags, banks, etc.	1	0.5
Clay	2	1
Silt	3	1
Sand	4	1
Small Gravel (<2")	5	1
Gravel (2"-4")	6	1
Cobble (4"-10")	7	0.6
Small Boulder(10"-2')	8	0.4
Large Boulder (>2')	9	0.05
Ledge/Bedrock	10	0.2
Detritus/vegetation	11	1

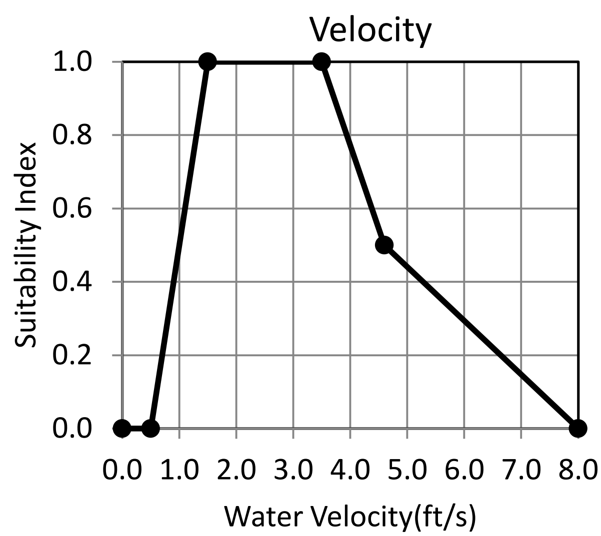


Macroinvertebrate HSI curves

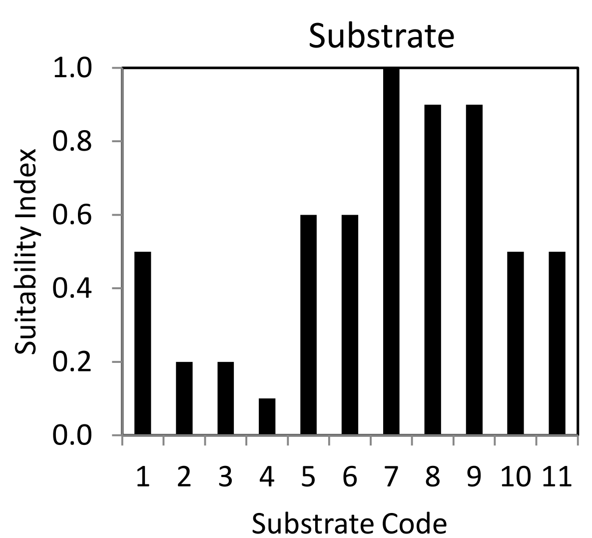
Depth (ft/s)	SI
0.00	0.00
0.10	0.00
0.40	1.00
3.00	1.00
5.00	0.50
6.50	0.25
8.00	0.15
10.00	0.15
100.00	0.00



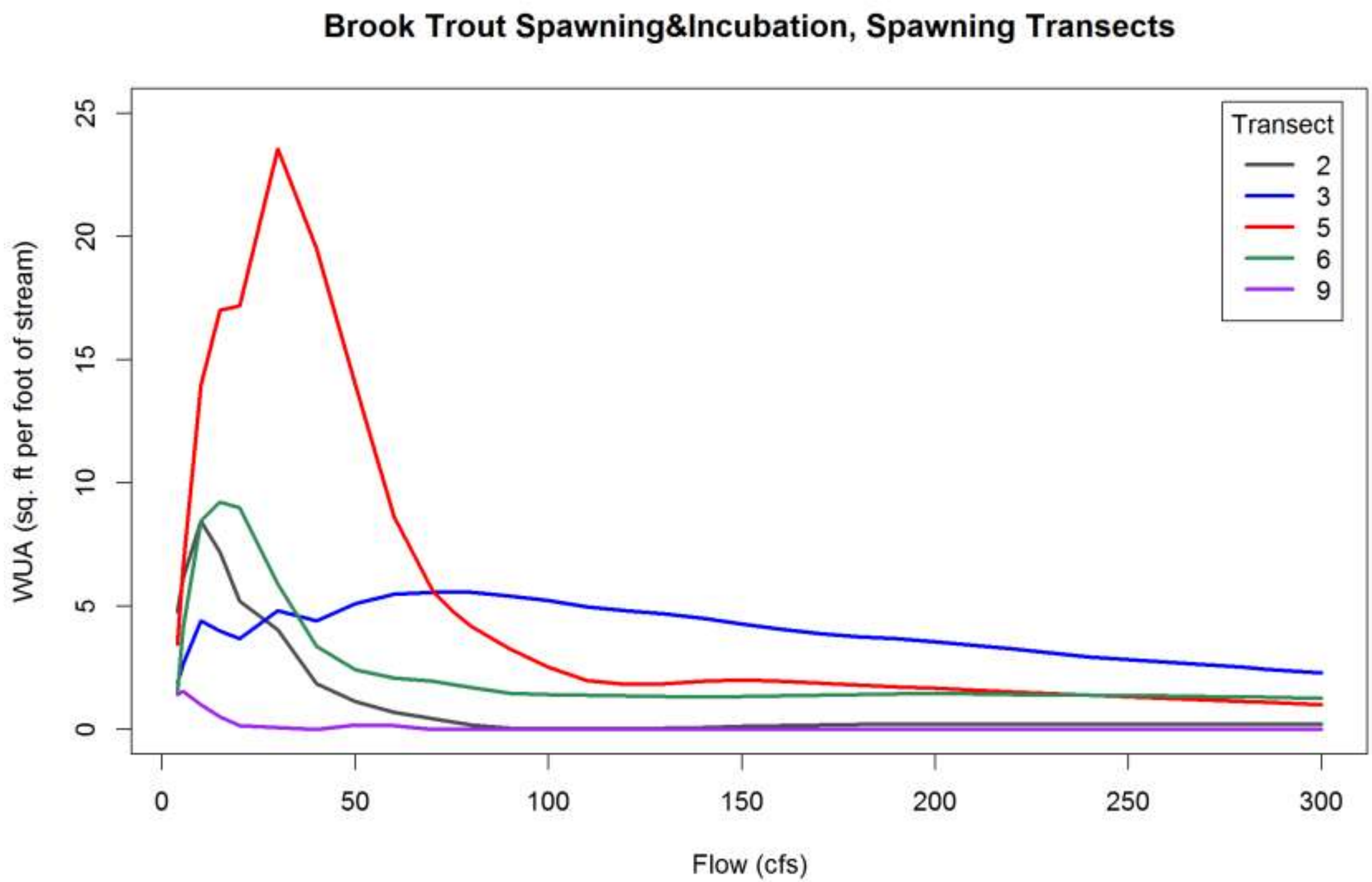
Velocity (ft/s)	SI
0.00	0.00
0.50	0.00
1.50	1.00
3.50	1.00
4.60	0.50
8.00	0.00
100.00	0.00

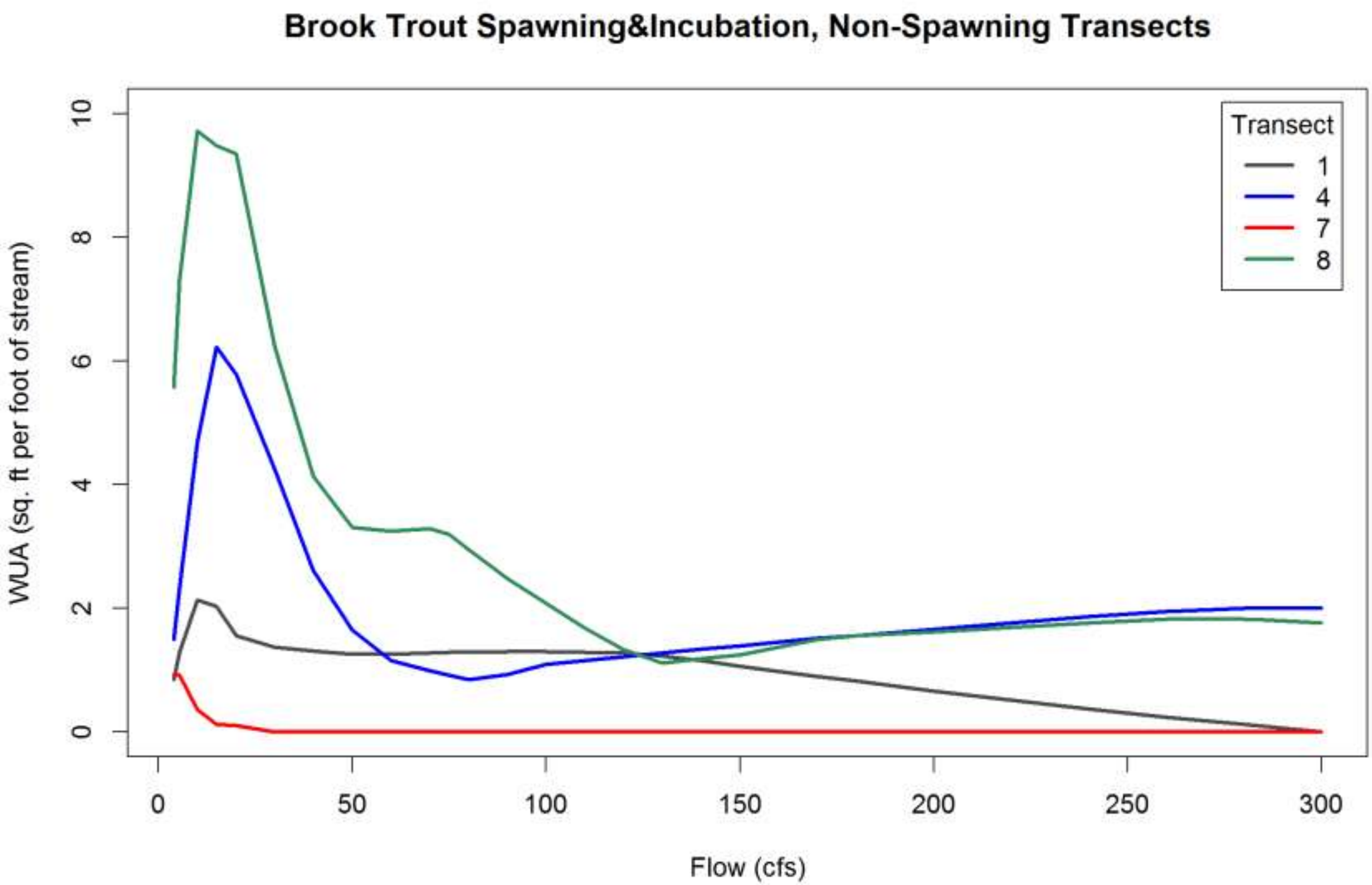


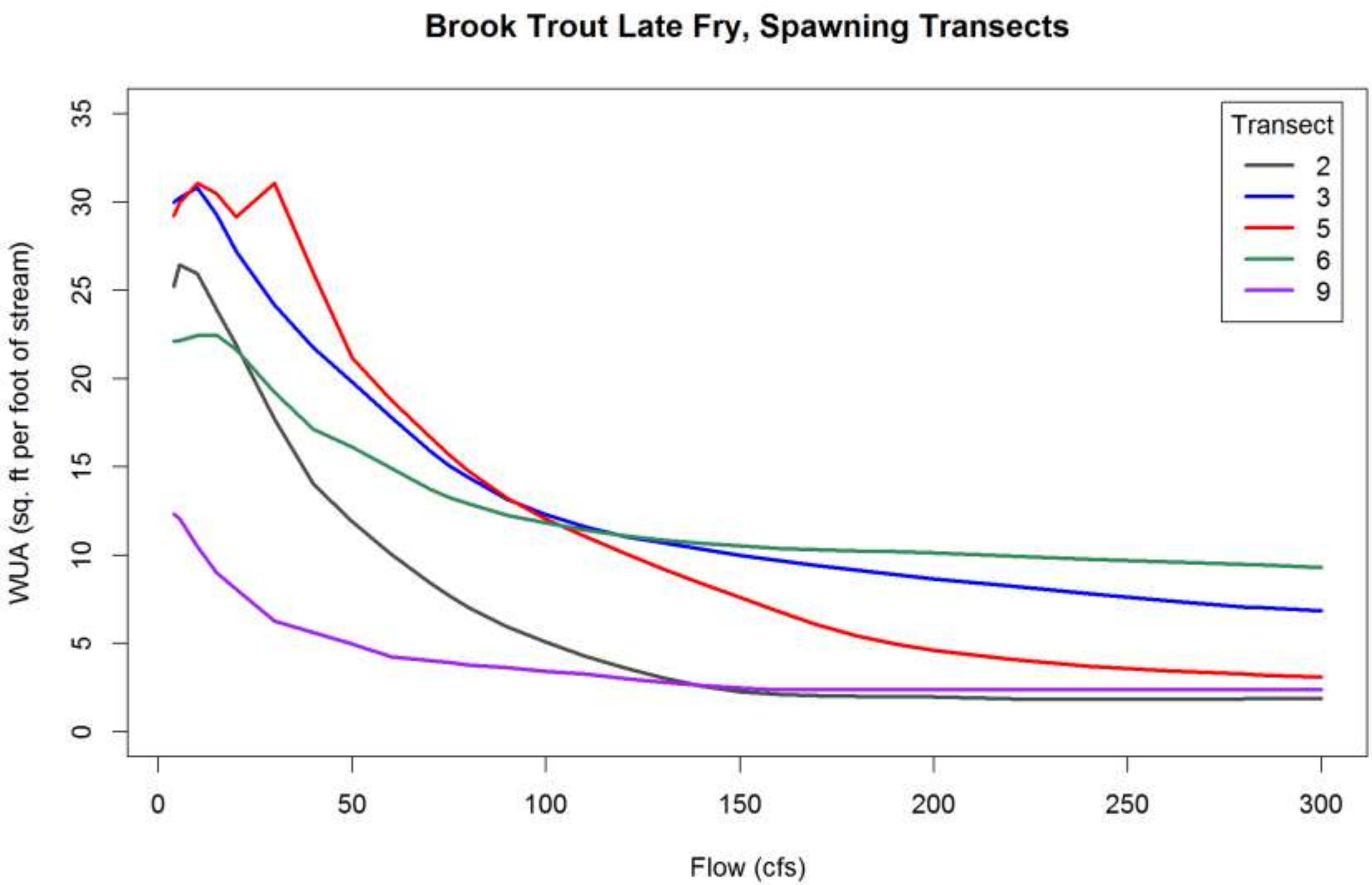
Substrate	Code	SI
Roots, snags, banks, etc.	1	0.50
Clay	2	0.20
Silt	3	0.20
Sand	4	0.10
Small Gravel (<2")	5	0.60
Gravel (2"-4")	6	0.60
Cobble (4"-10")	7	1.00
Small Boulder(10"-2')	8	0.90
Large Boulder (>2')	9	0.90
Ledge/Bedrock	10	0.50
Detritus/vegetation	11	0.50



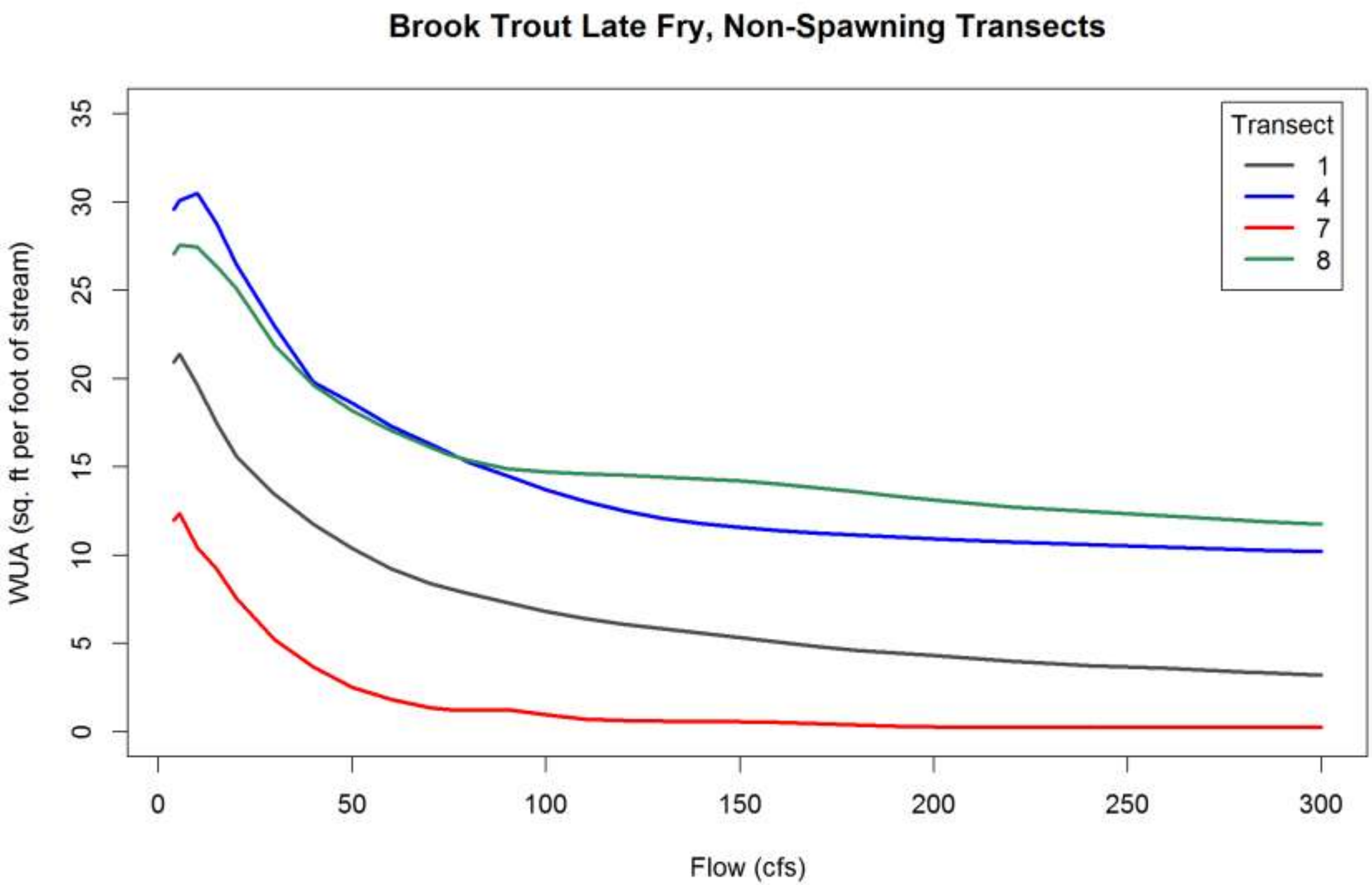
Appendix D: WUA vs flow curves for all modeled transects and target species/life stages


Brook Trout Spawning&Incubation, Spawning Transects
Transect
2
3
5
6
9
WUA (sq. ft per foot of stream)
0
5
10
15
20
25
0
50
100
150
200
250
300
Flow (cfs)

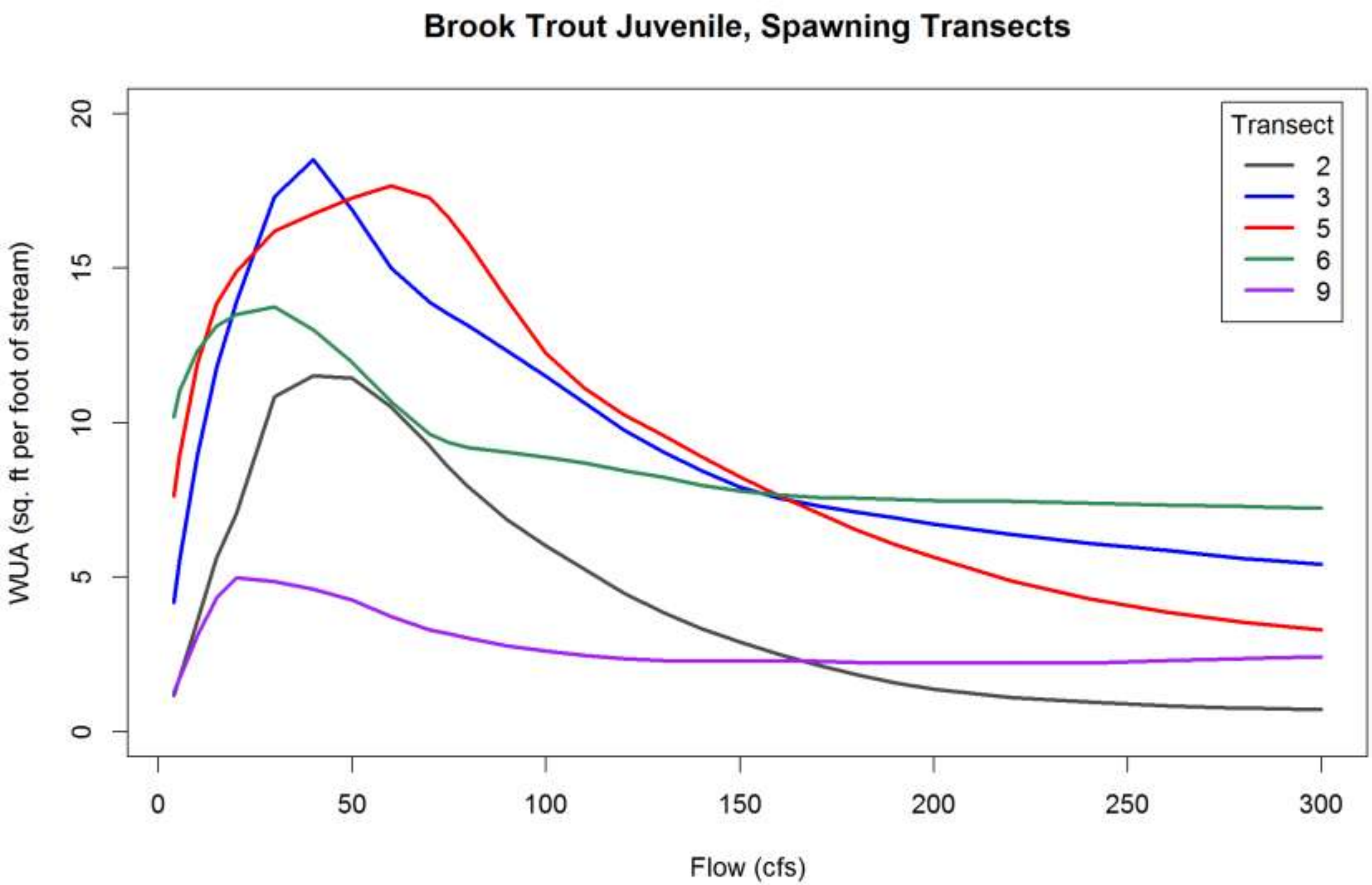

Brook Trout Spawning&Incubation, Non-Spawning Transects
WUA (sq. ft per foot of stream)
0
2
4
6
8
10
0
50
100
150
200
250
300
Flow (cfs)
Transect
1
4
7
8

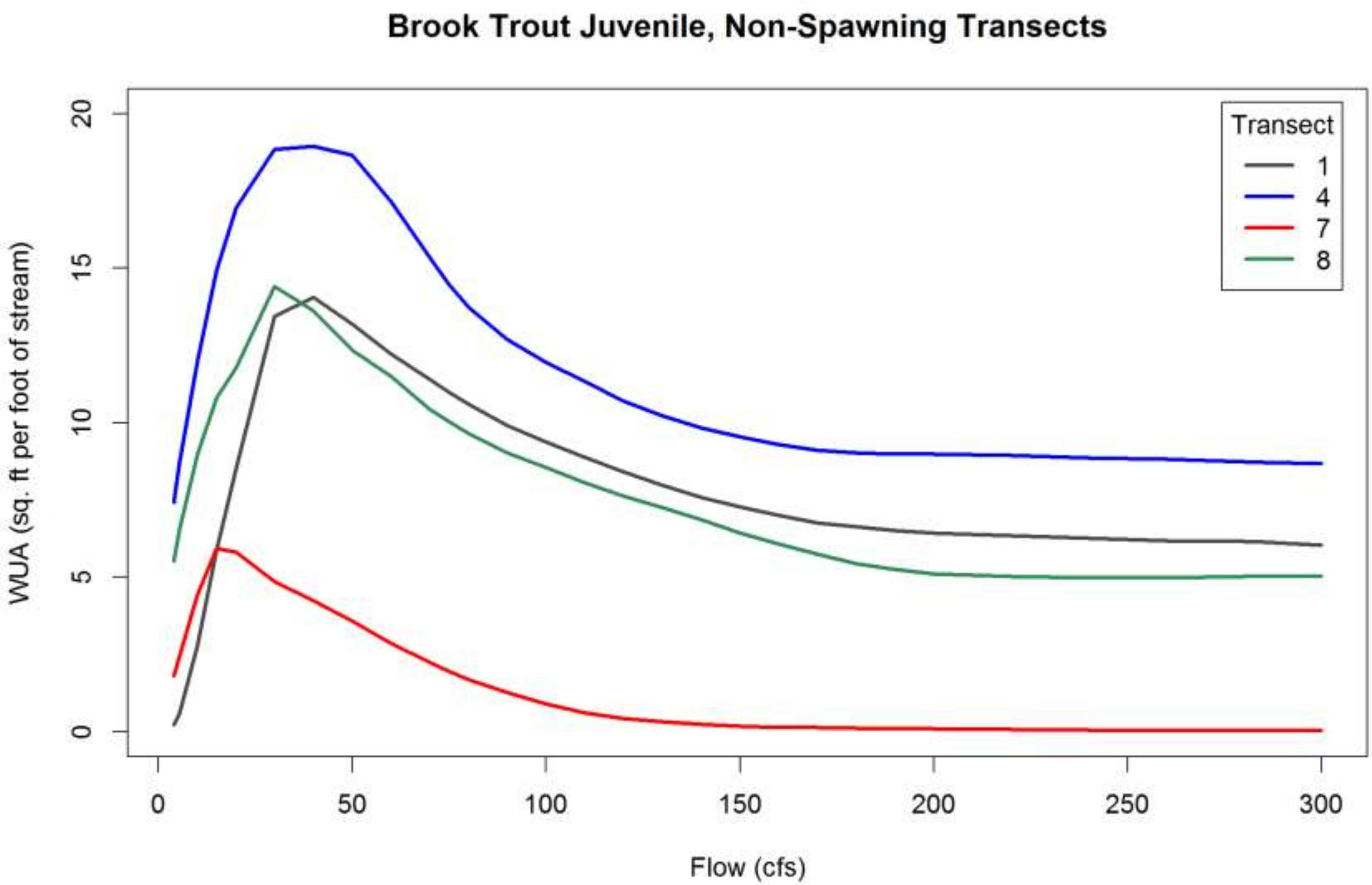


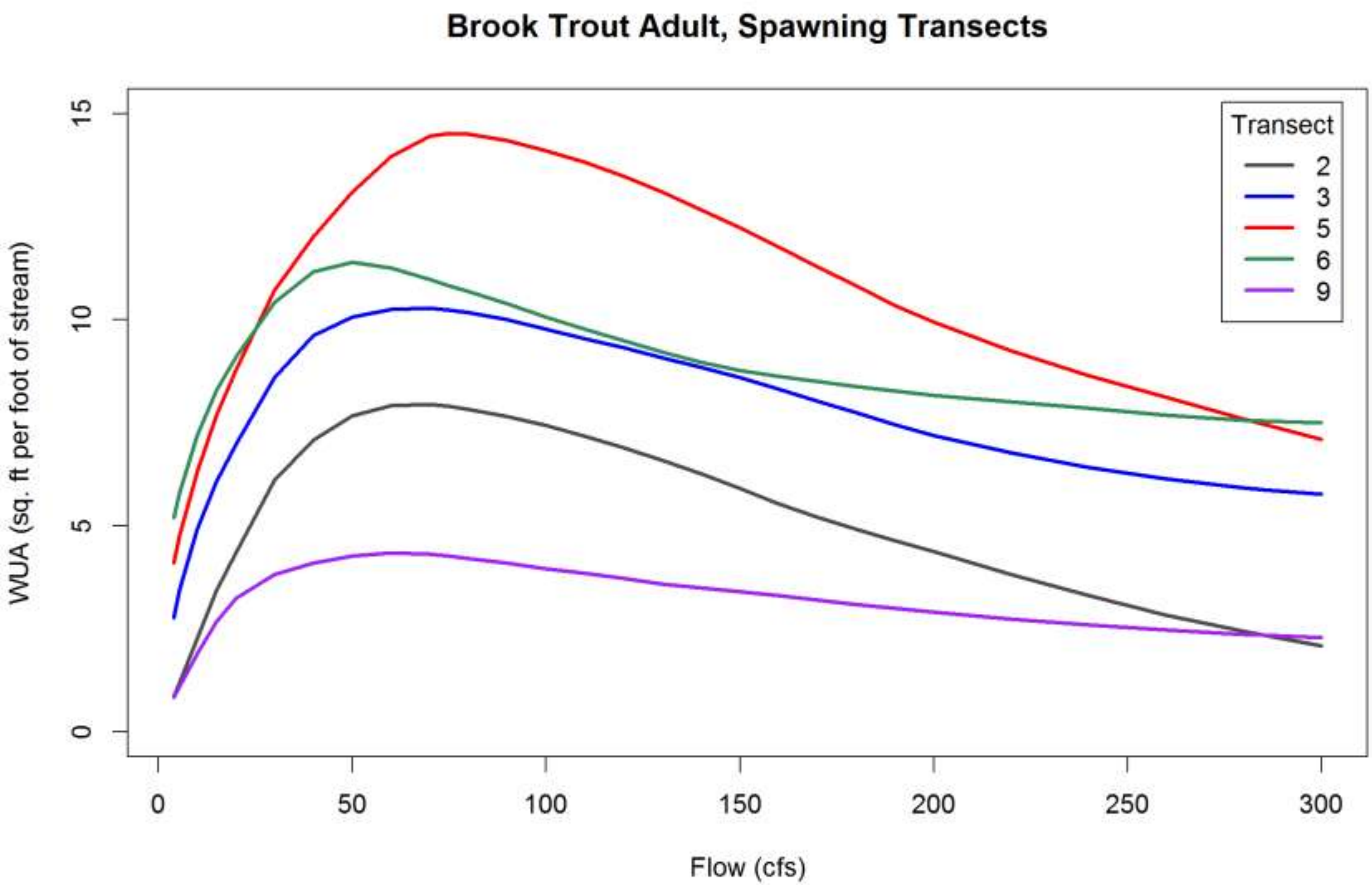
Brook Trout Late Fry, Spawning Transects
Transect
2
3
5
6
9
WUA (sq. ft per foot of stream)
0
5
10
15
20
25
30
35
0
50
100
150
200
250
300
Flow (cfs)



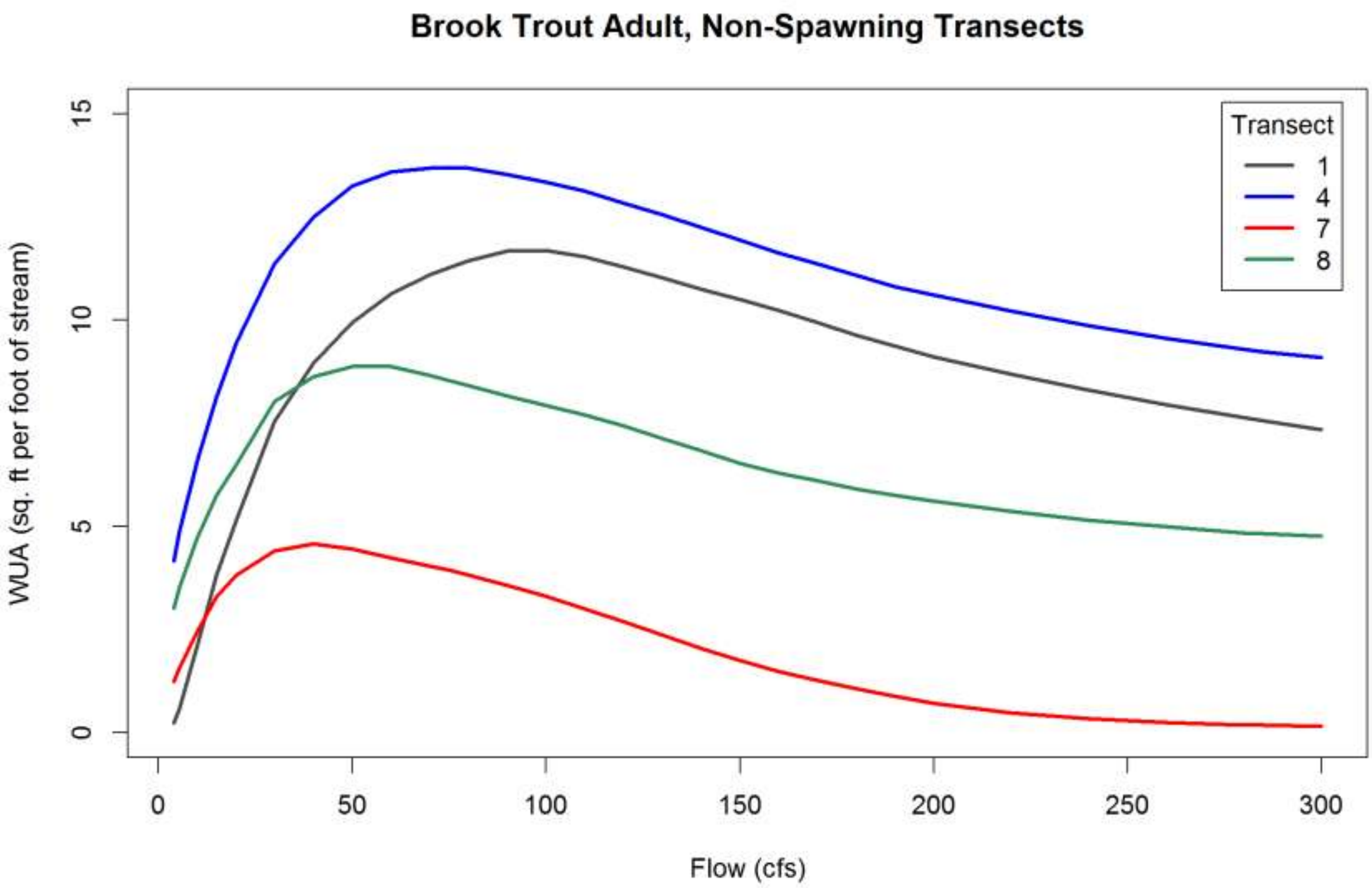
Brook Trout Late Fry, Non-Spawning Transects
WUA (sq. ft per foot of stream)
Flow (cfs)
Transect
1
4
7
8
0
5
10
15
20
25
30
35
0
50
100
150
200
250
300

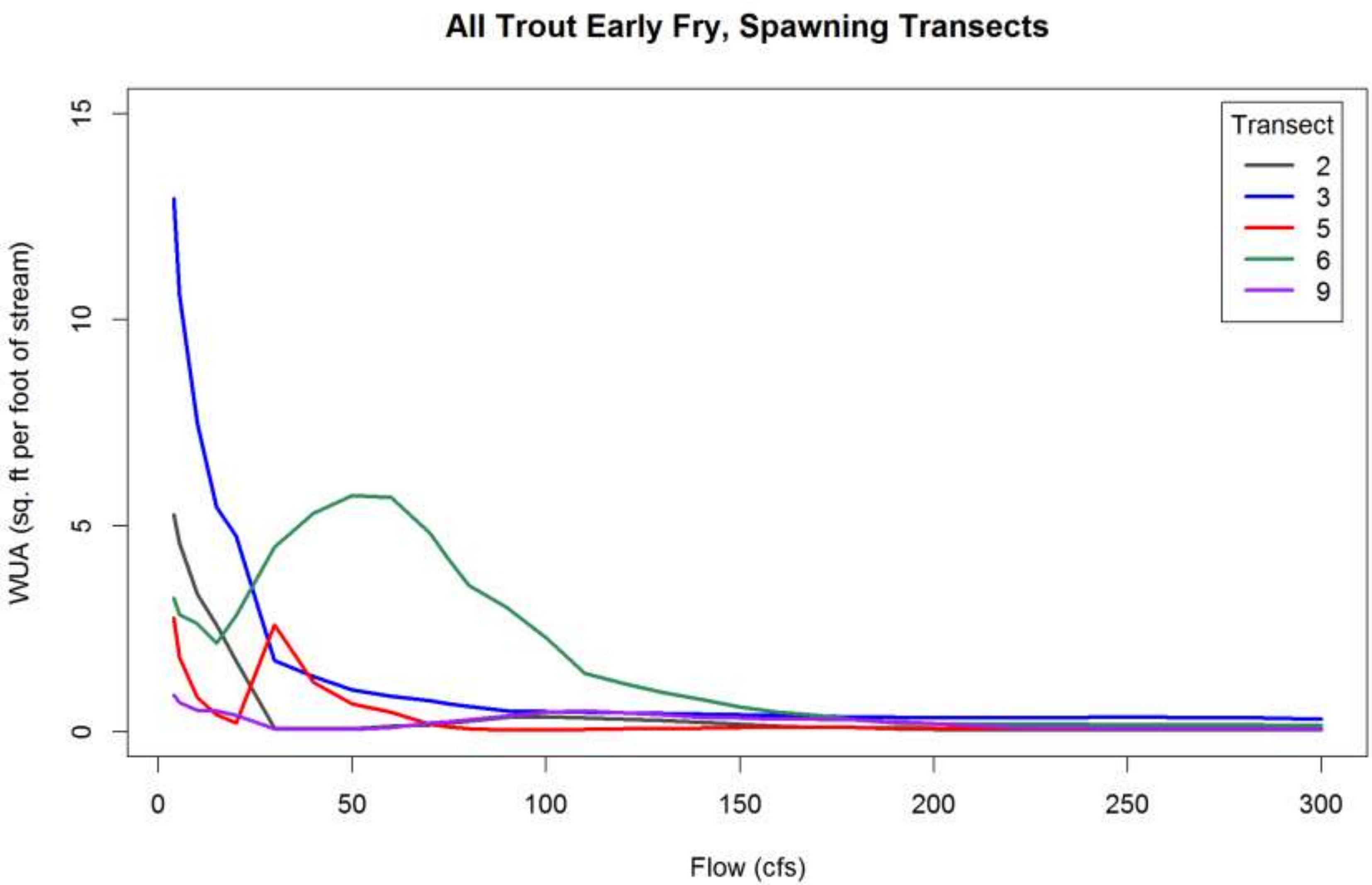

Brook Trout Juvenile, Spawning Transects
WUA (sq. ft per foot of stream)
0
5
10
15
20
Flow (cfs)
0
50
100
150
200
250
300
Transect
2
3
5
6
9

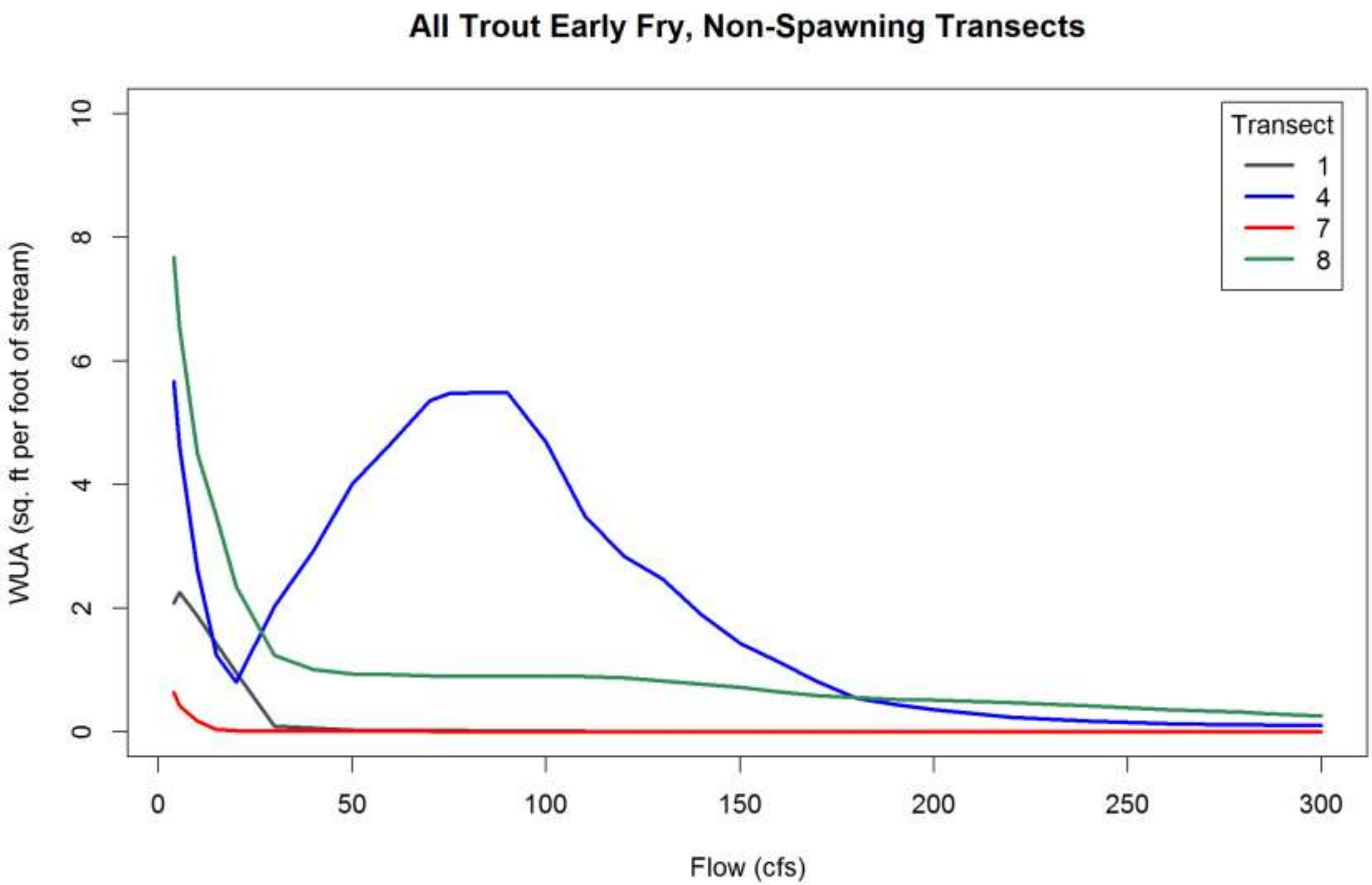

Brook Trout Juvenile, Non-Spawning Transects
WUA (sq. ft per foot of stream)
0
5
10
15
20
0
50
100
150
200
250
300
Flow (cfs)
Transect
1
4
7
8

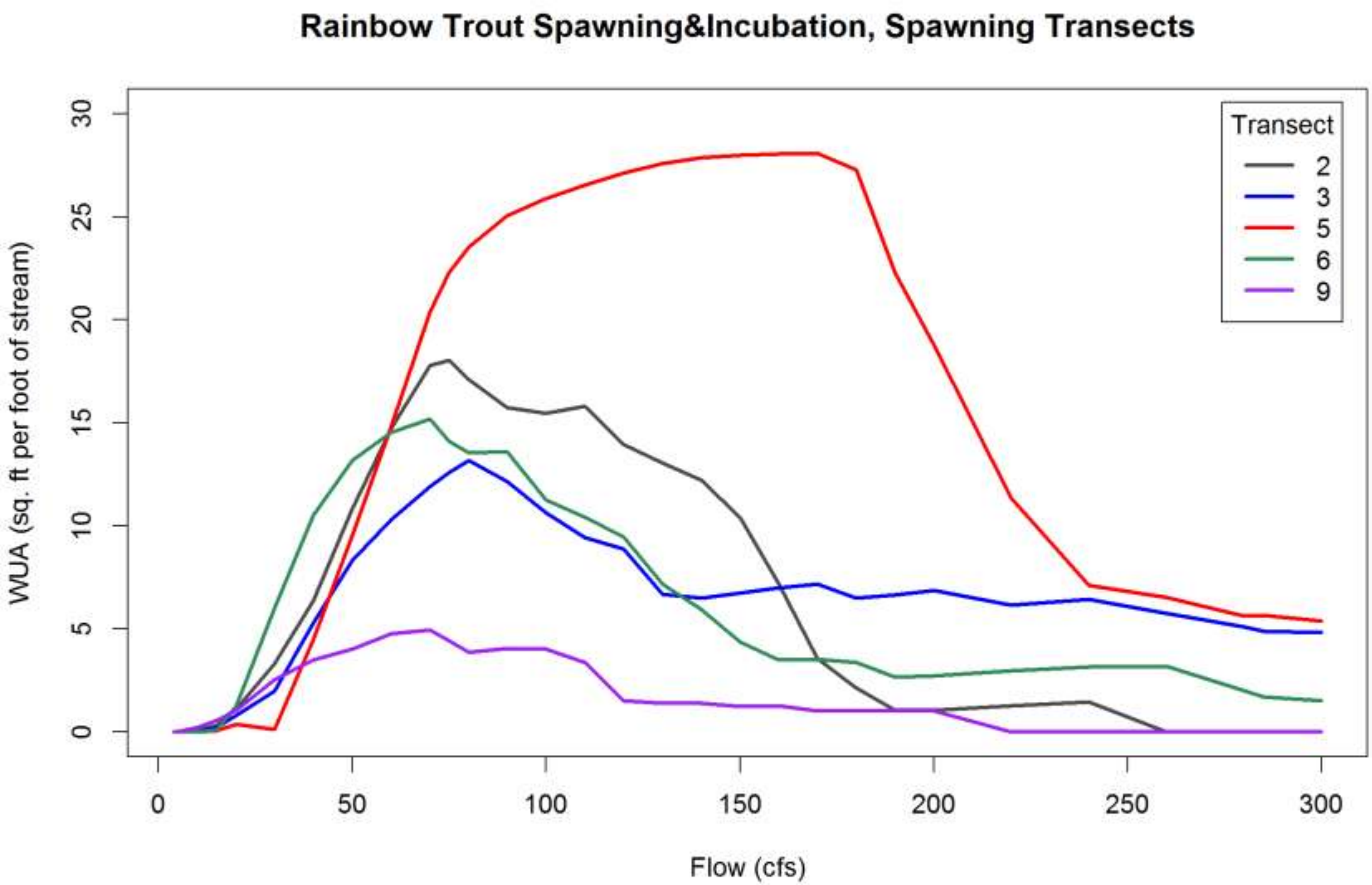


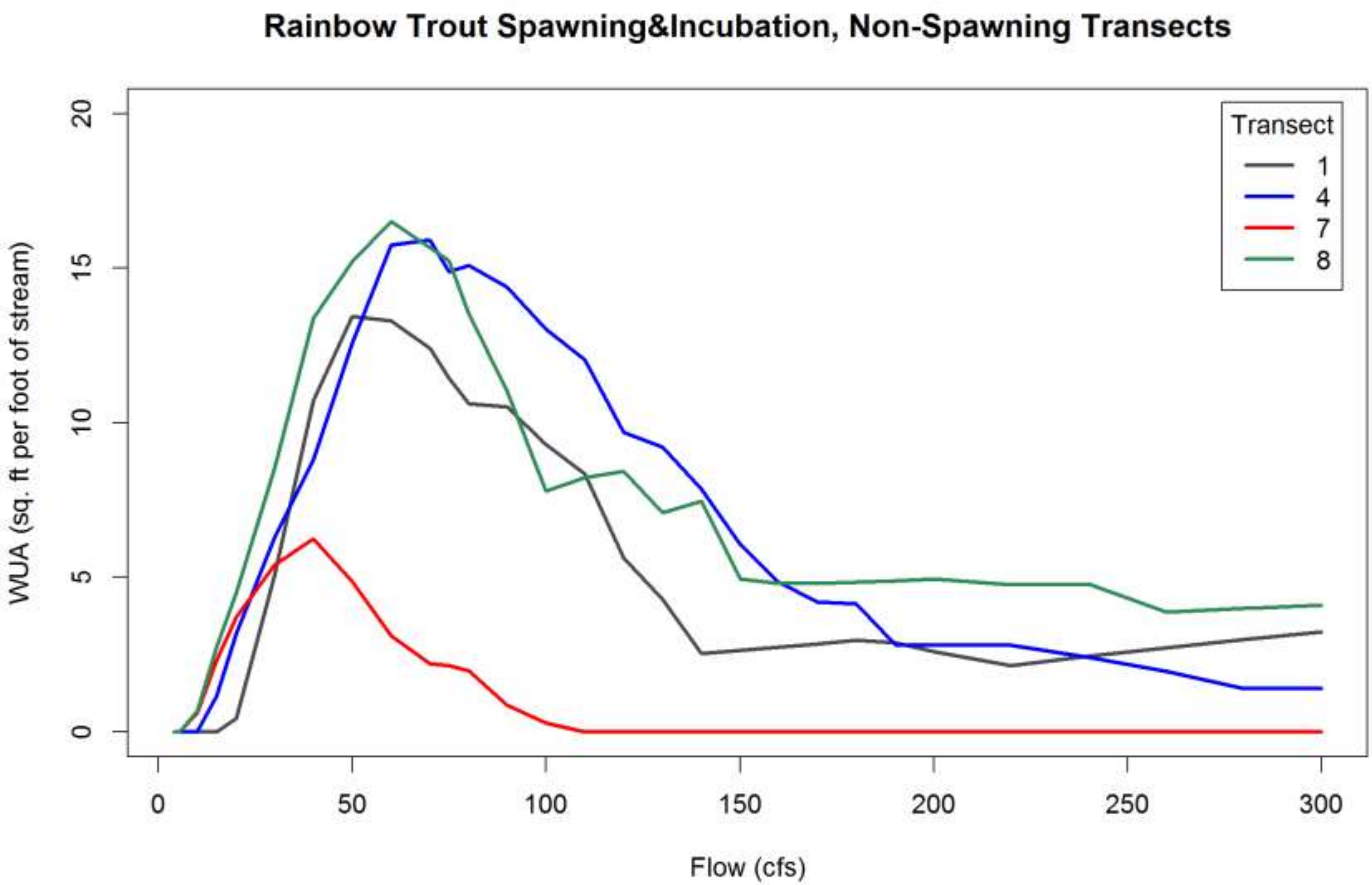
Brook Trout Adult, Spawning Transects
WUA (sq. ft per foot of stream)
Flow (cfs)
Transect
2
3
5
6
9
0
5
10
15
0
50
100
150
200
250
300

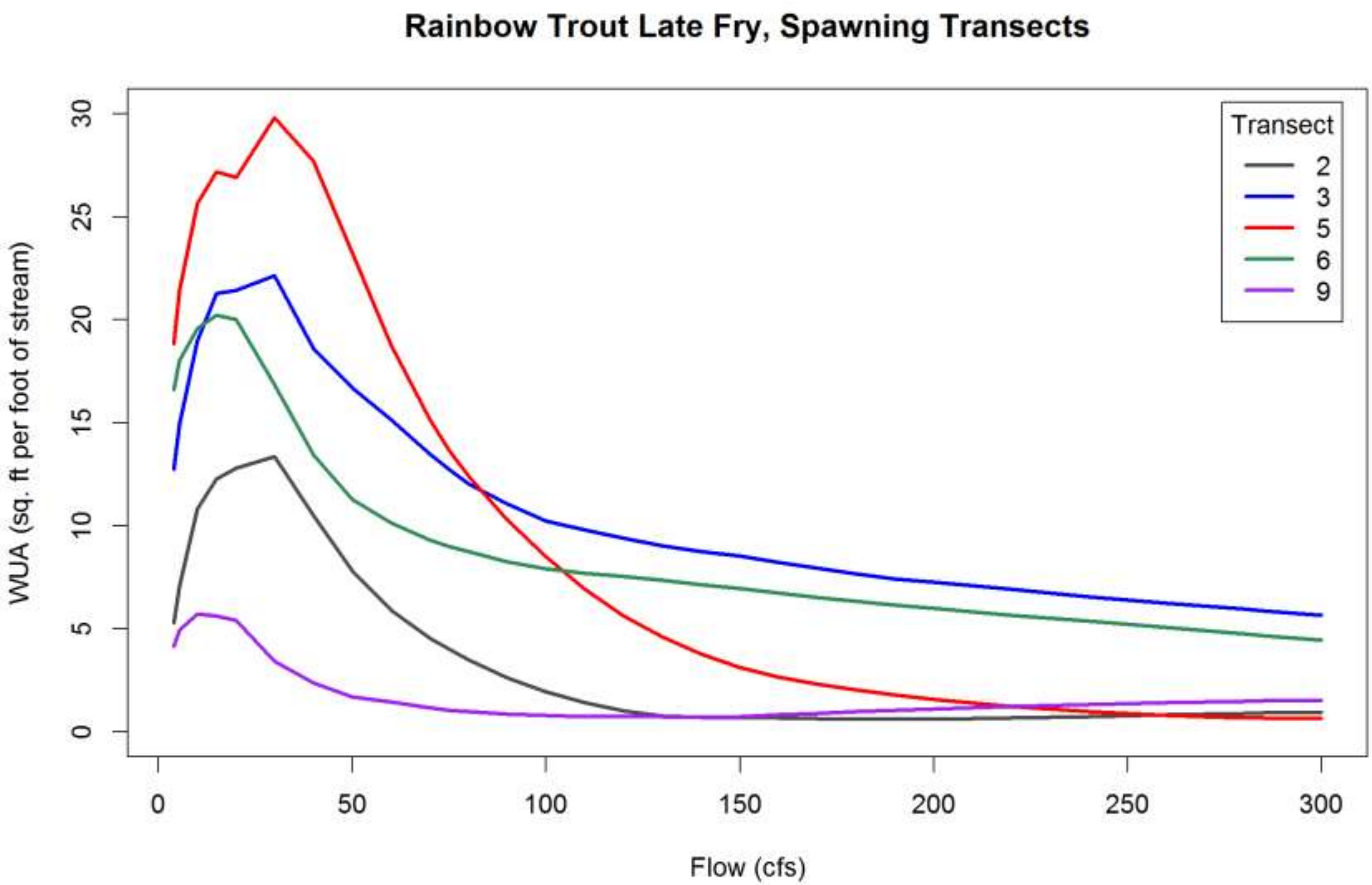

Brook Trout Adult, Non-Spawning Transects
Transect
1
4
7
8
WUA (sq. ft per foot of stream)
0
5
10
15
0
50
100
150
200
250
300
Flow (cfs)

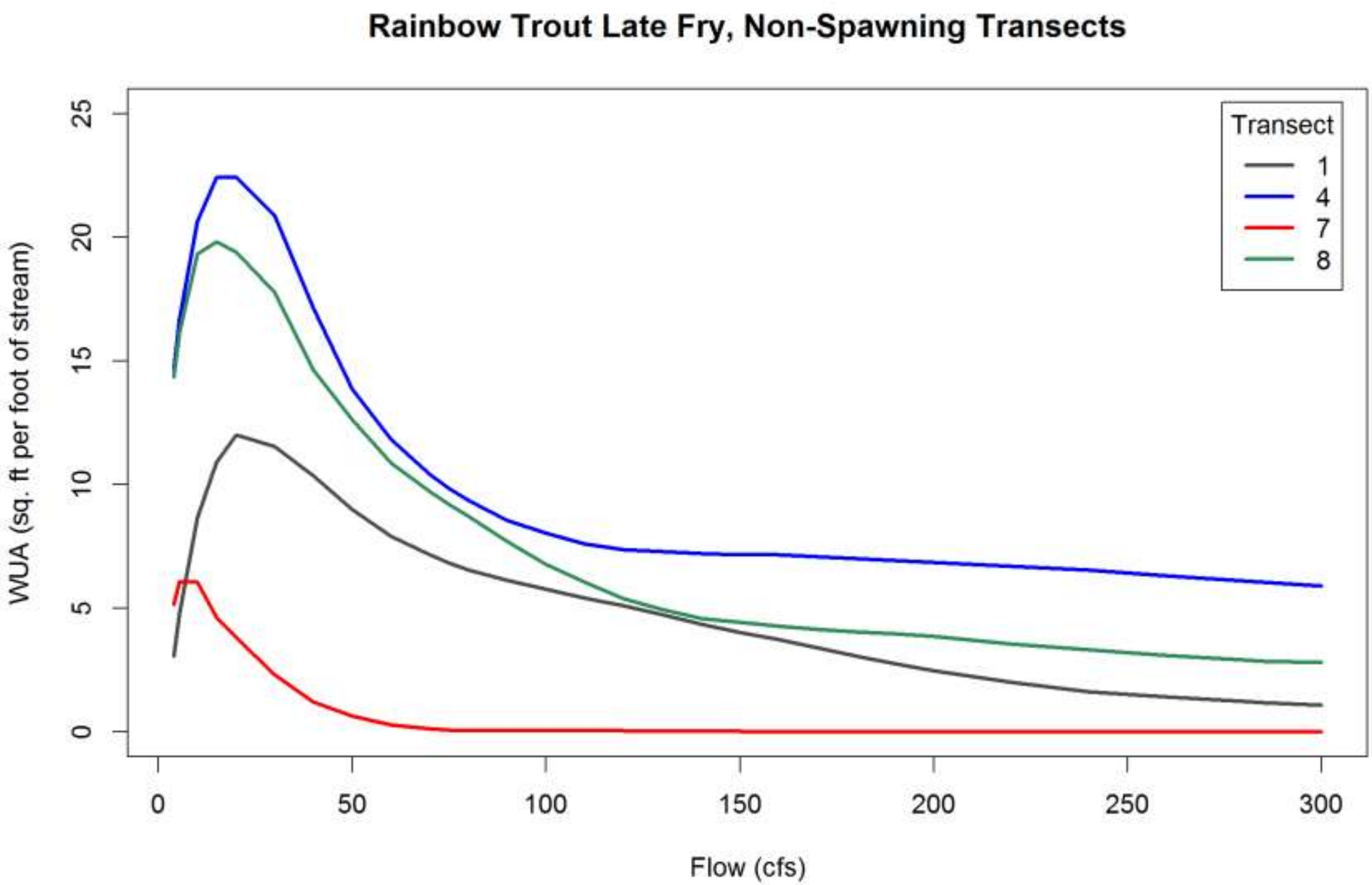

All Trout Early Fry, Spawning Transects
Transect
2
3
5
6
9
WUA (sq. ft per foot of stream)
0
5
10
15
Flow (cfs)
0
50
100
150
200
250
300

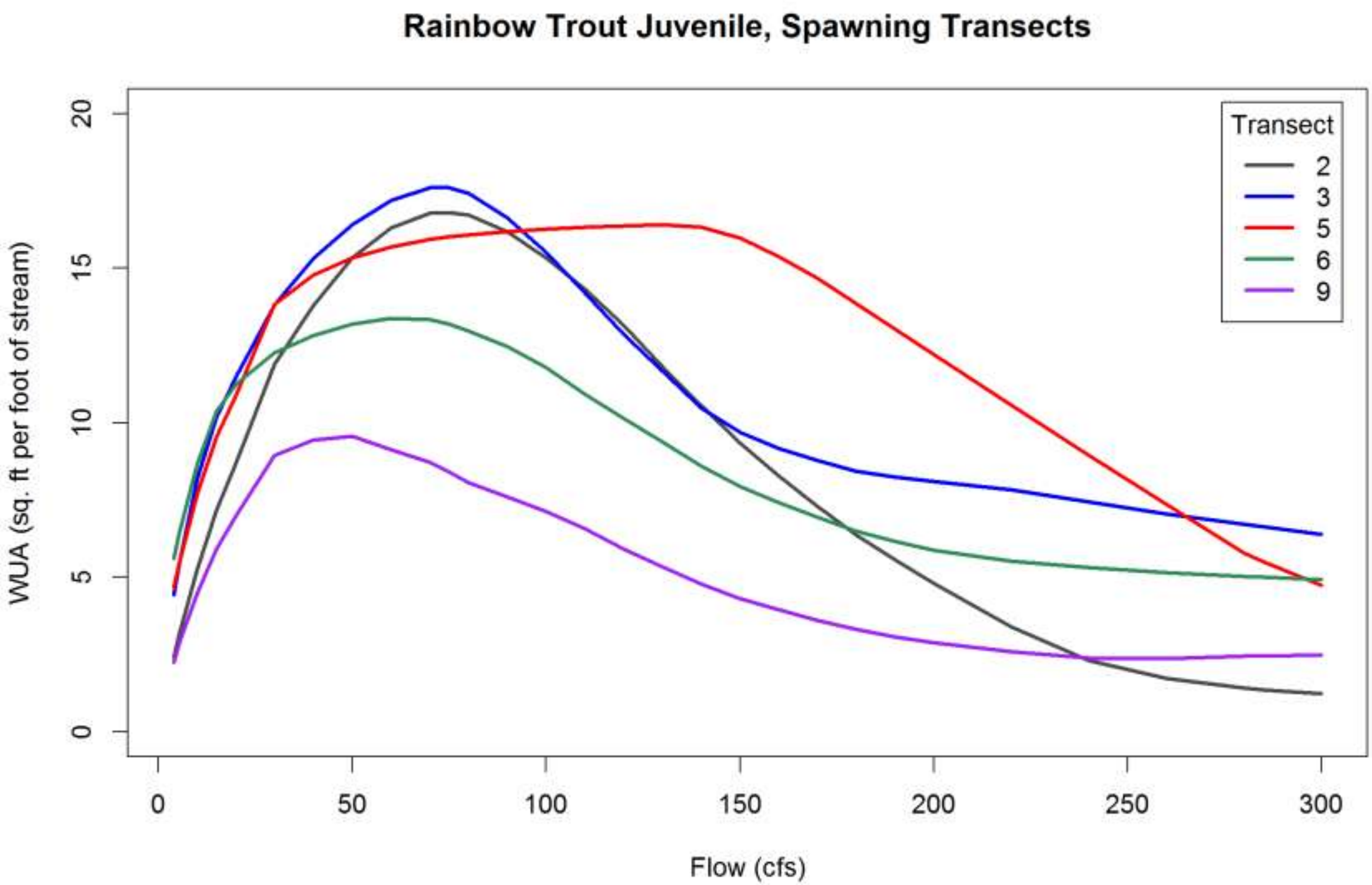

All Trout Early Fry, Non-Spawning Transects
WUA (sq. ft per foot of stream)
Flow (cfs)
Transect
1
4
7
8
0
2
4
6
8
10
0
50
100
150
200
250
300

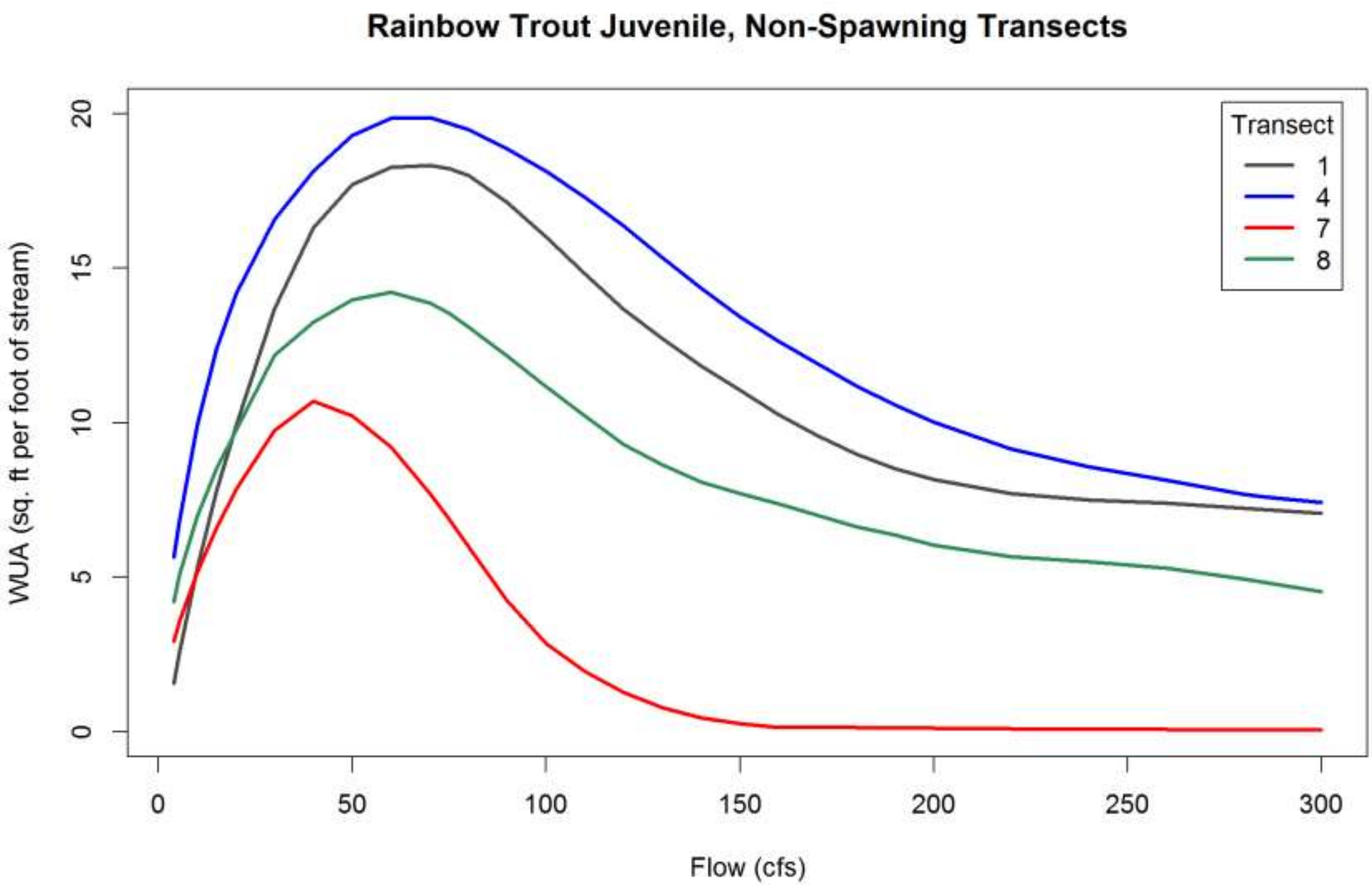

Rainbow Trout Spawning&Incubation, Spawning Transects
WUA (sq. ft per foot of stream)
Flow (cfs)
Transect
2
3
5
6
9
0
5
10
15
20
25
30
0
50
100
150
200
250
300


Rainbow Trout Spawning&Incubation, Non-Spawning Transects
WUA (sq. ft per foot of stream)
0
5
10
15
20
Flow (cfs)
0
50
100
150
200
250
300
Transect
1
4
7
8

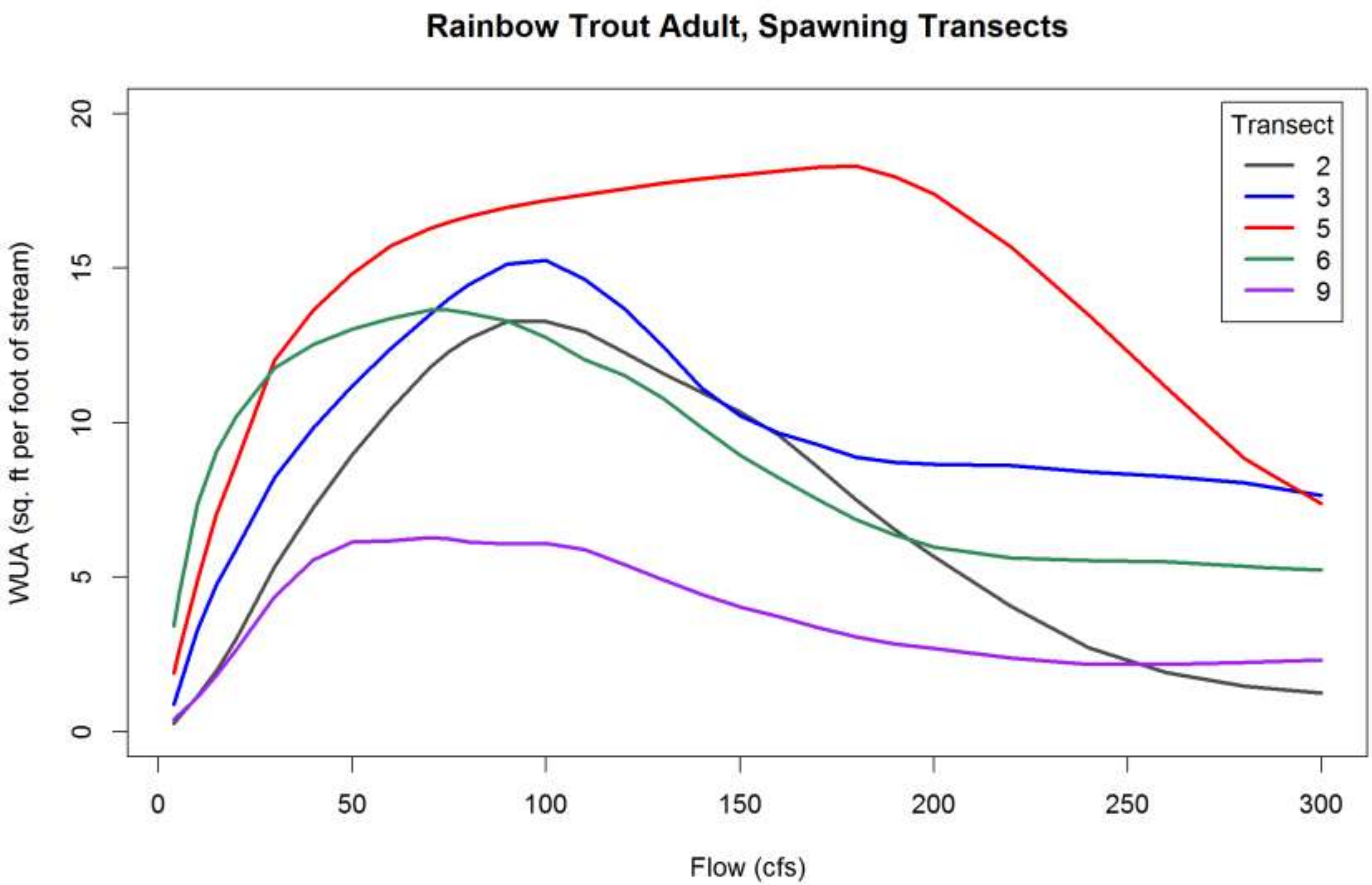

Rainbow Trout Late Fry, Spawning Transects
WUA (sq. ft per foot of stream)
0
5
10
15
20
25
30
Flow (cfs)
0
50
100
150
200
250
300
Transect
2
3
5
6
9

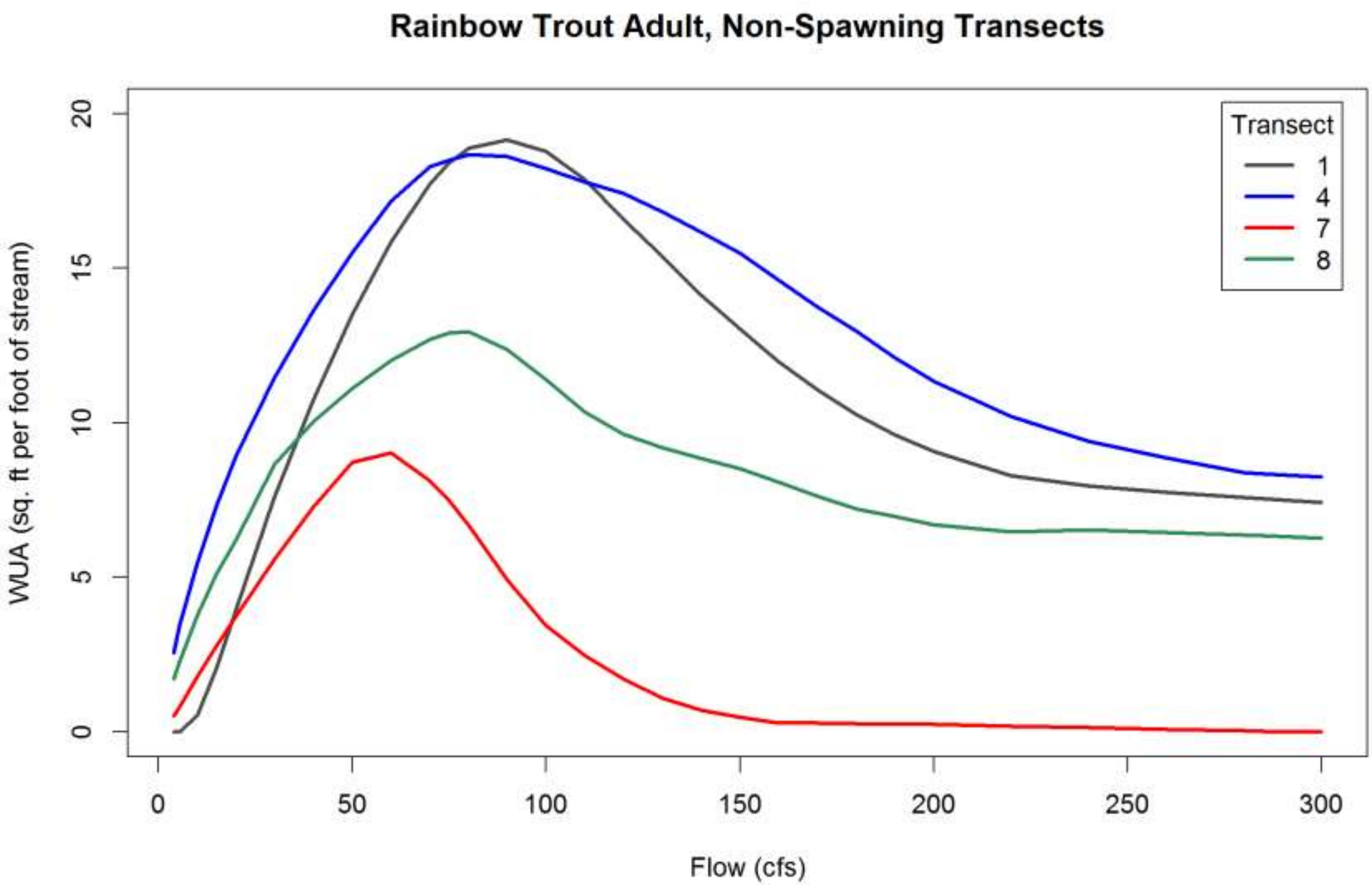

Rainbow Trout Late Fry, Non-Spawning Transects
Transect
1
4
7
8
WUA (sq. ft per foot of stream)
Flow (cfs)
0
5
10
15
20
25
0
50
100
150
200
250
300


Rainbow Trout Juvenile, Spawning Transects
Transect
2
3
5
6
9
WUA (sq. ft per foot of stream)
0
5
10
15
20
0
50
100
150
200
250
300
Flow (cfs)

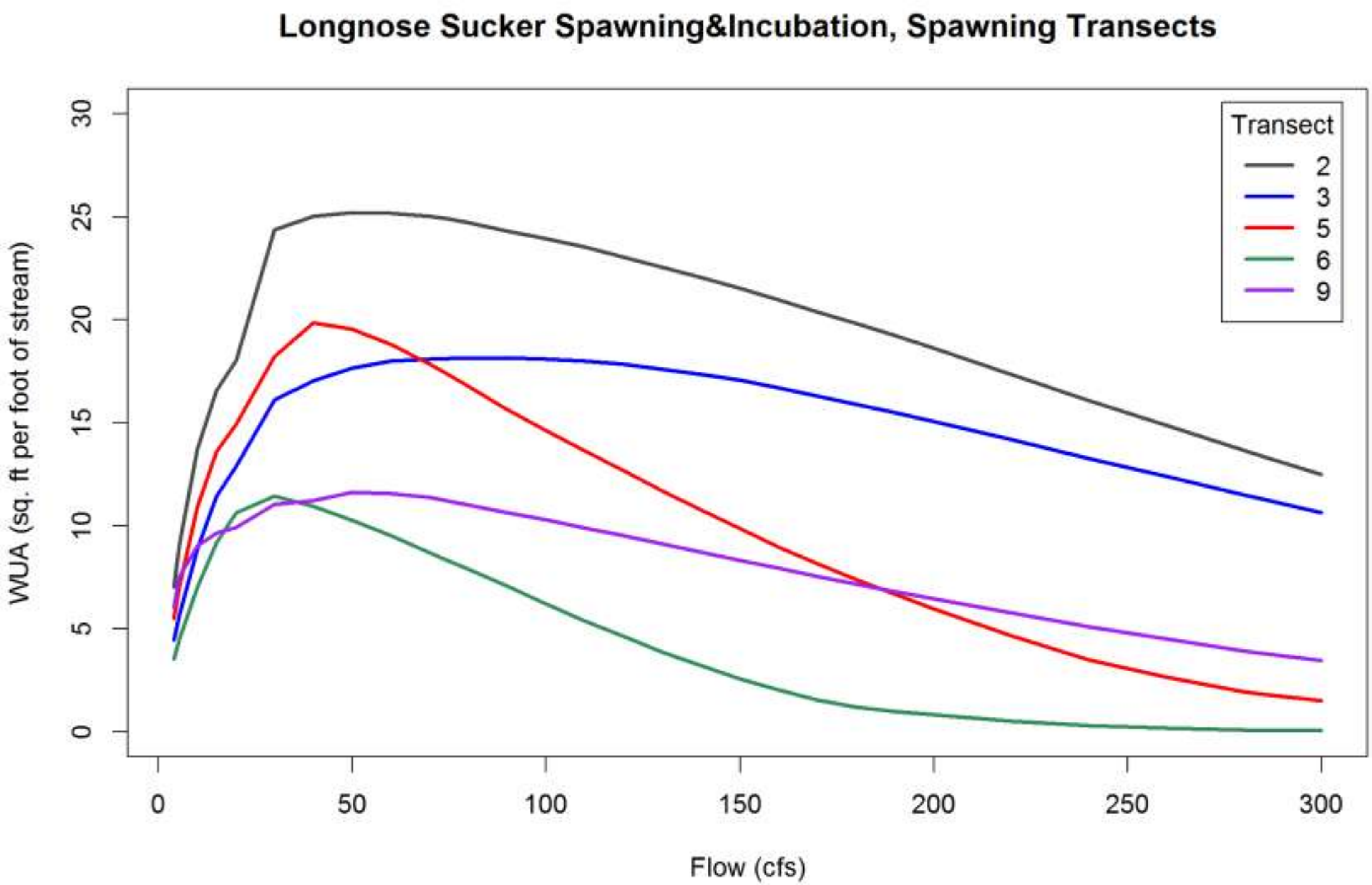


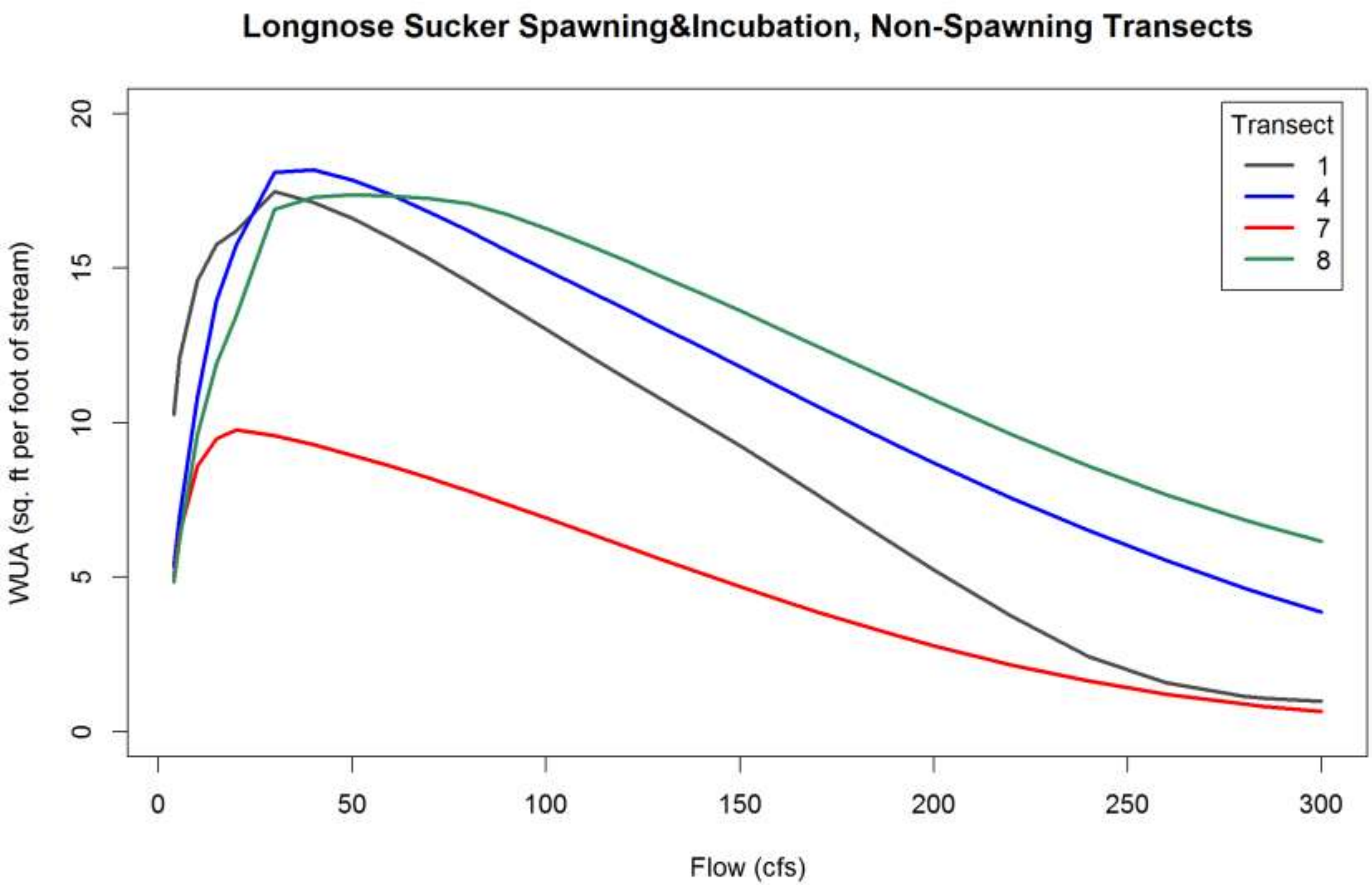
Rainbow Trout Juvenile, Non-Spawning Transects
Transect
1
4
7
8
WUA (sq. ft per foot of stream)
0
5
10
15
20
0
50
100
150
200
250
300
Flow (cfs)

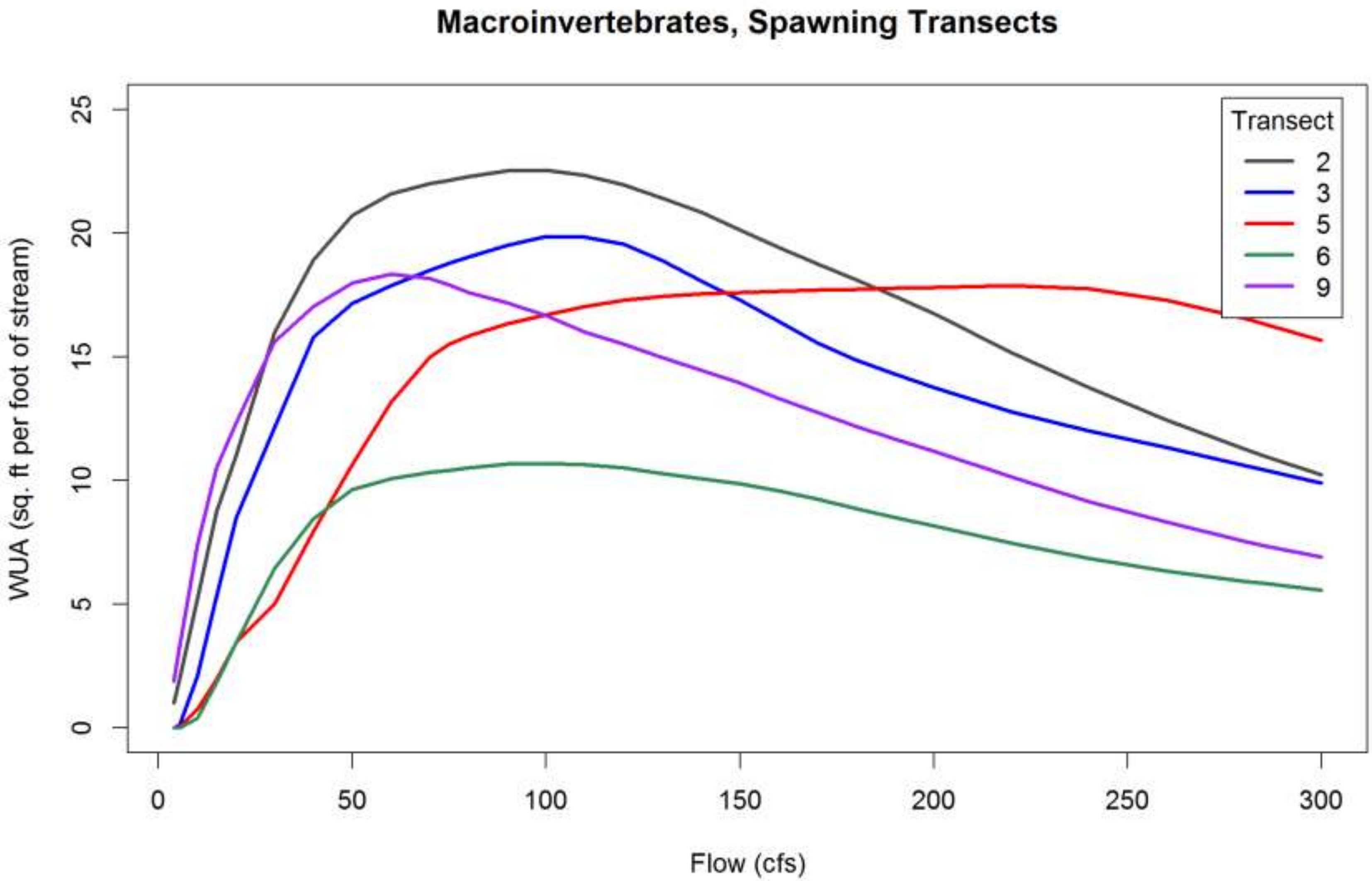

Rainbow Trout Adult, Spawning Transects
Transect
2
3
5
6
9
WUA (sq. ft per foot of stream)
0
5
10
15
20
0
50
100
150
200
250
300
Flow (cfs)

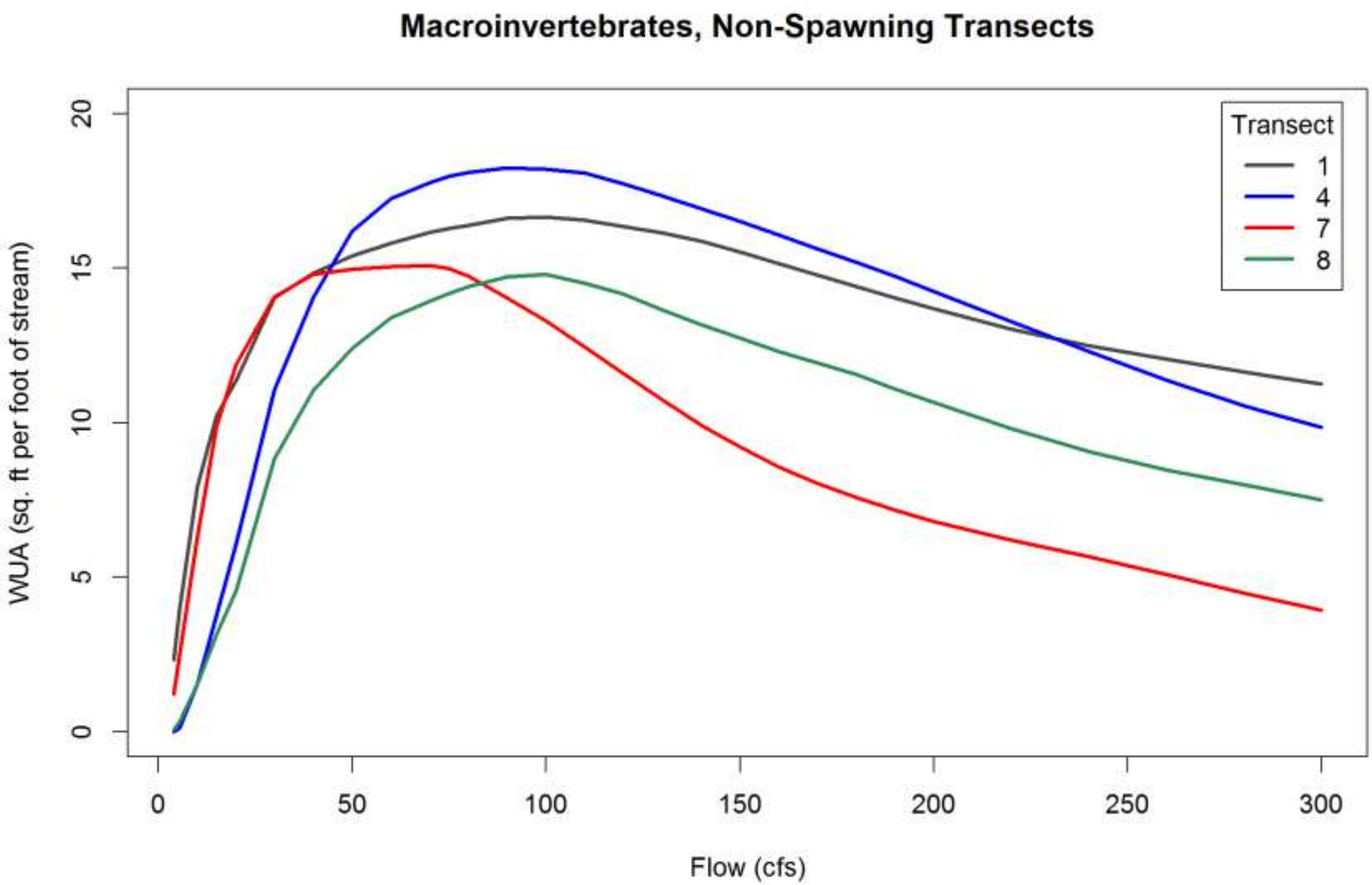


Rainbow Trout Adult, Non-Spawning Transects
Transect
1
4
7
8
WUA (sq. ft per foot of stream)
Flow (cfs)
0
5
10
15
20
0
50
100
150
200
250
300


Longnose Sucker Spawning&Incubation, Spawning Transects
WUA (sq. ft per foot of stream)
Flow (cfs)
Transect
2
3
5
6
9
0
5
10
15
20
25
30
0
50
100
150
200
250
300

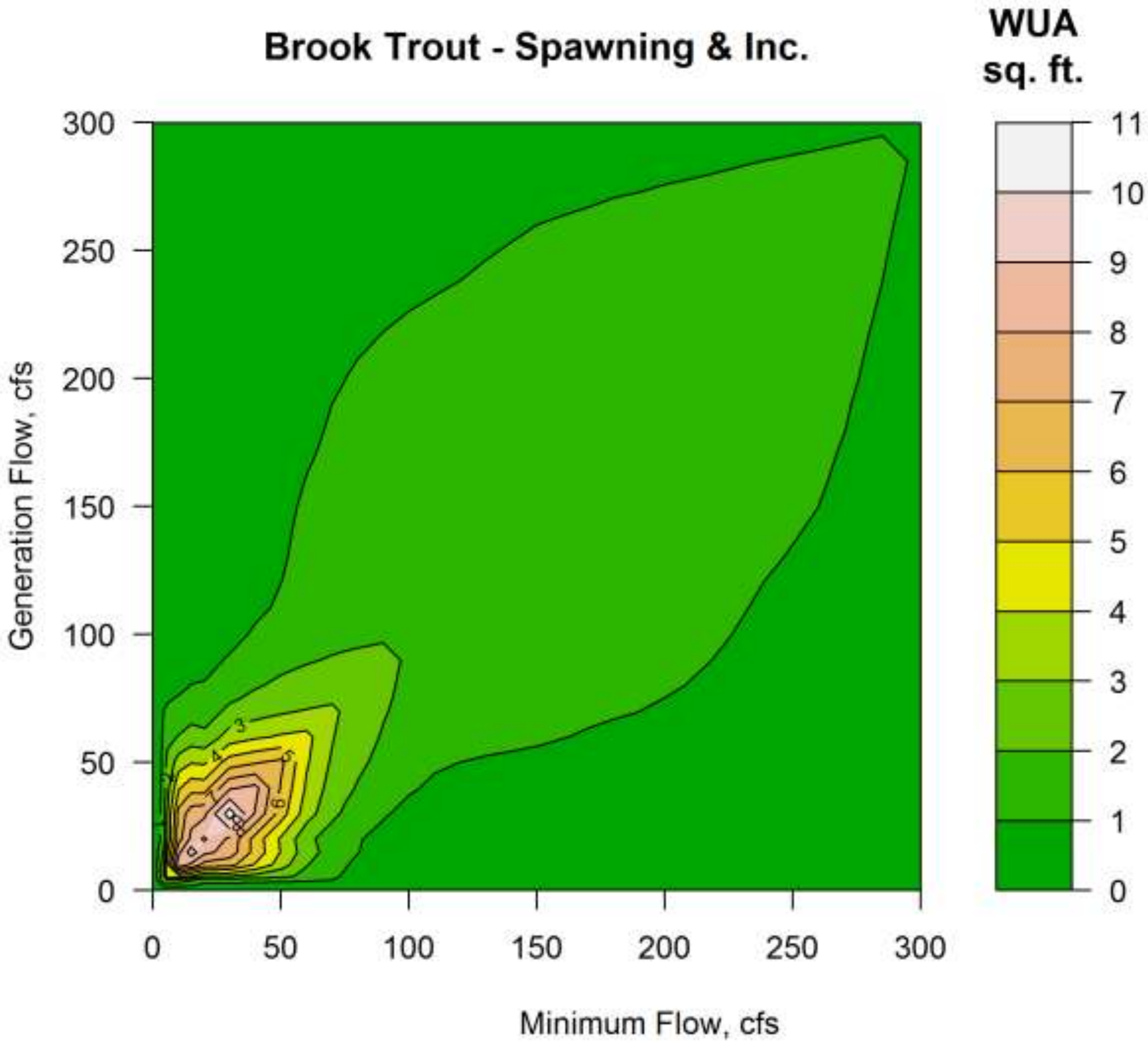

Longnose Sucker Spawning&Incubation, Non-Spawning Transects
Transect
1
4
7
8
WUA (sq. ft per foot of stream)
0
5
10
15
20
0
50
100
150
200
250
300
Flow (cfs)

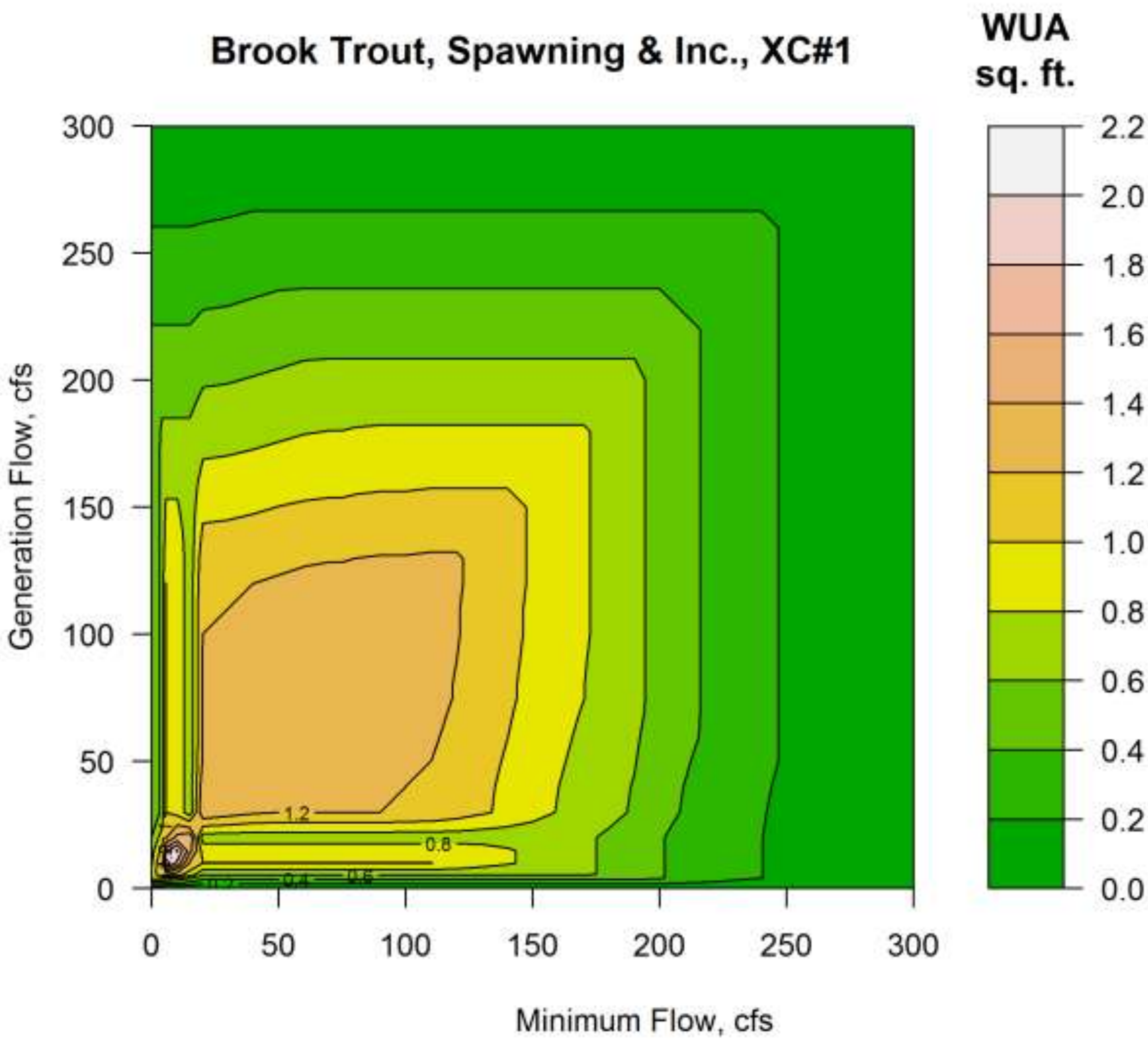

Macroinvertebrates, Spawning Transects
Transect
2
3
5
6
9
WUA (sq. ft per foot of stream)
0
5
10
15
20
25
0
50
100
150
200
250
300
Flow (cfs)

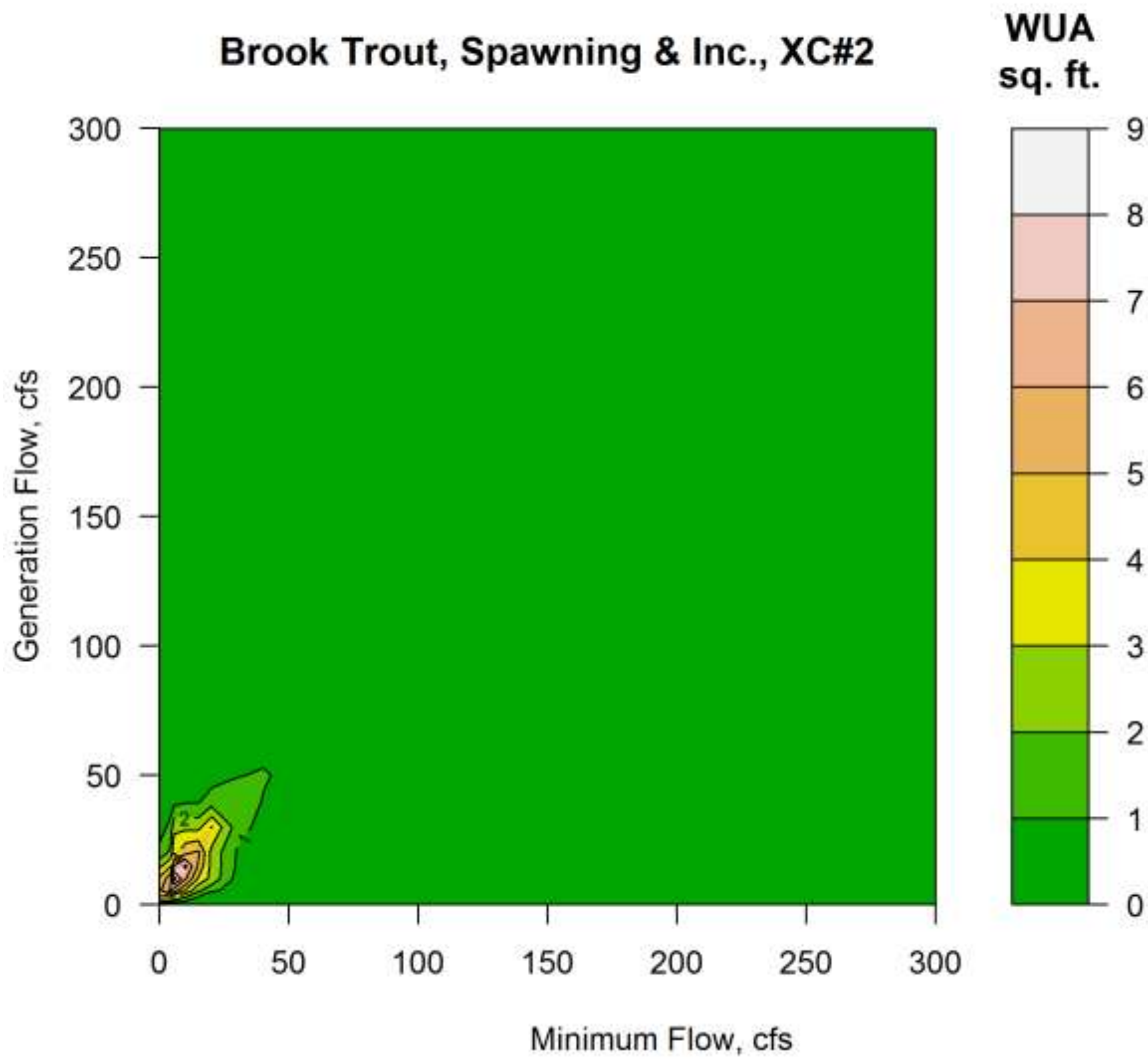


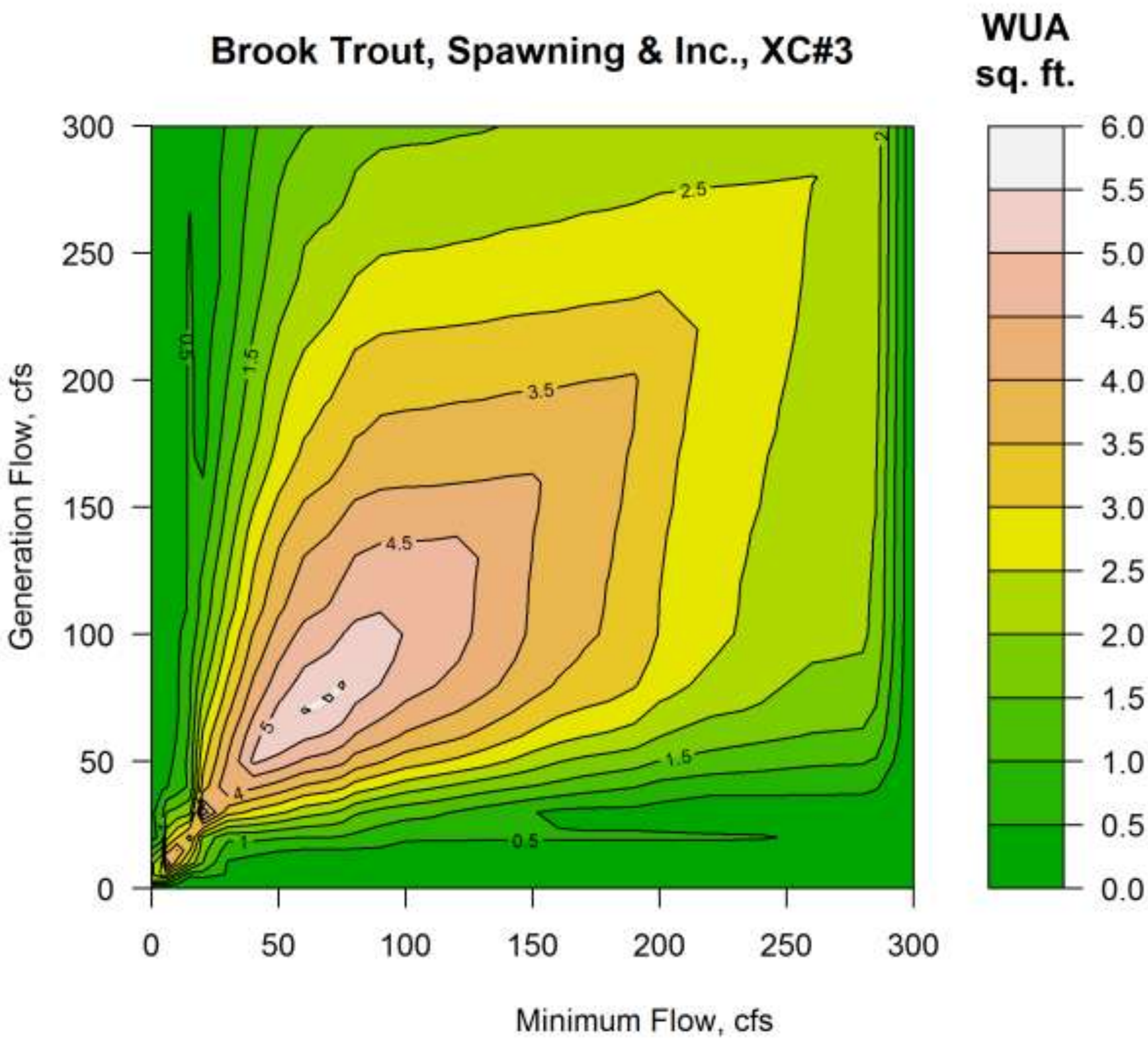
Macroinvertebrates, Non-Spawning Transects
Transect
1
4
7
8
WUA (sq. ft per foot of stream)
0
5
10
15
20
0
50
100
150
200
250
300
Flow (cfs)

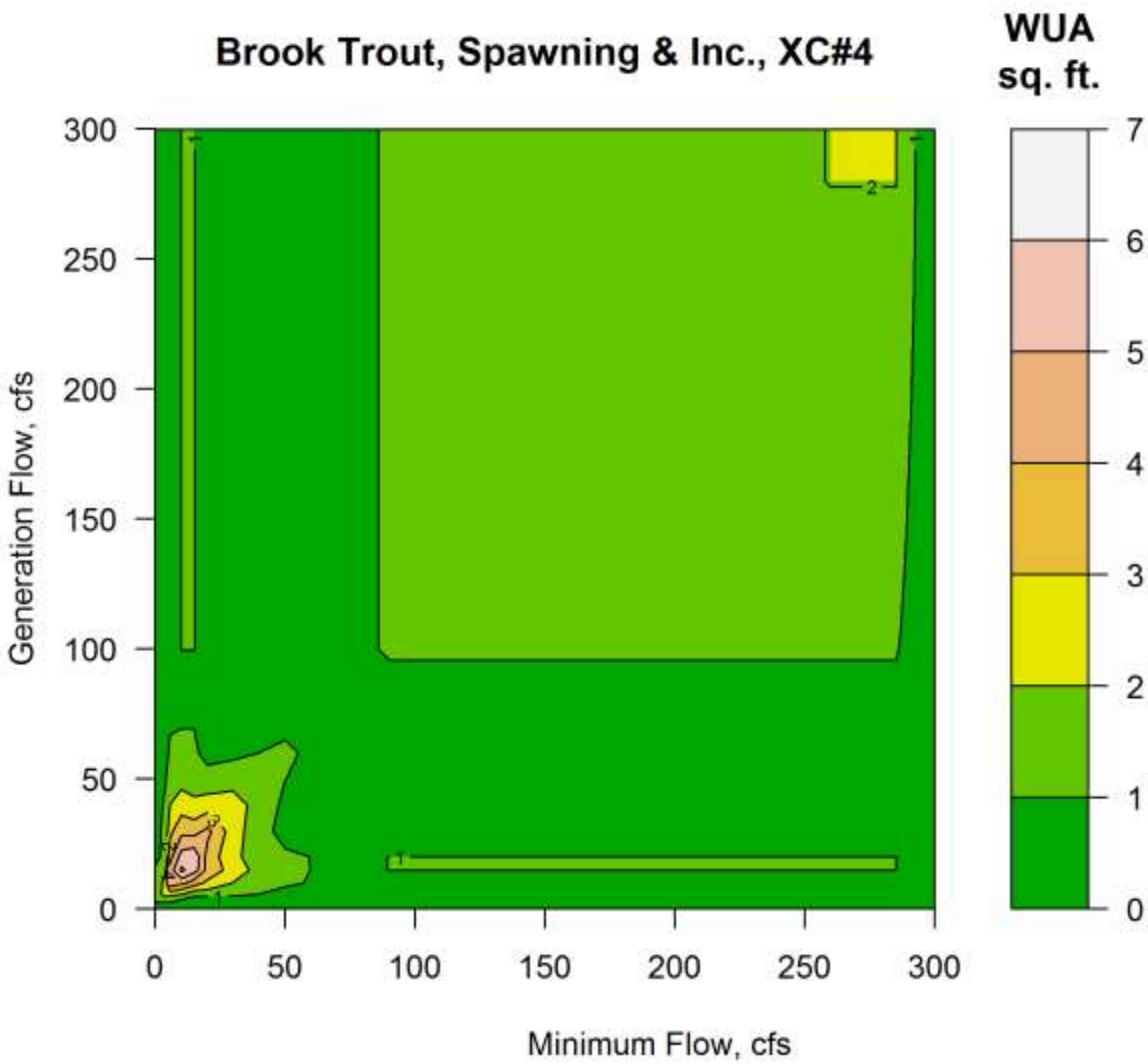
Appendix E: Dual-flow analysis dual-flow habitat flow curves for all modeled transects and target species/life stages

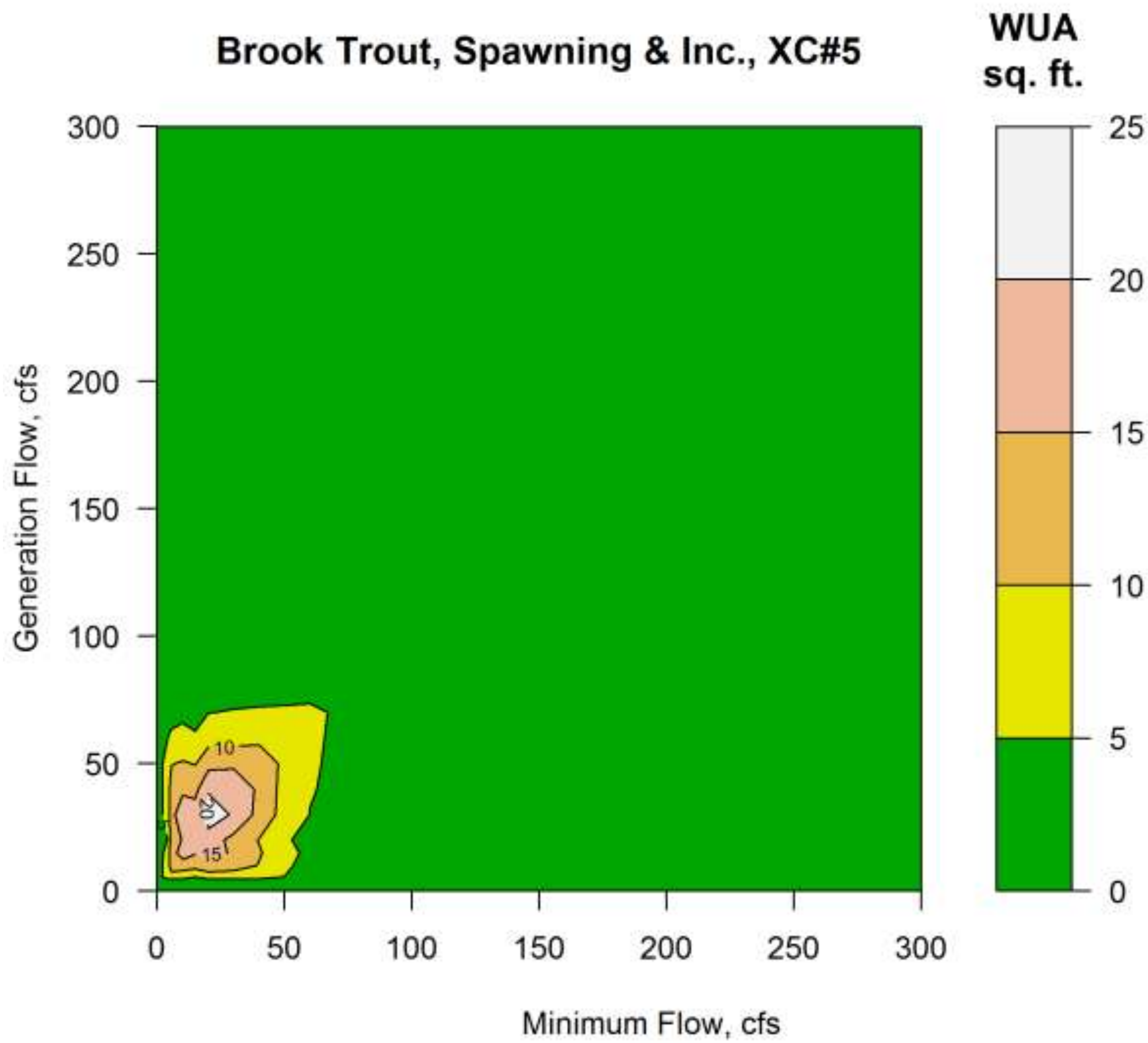

Brook Trout - Spawning & Inc.
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
11
10
9
8
7
6
5
4
3
2
1
0

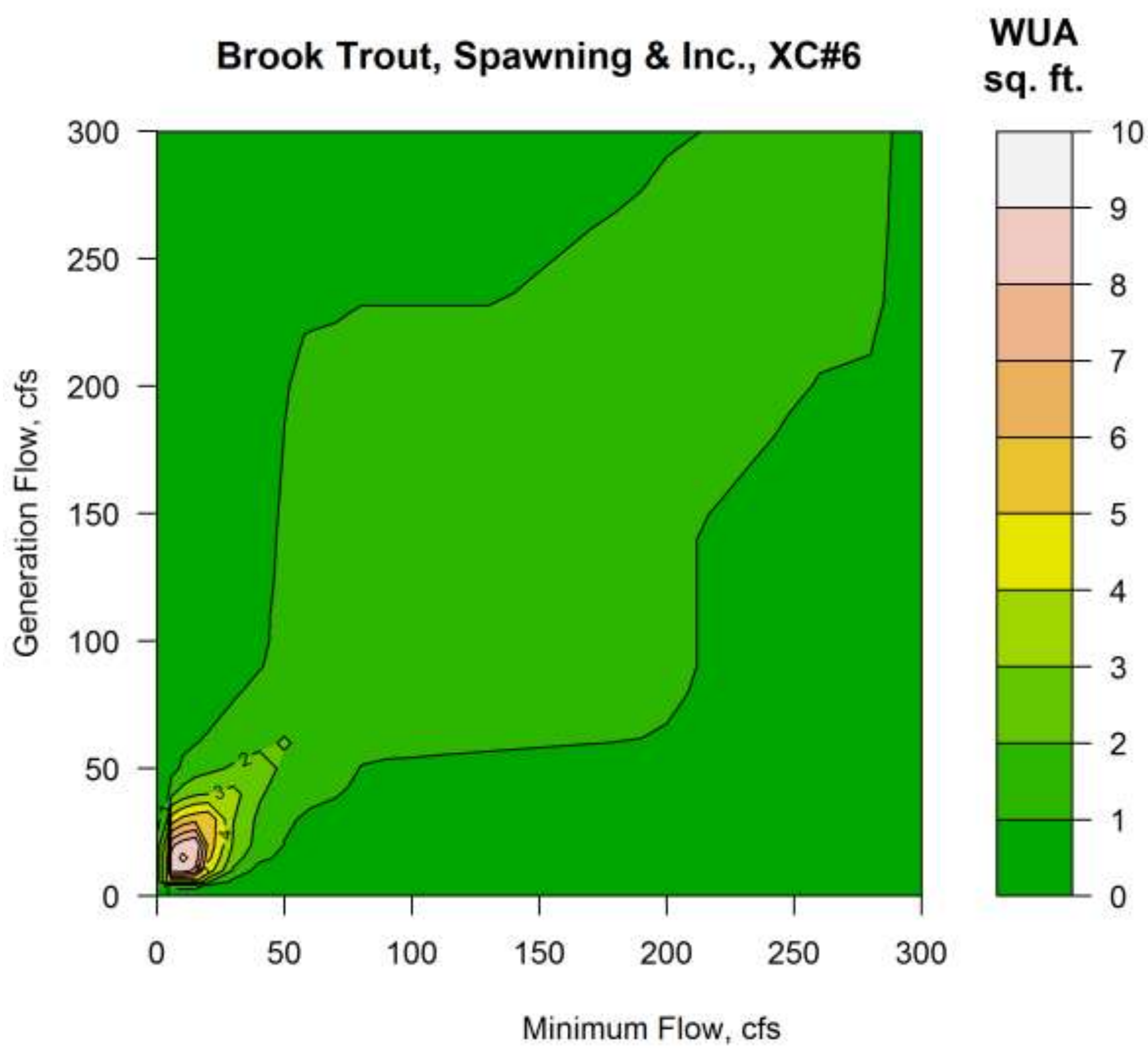

Brook Trout, Spawning & Inc., XC#1
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
1.2
0.8
0.4
0.6
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0

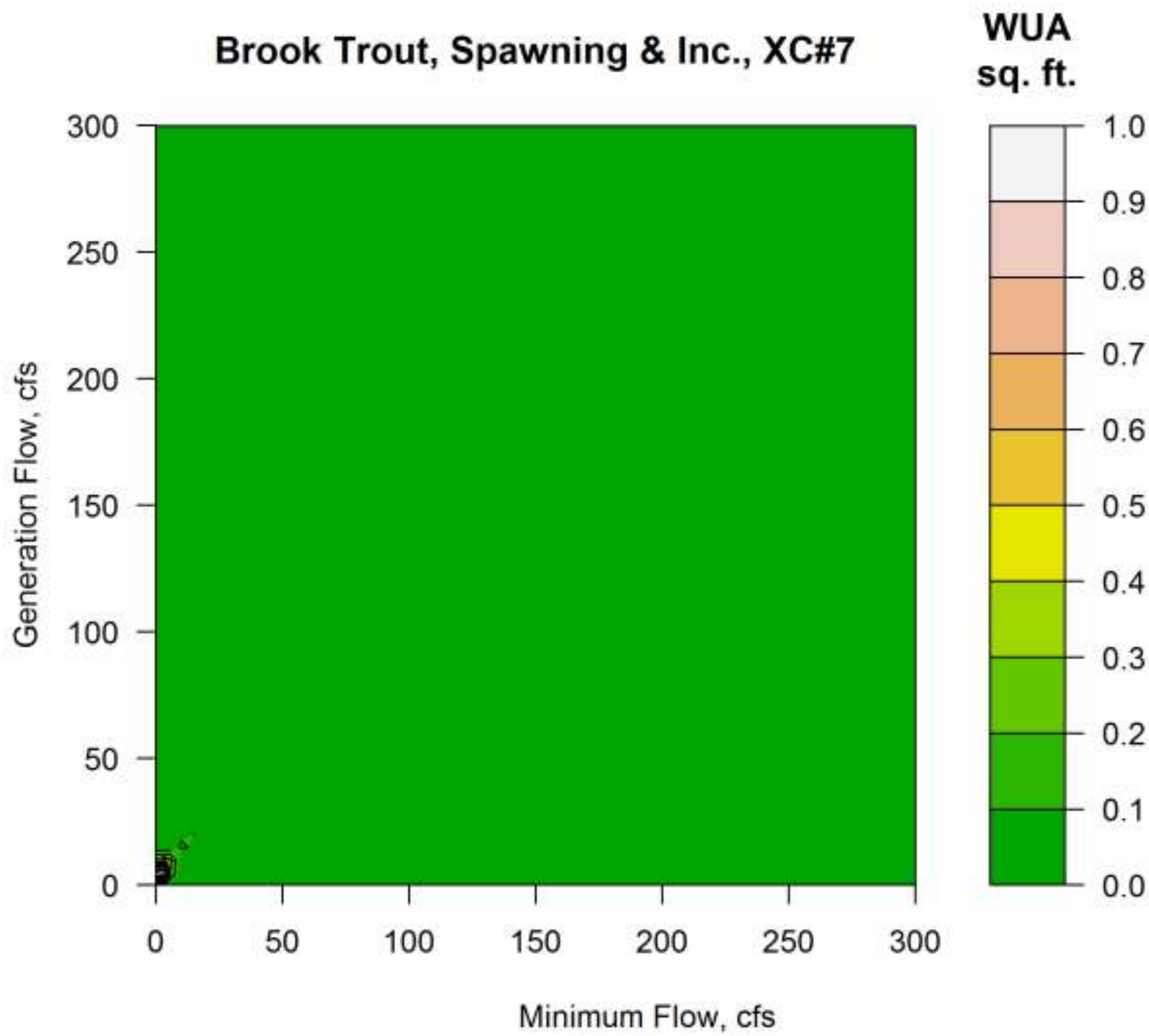

Brook Trout, Spawning & Inc., XC#2
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
300
250
200
150
100
50
0
0
50
100
150
200
250
300
9
8
7
6
5
4
3
2
1
0
2

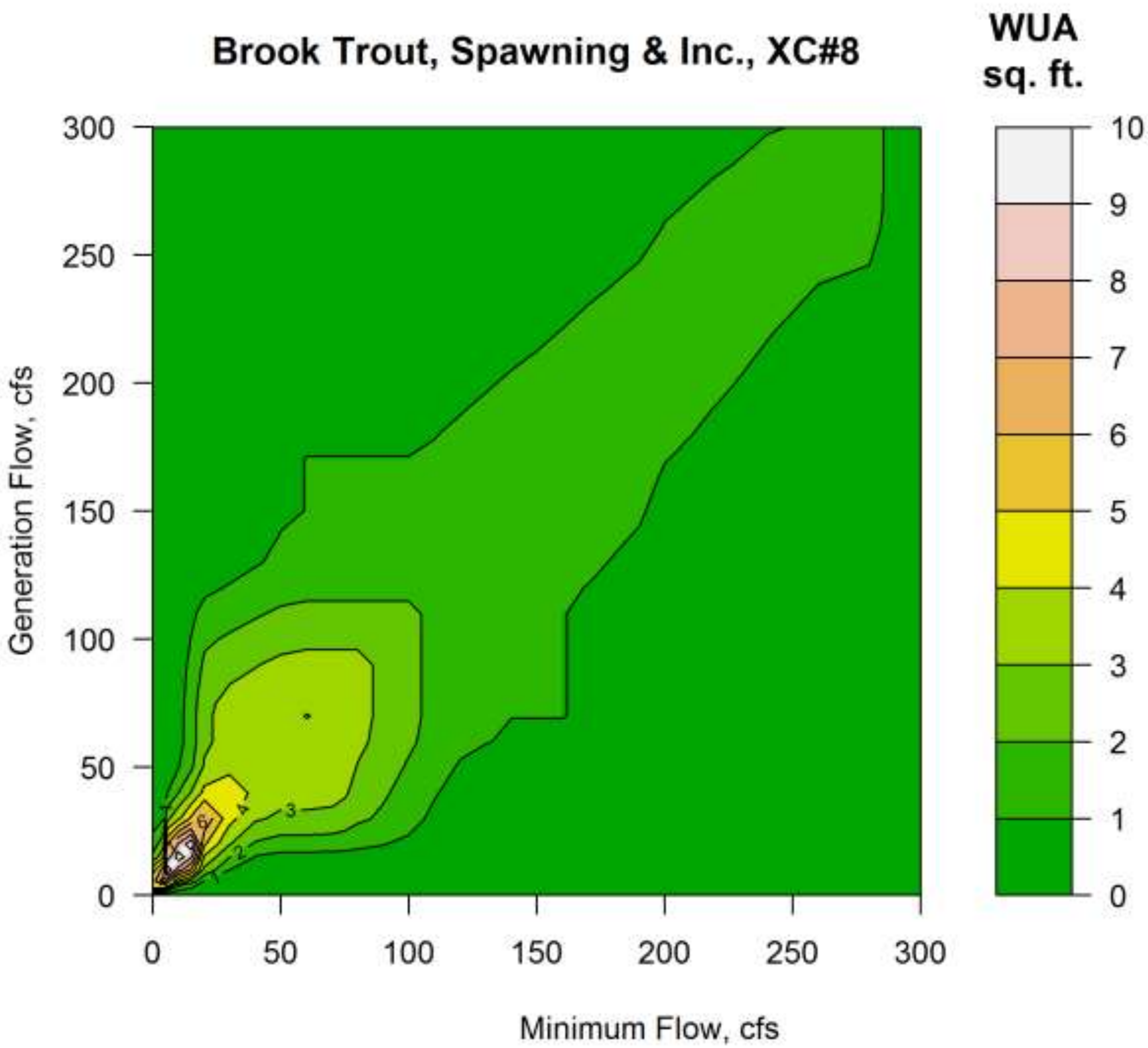

Brook Trout, Spawning & Inc., XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0

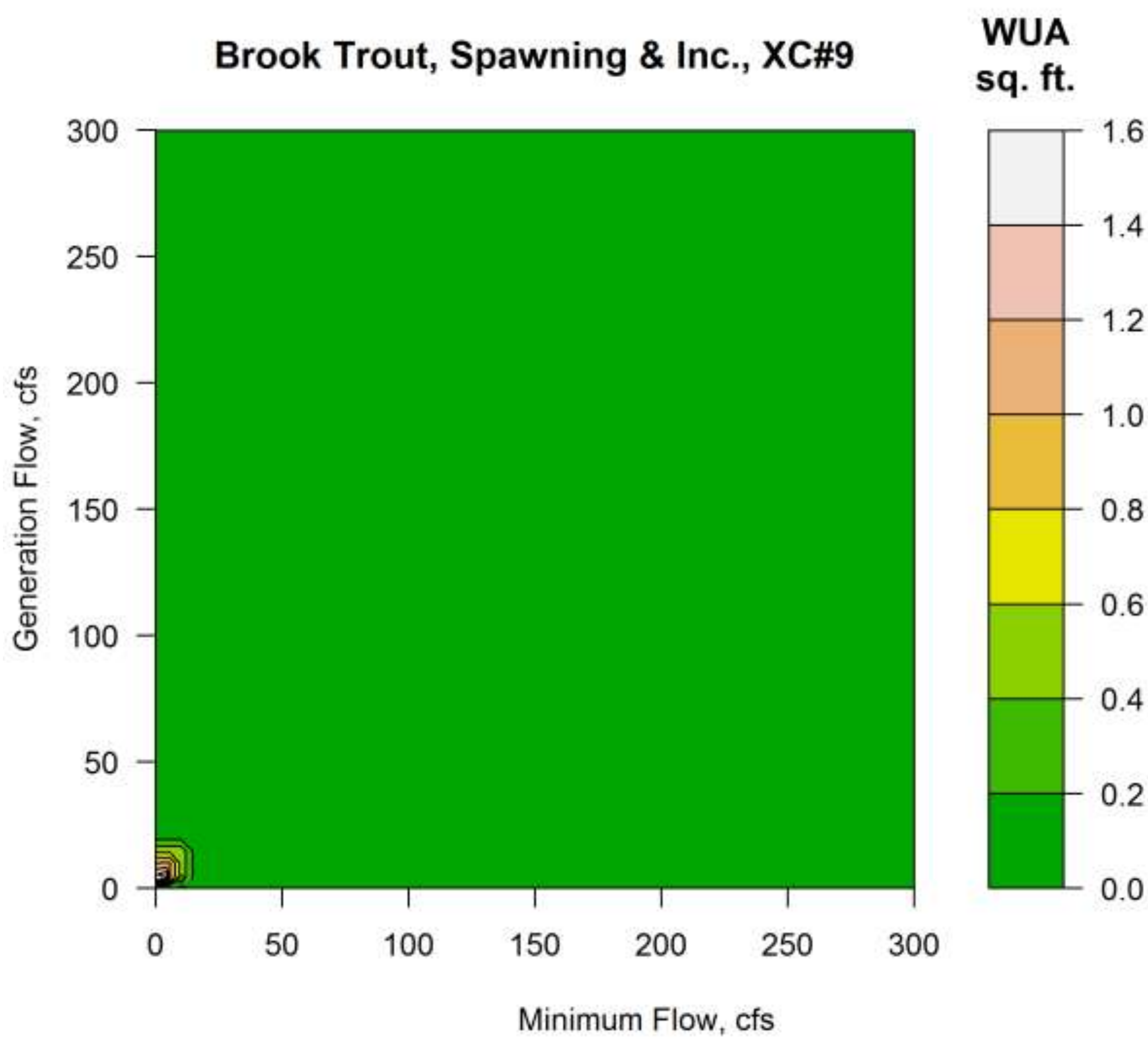

Brook Trout, Spawning & Inc., XC#4
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
1
2
3
4
5
6
7

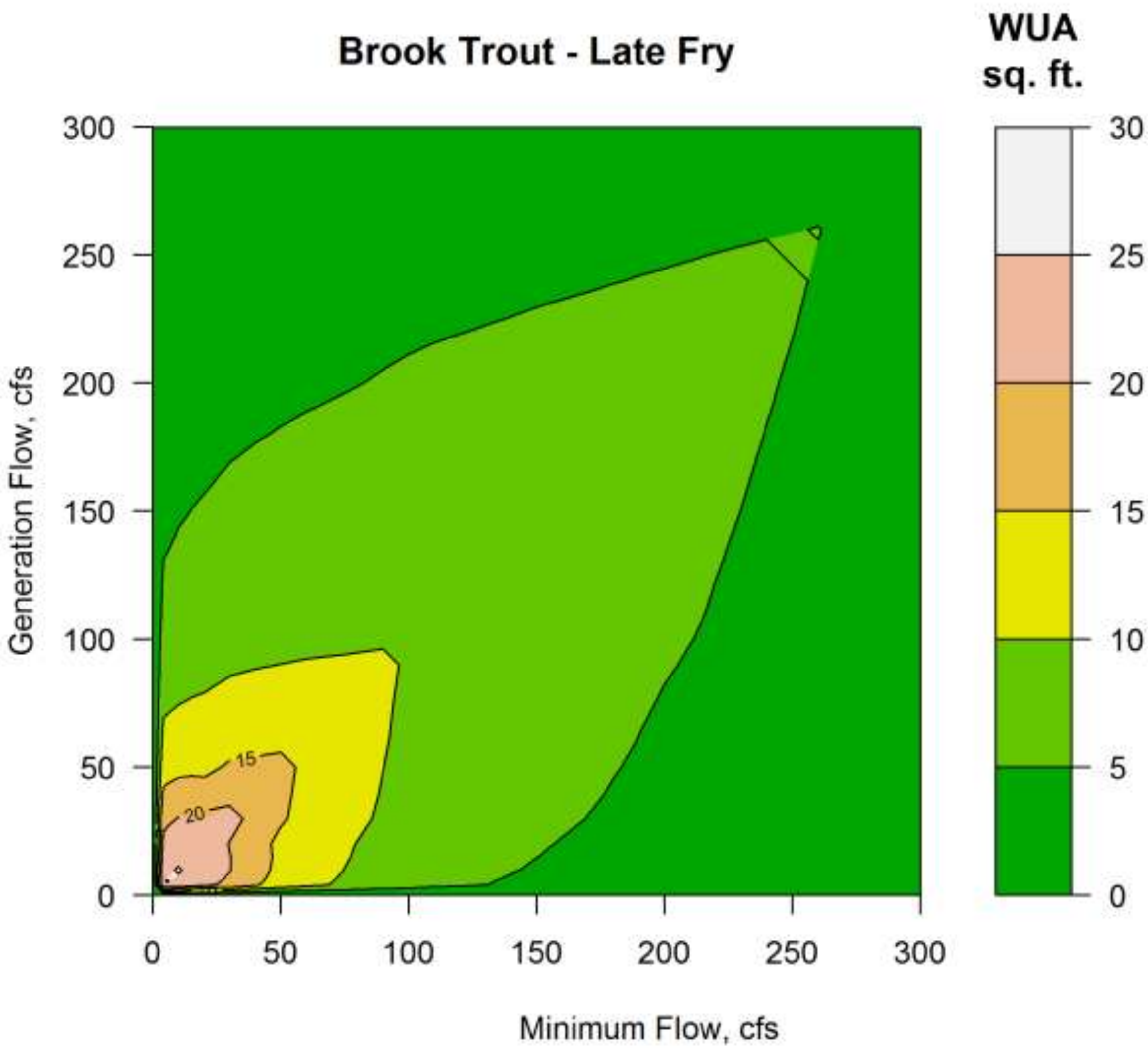

Brook Trout, Spawning & Inc., XC#5
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
10
15
20
25
20
15
10
5
0

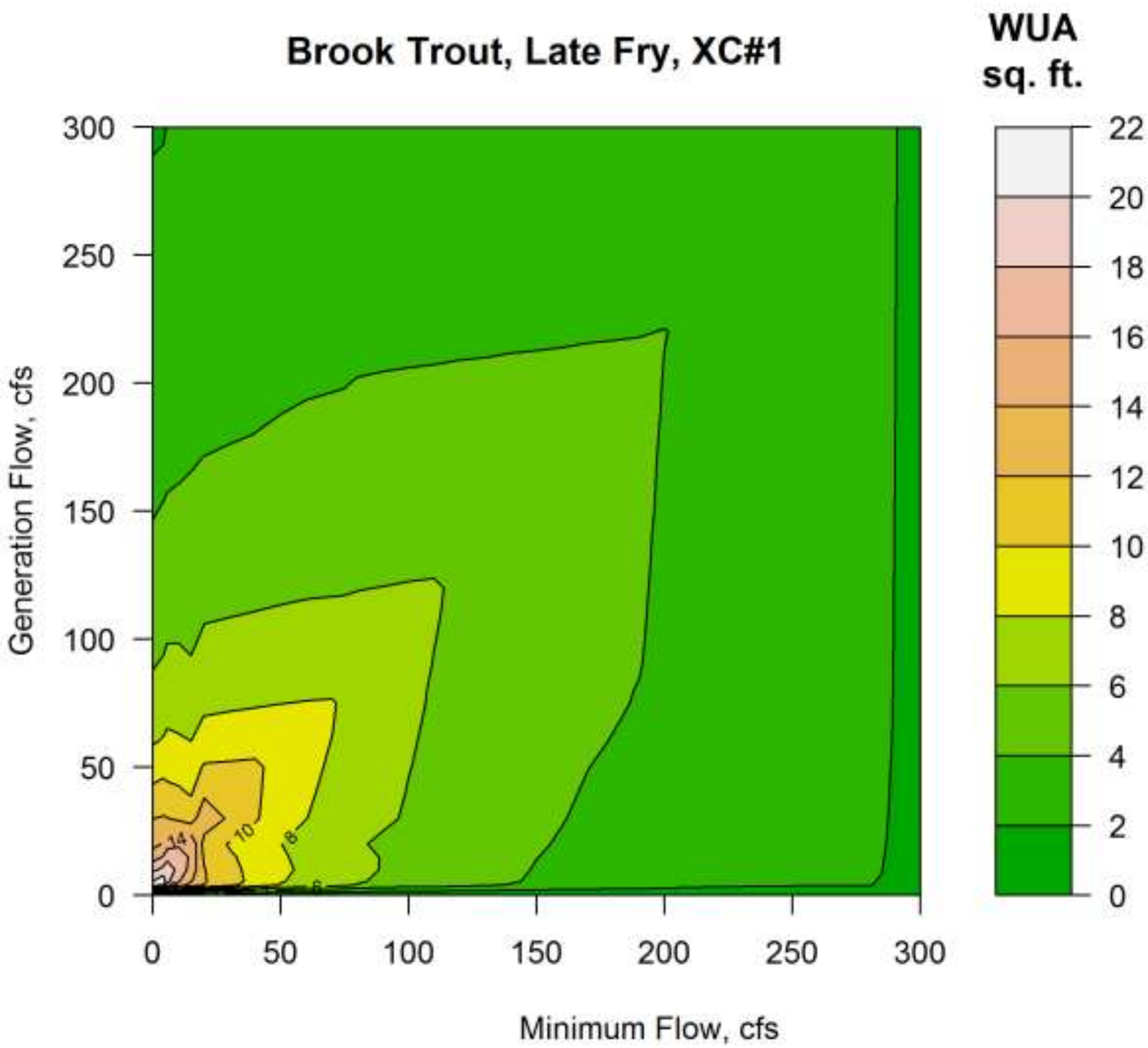

Brook Trout, Spawning & Inc., XC#6
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
10
9
8
7
6
5
4
3
2
1


Brook Trout, Spawning & Inc., XC#7
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

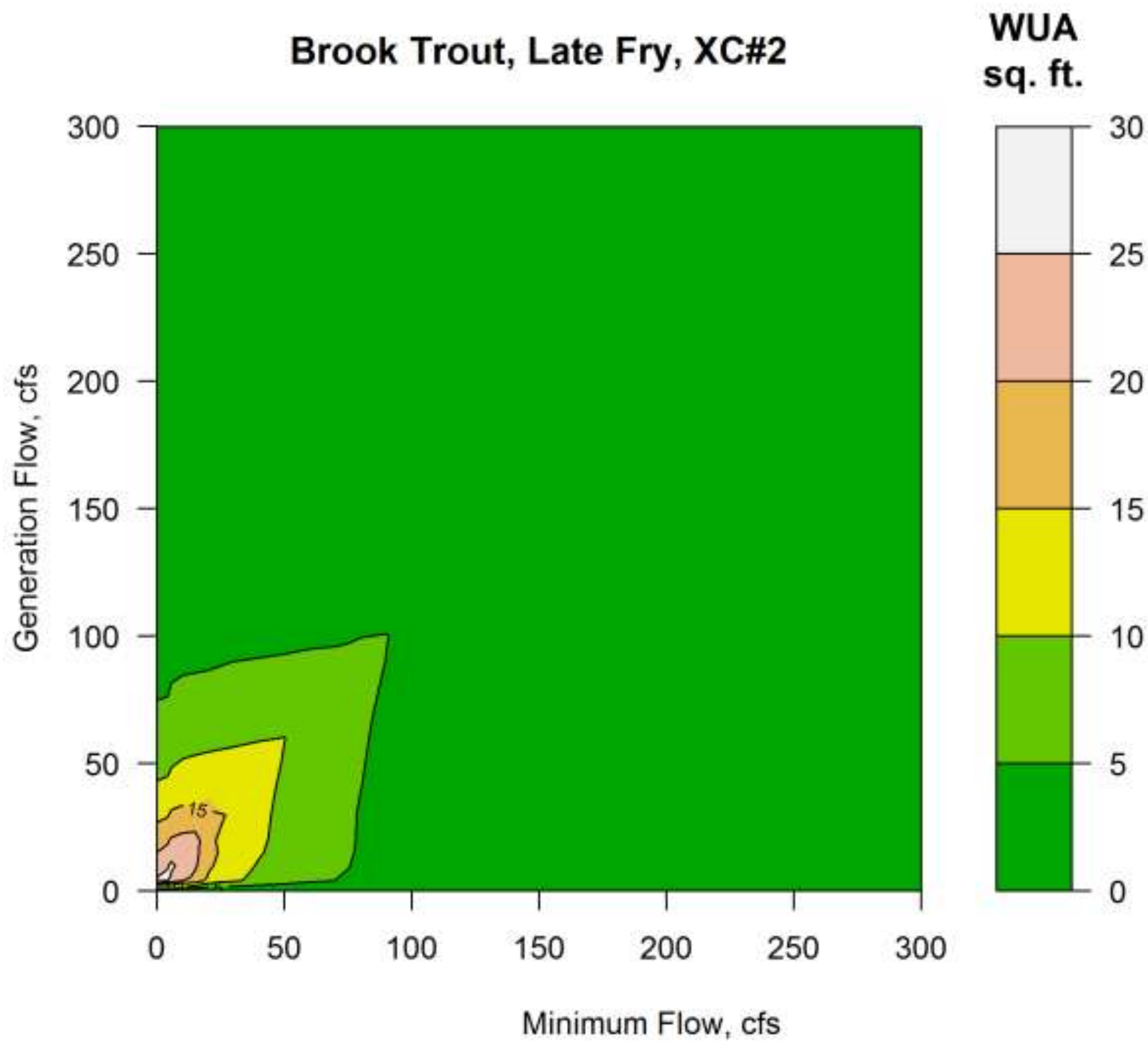

Brook Trout, Spawning & Inc., XC#8
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
10

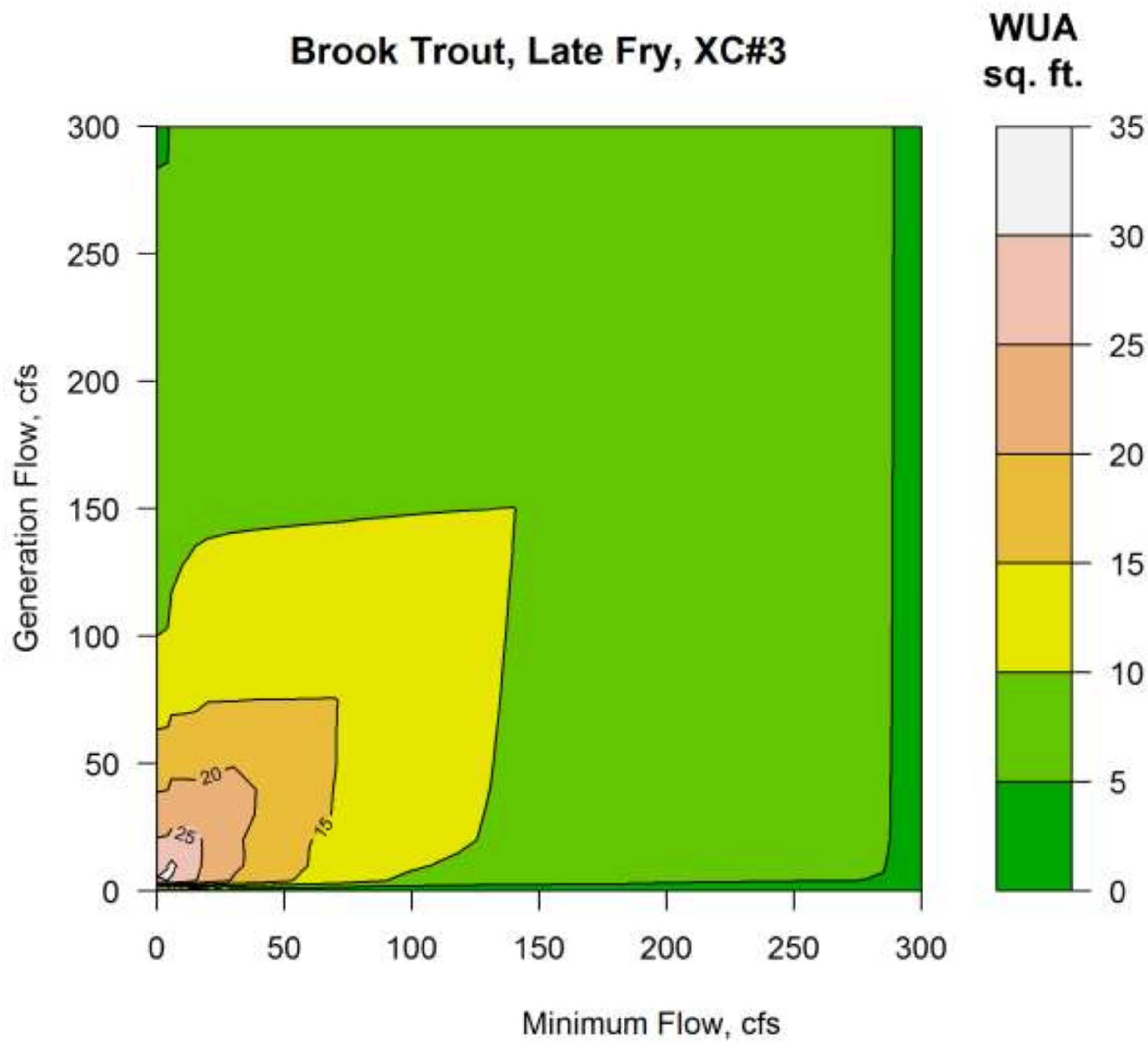

Brook Trout, Spawning & Inc., XC#9
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

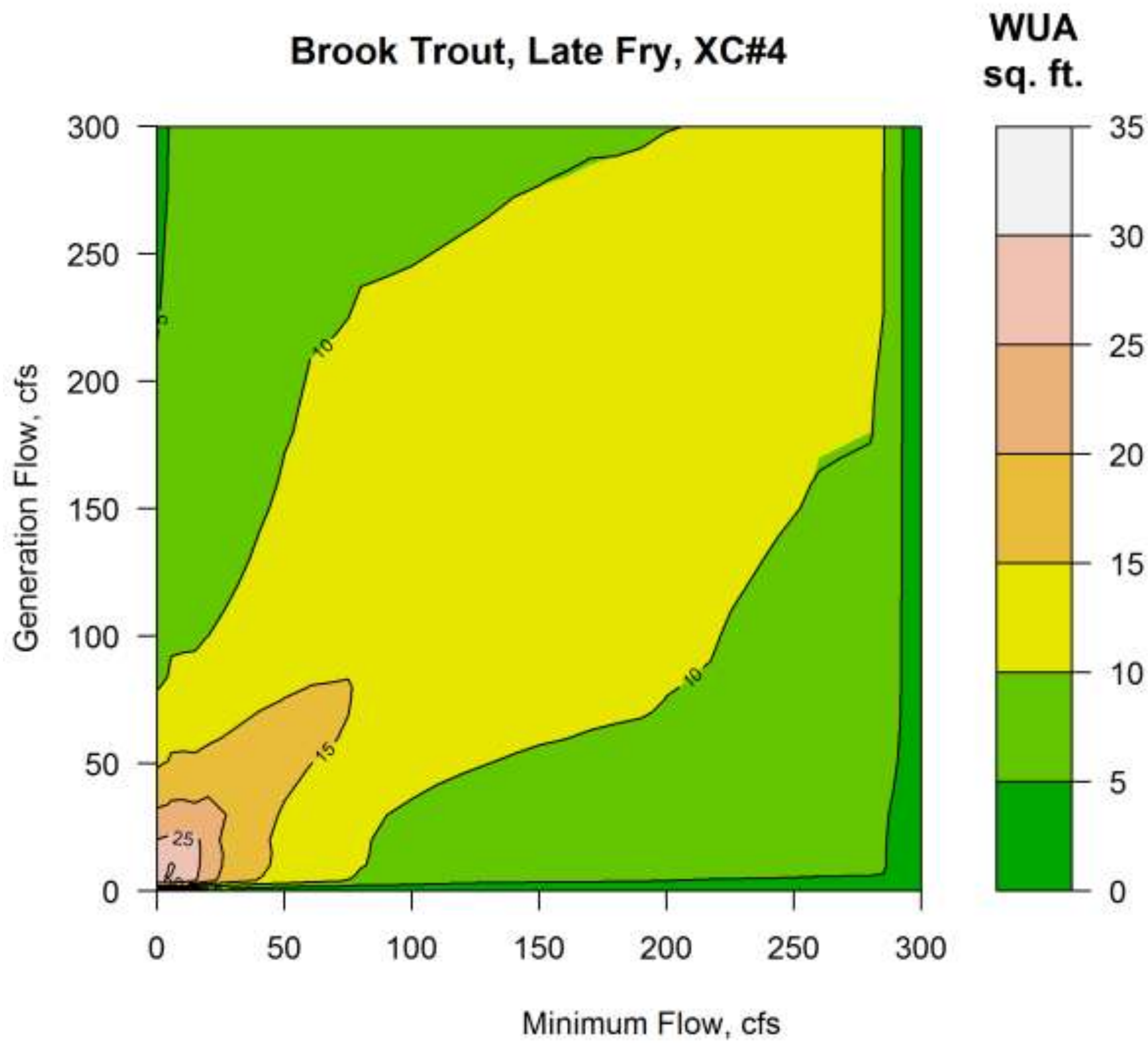

Brook Trout - Late Fry
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
15
20
30
25
20
15
10
5
0

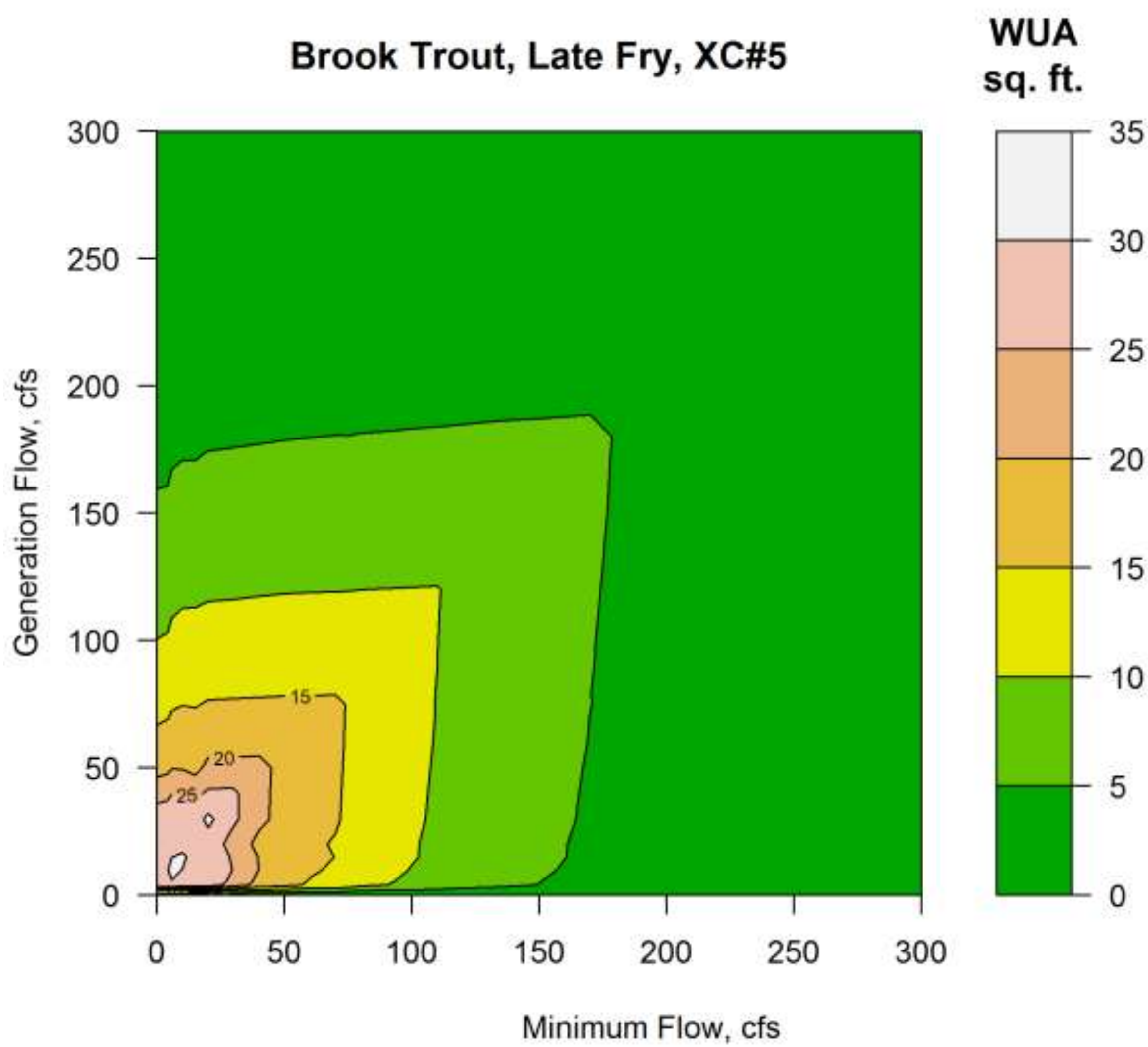


Brook Trout, Late Fry, XC#1
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
300
250
200
150
100
50
0
0
50
100
150
200
250
300
22
20
18
16
14
12
10
8
6
4
2
0

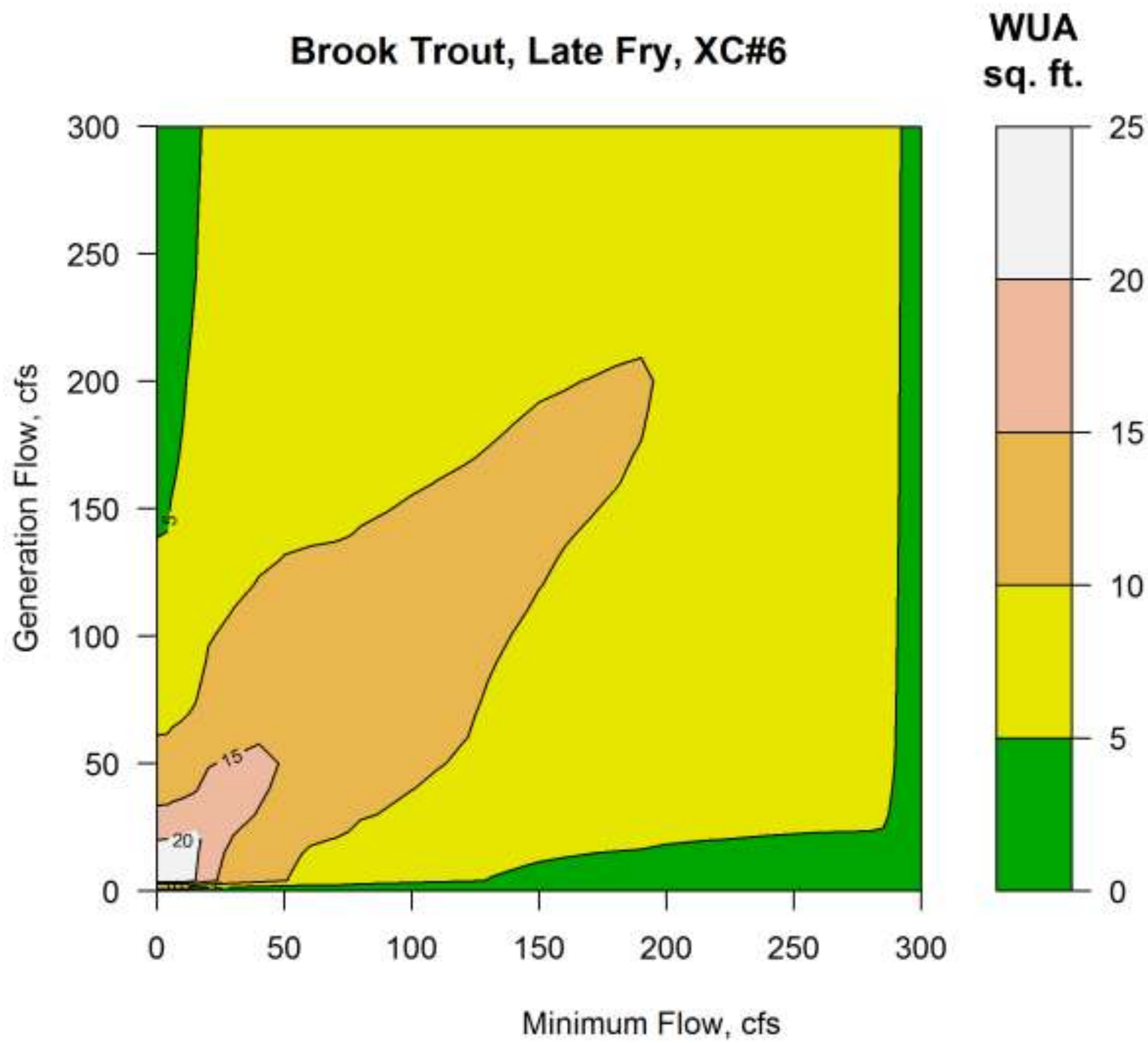

Brook Trout, Late Fry, XC#2
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
15
0
50
100
150
200
250
300
Minimum Flow, cfs
30
25
20
15
10
5
0


Brook Trout, Late Fry, XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
5
10
15
20
25
30
35

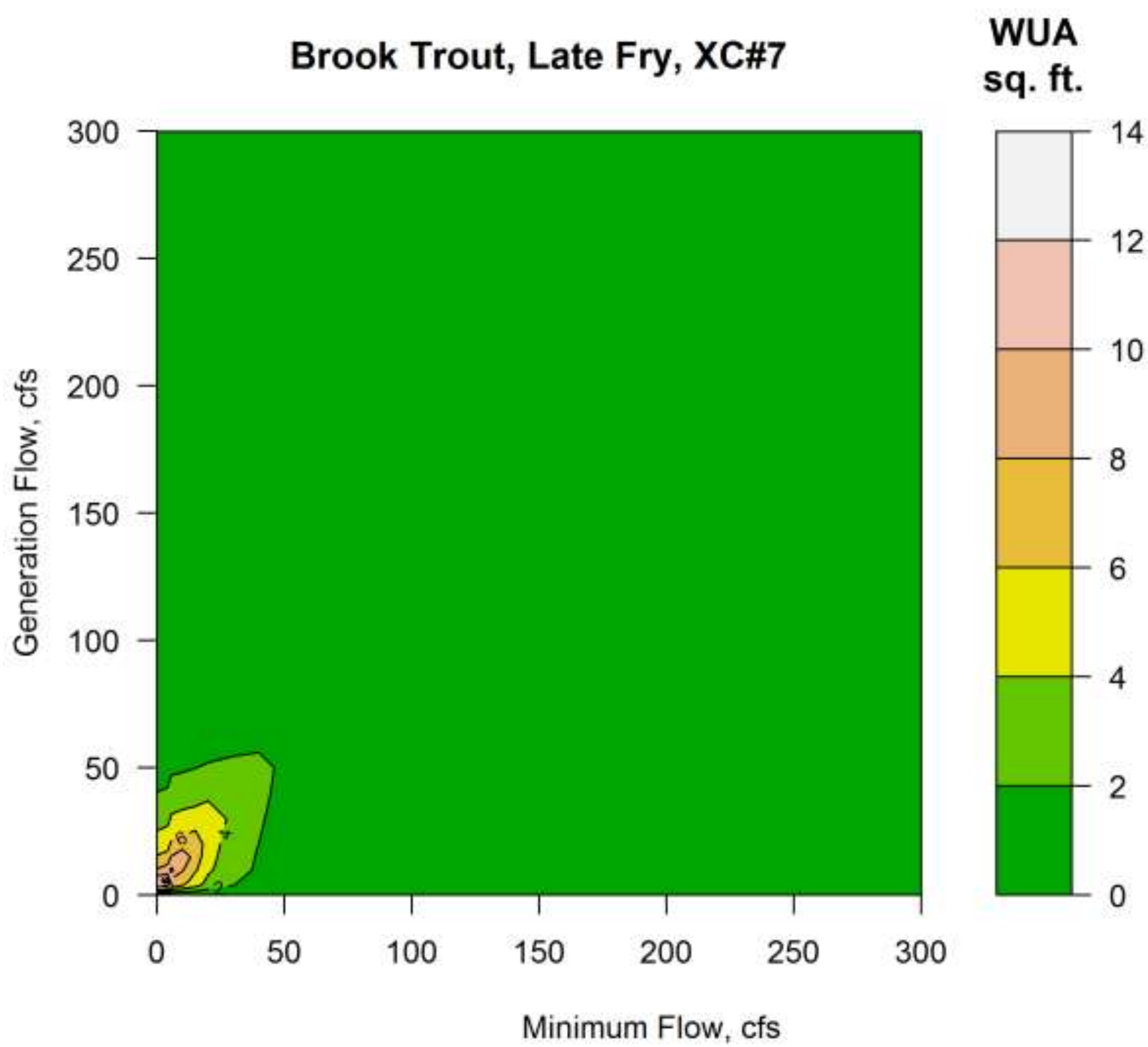

Brook Trout, Late Fry, XC#4
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
35
30
25
20
15
10
5
0
10
15
25
10

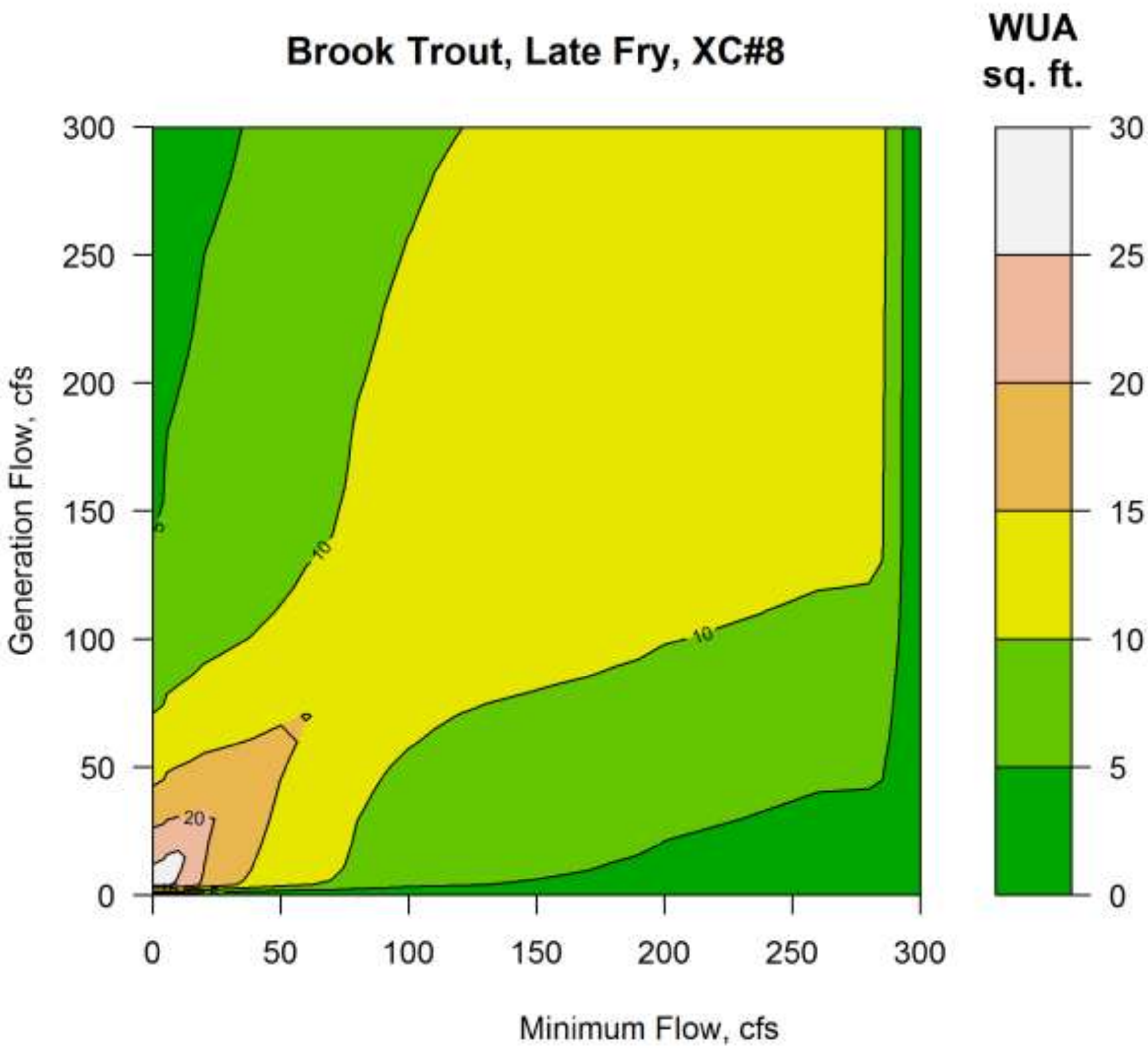


Brook Trout, Late Fry, XC#5
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
15
20
25
35
30
25
20
15
10
5
0

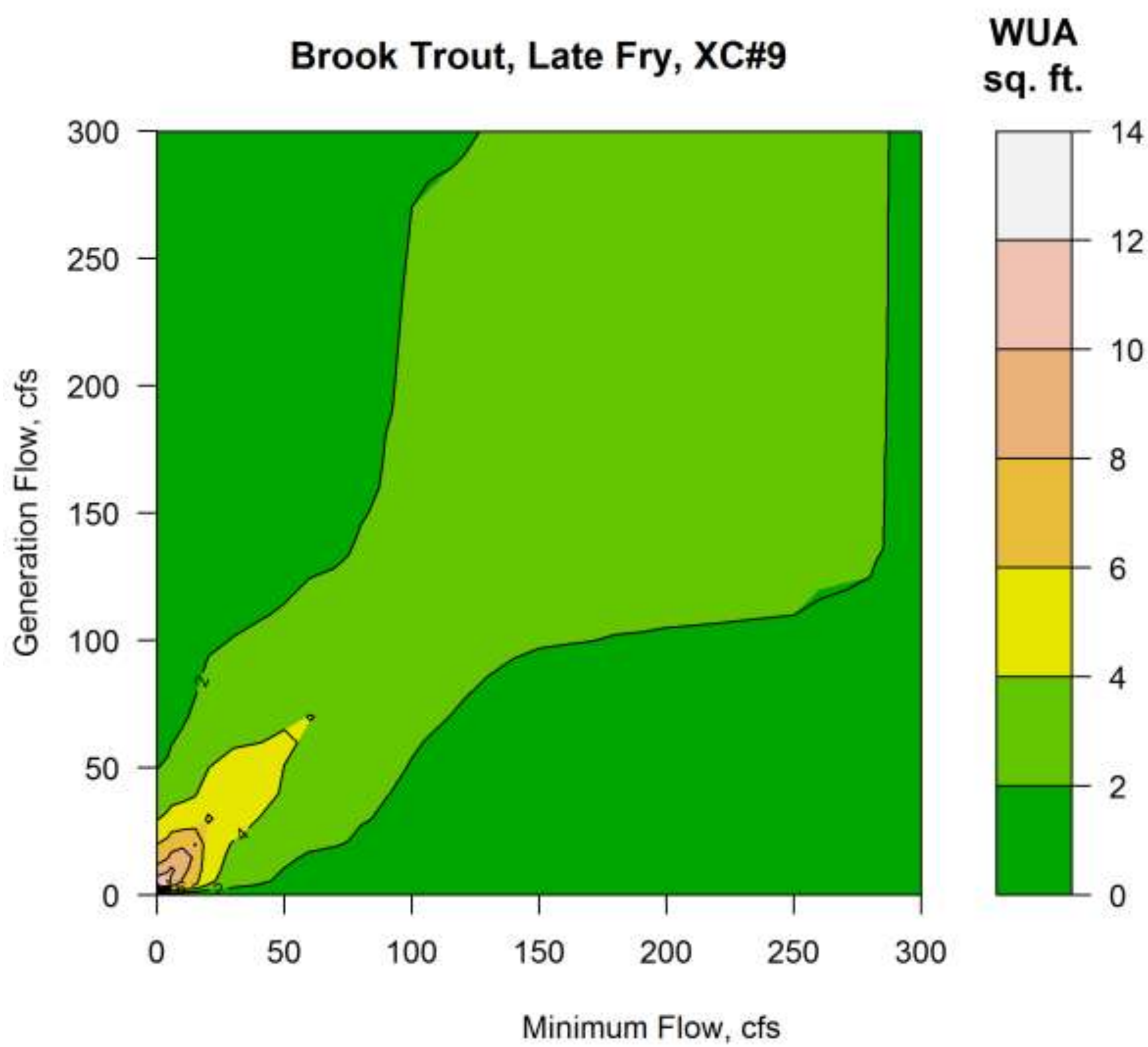


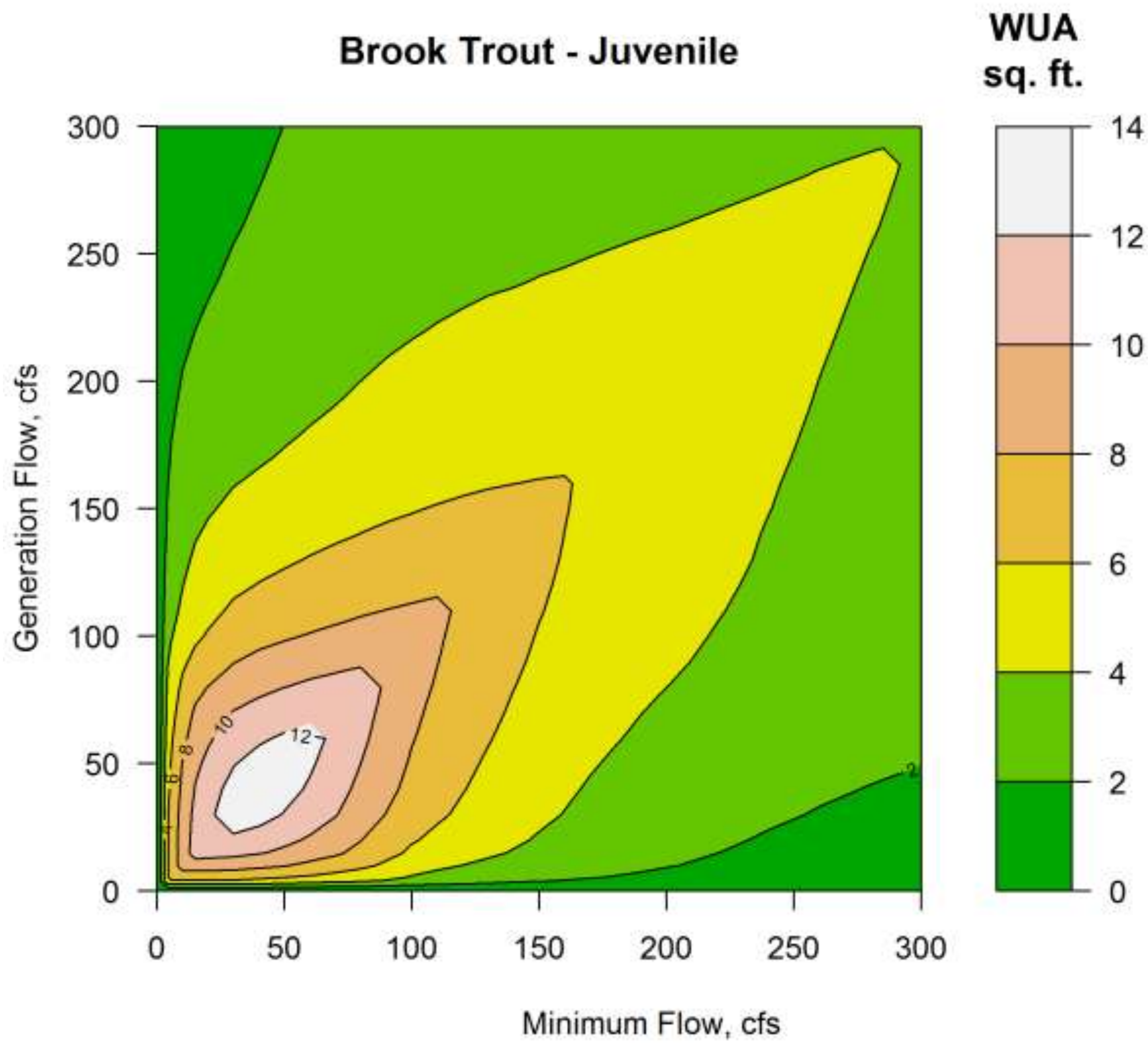
Brook Trout, Late Fry, XC#6
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
25
20
15
10
5
0
15
20


Brook Trout, Late Fry, XC#7
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
14
12
10
8
6
4
2
0

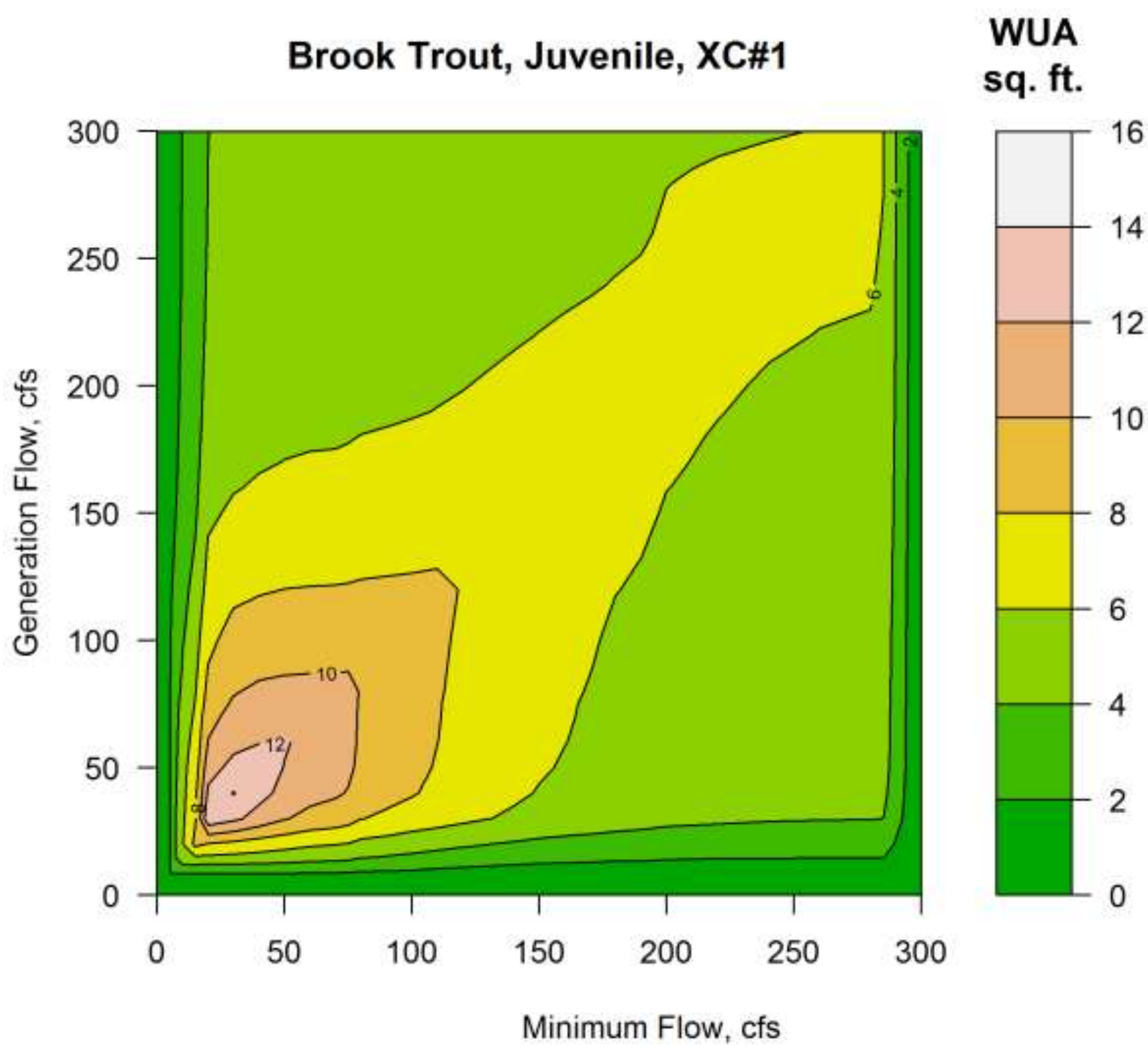


Brook Trout, Late Fry, XC#8
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
30
25
20
15
10
5
0
10
10
20

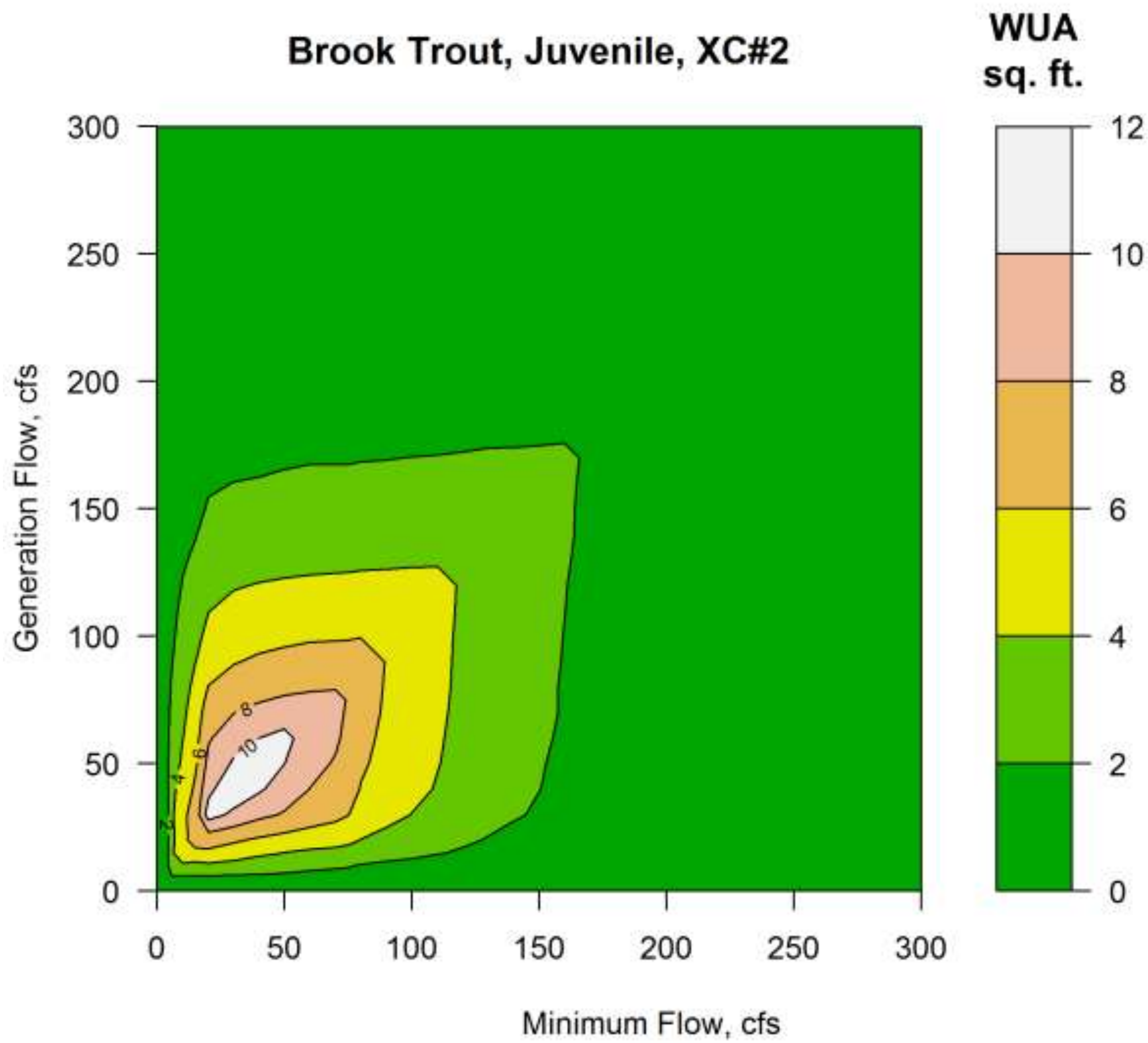

Brook Trout, Late Fry, XC#9
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
2
4
6
8
10
12
14

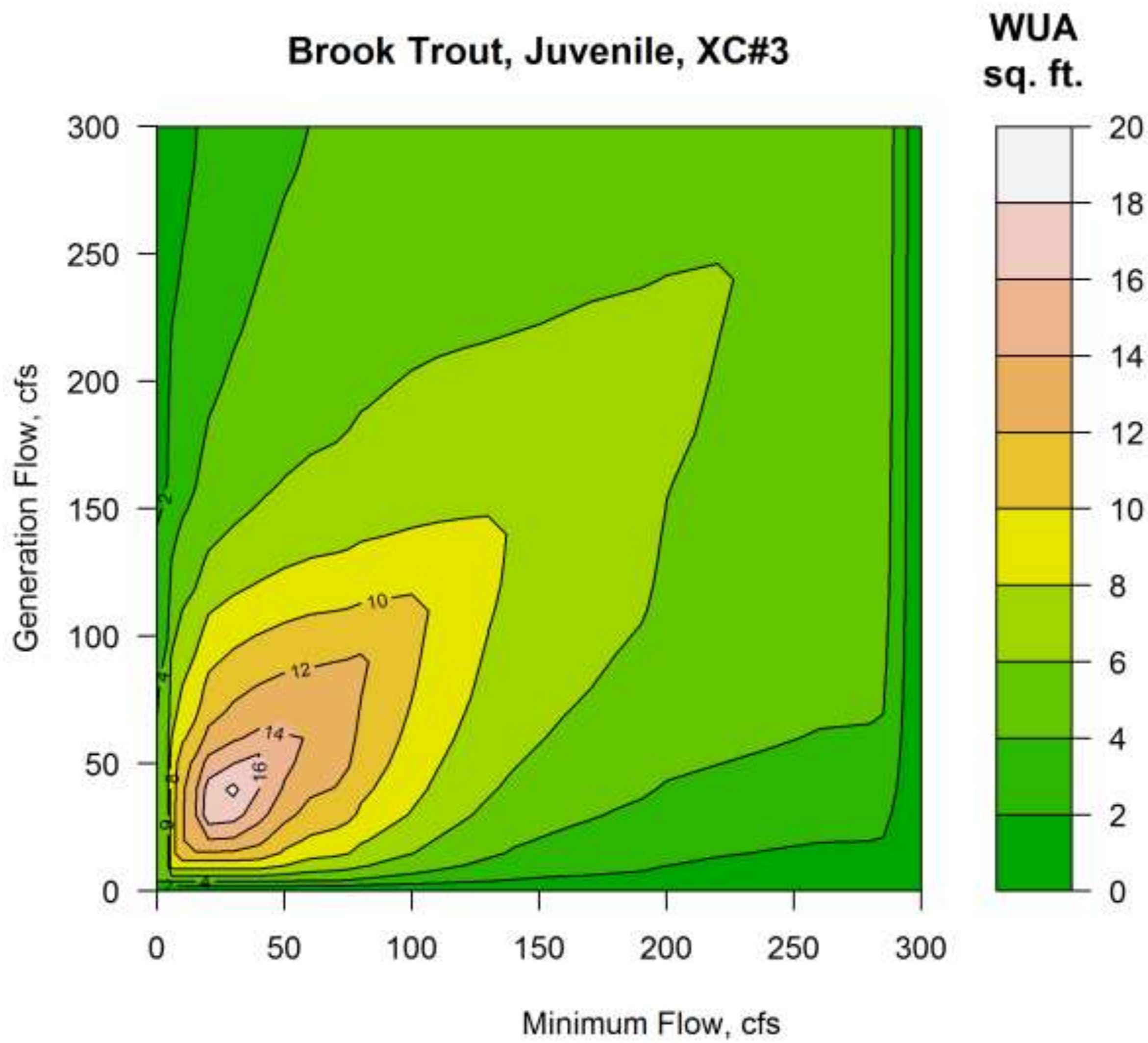


Brook Trout - Juvenile
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
14
12
10
8
6
4
2
0

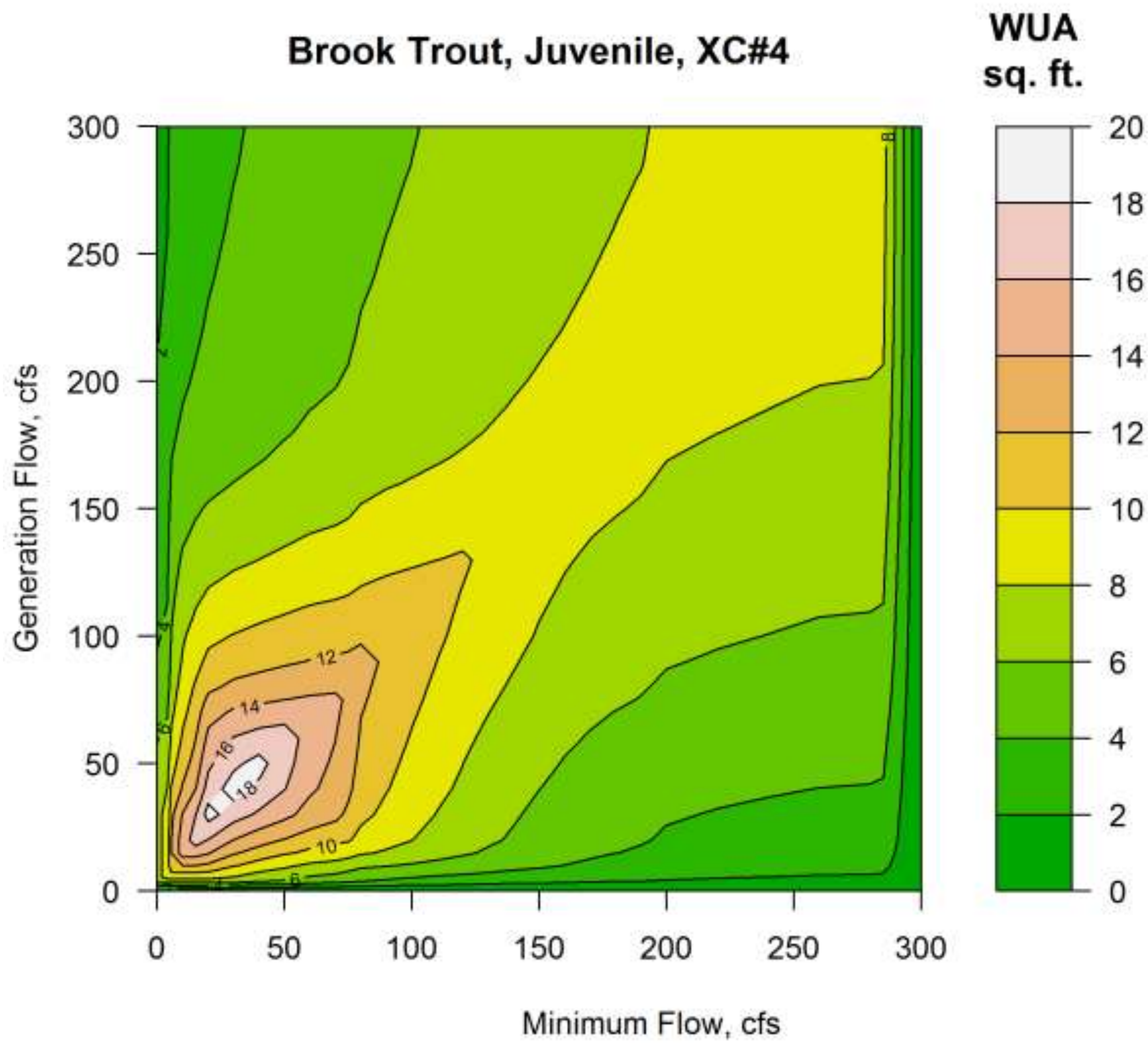


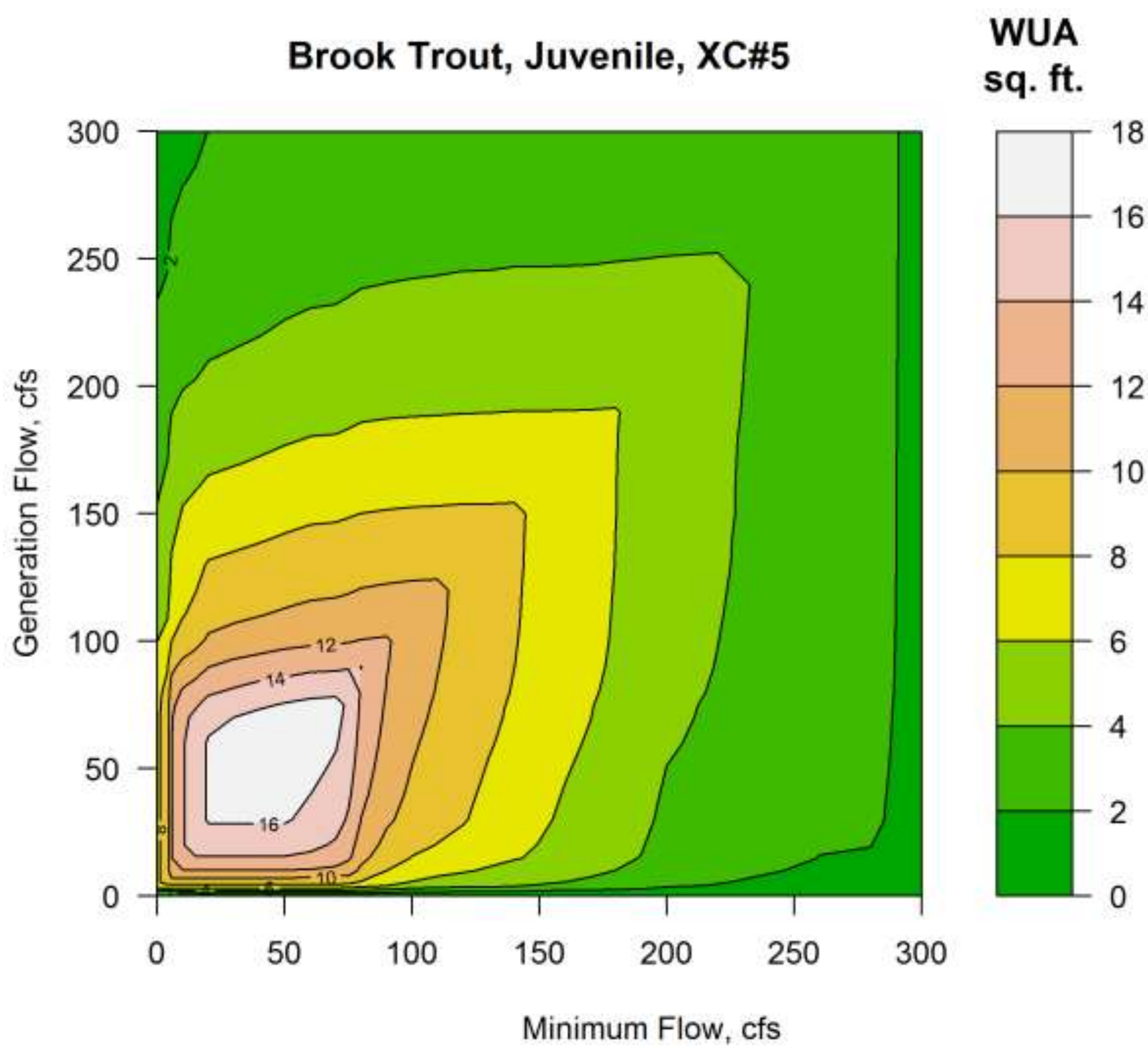
Brook Trout, Juvenile, XC#1
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
10
12
8
6
4
2
16
14
12
10
8
6
4
2
0

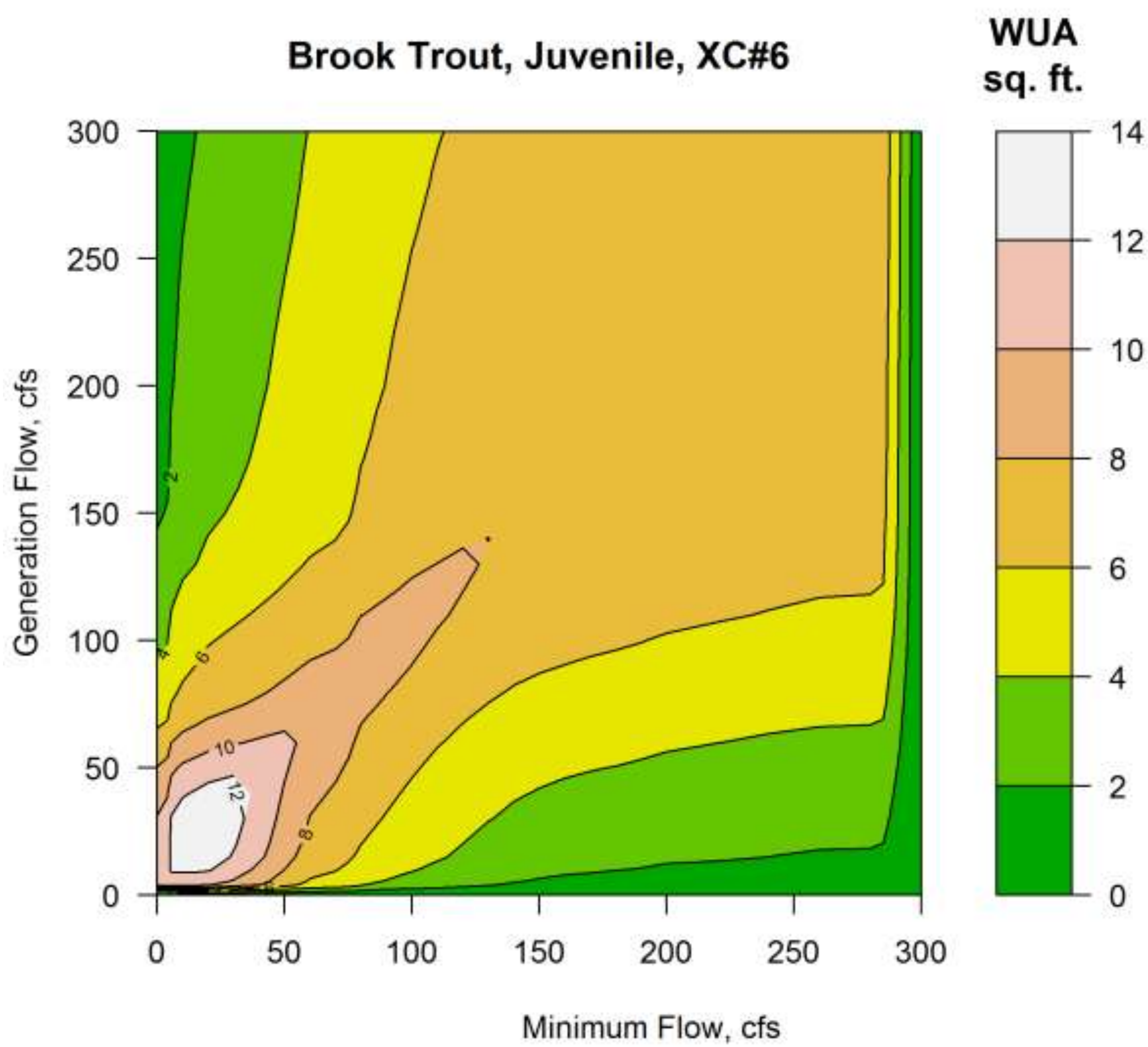

Brook Trout, Juvenile, XC#2
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
2
4
6
8
10
12

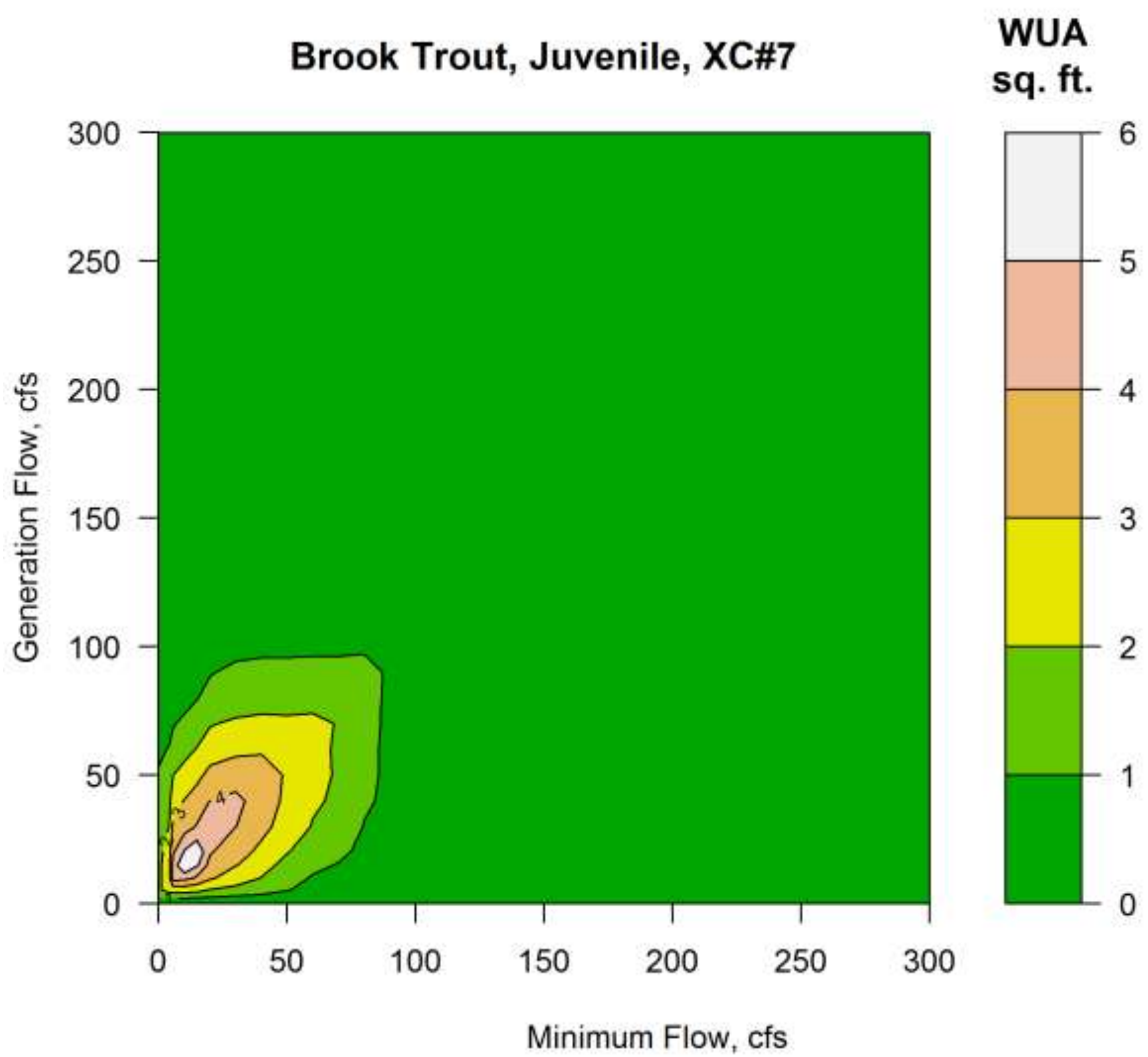


Brook Trout, Juvenile, XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
2
4
6
8
10
12
14
16
18
20

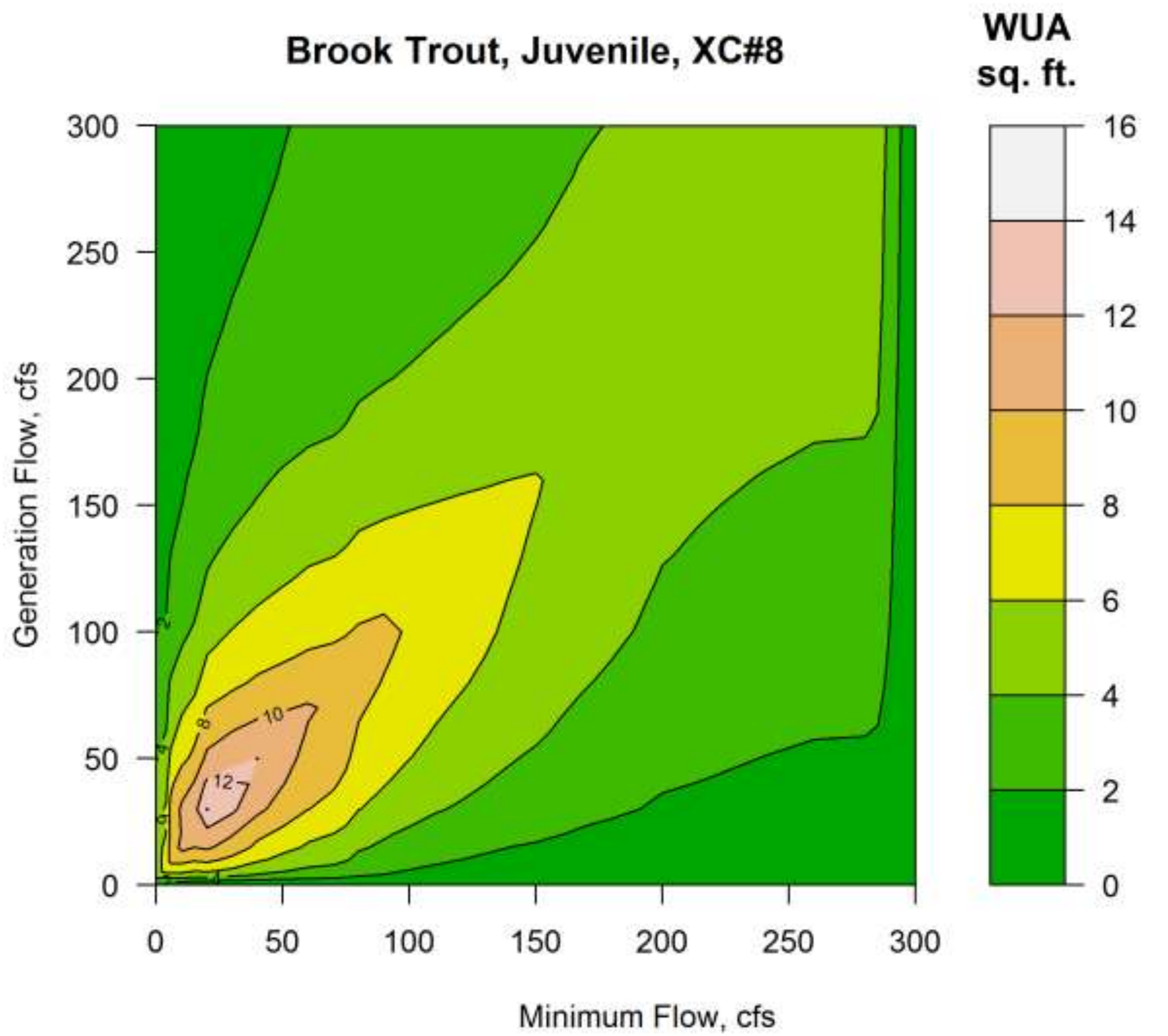

Brook Trout, Juvenile, XC#4
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
20
18
16
14
12
10
8
6
4
2
0

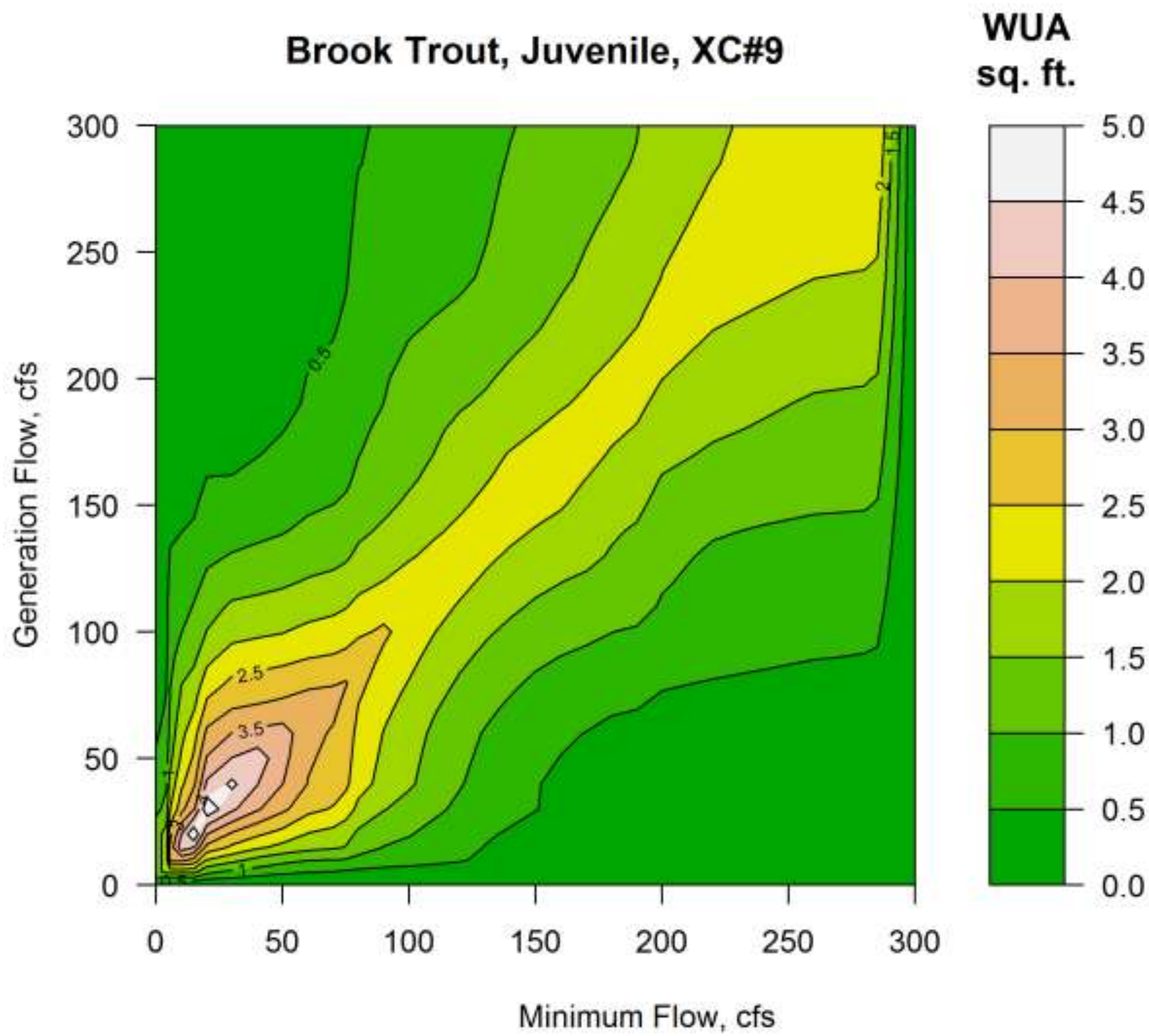

Brook Trout, Juvenile, XC#5
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
2
4
6
8
10
12
14
16
18

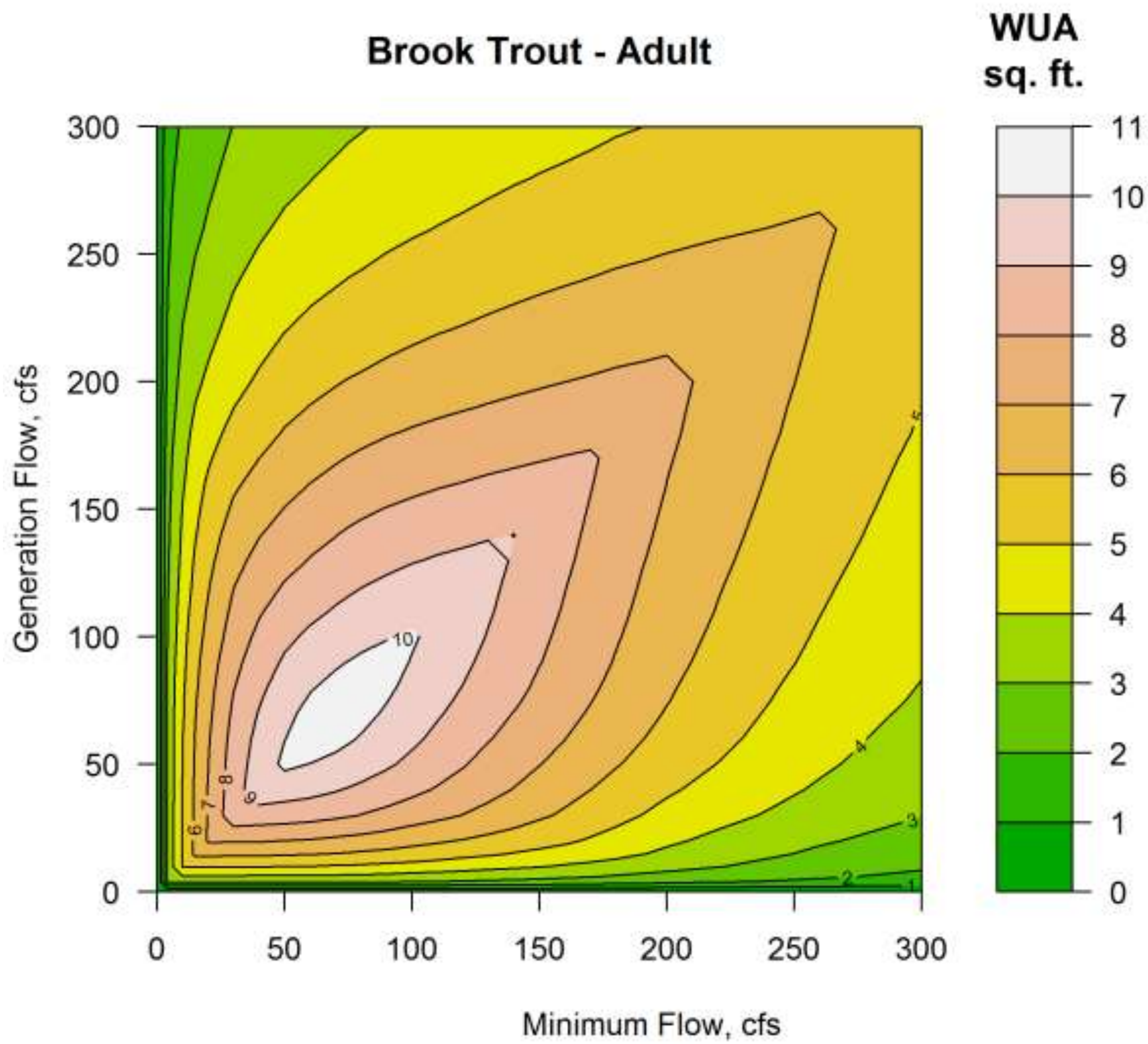

Brook Trout, Juvenile, XC#6
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
2
4
6
8
10
12
14

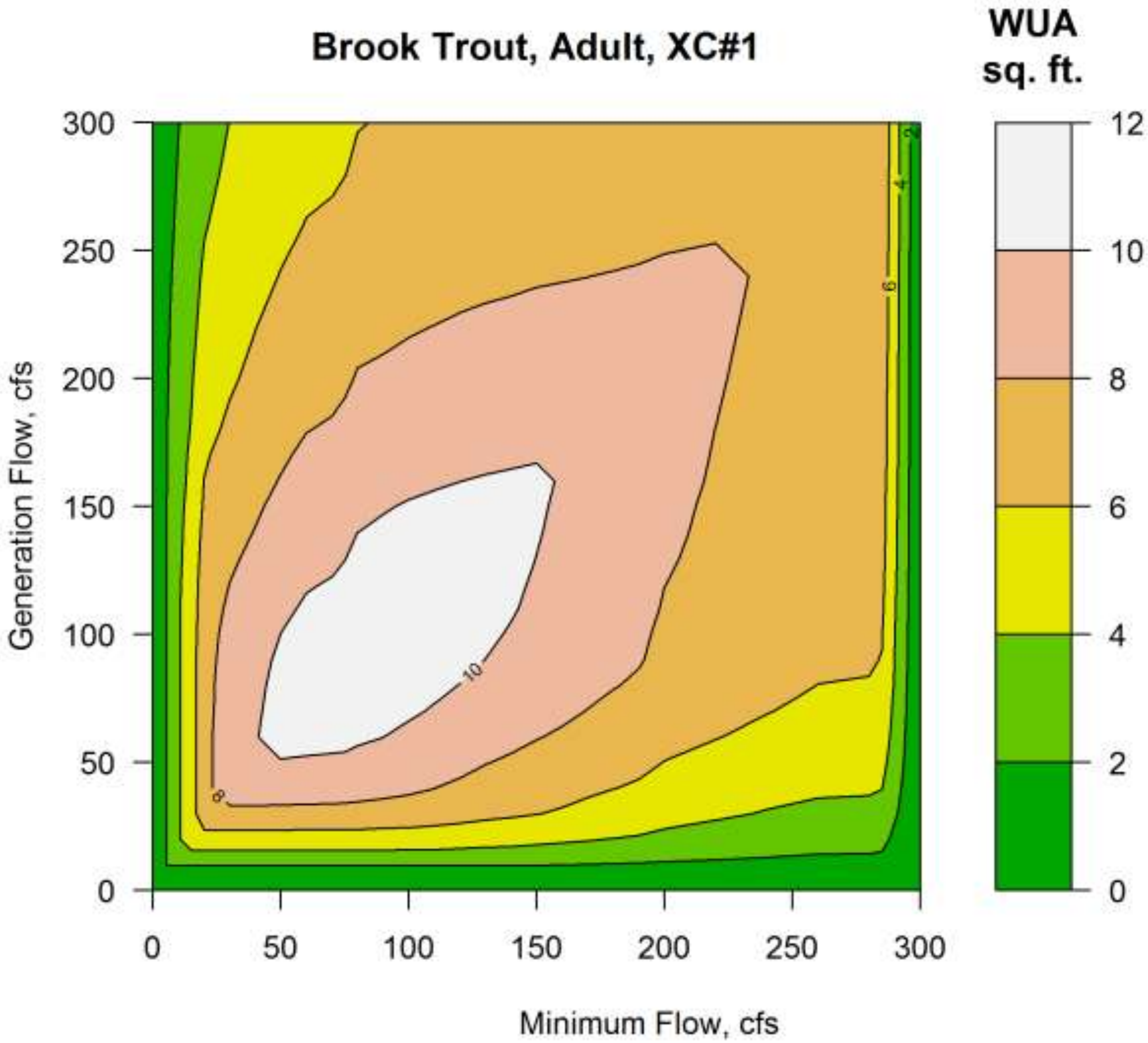


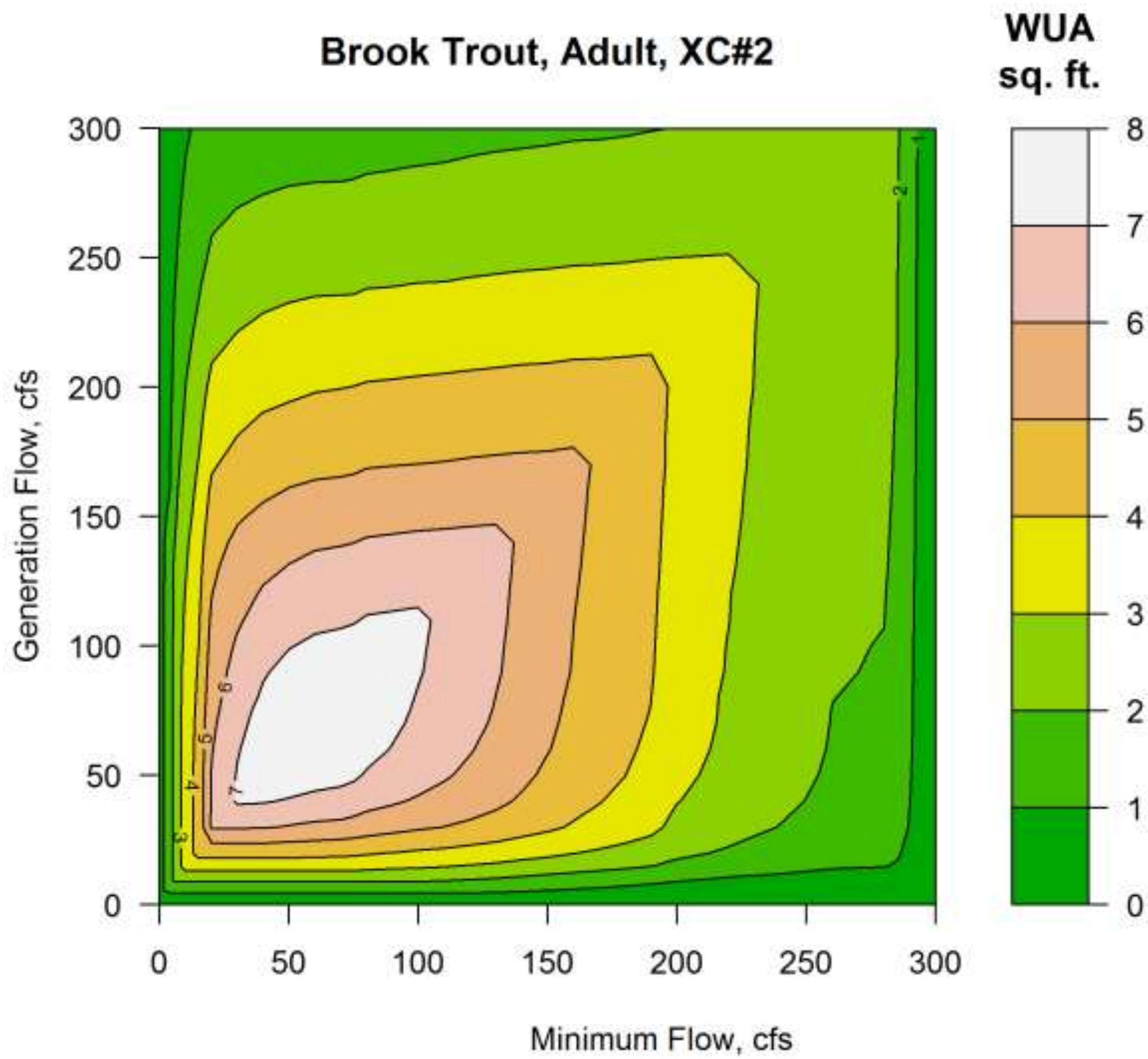
Brook Trout, Juvenile, XC#7
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
300
250
200
150
100
50
0
0
50
100
150
200
250
300
6
5
4
3
2
1
0

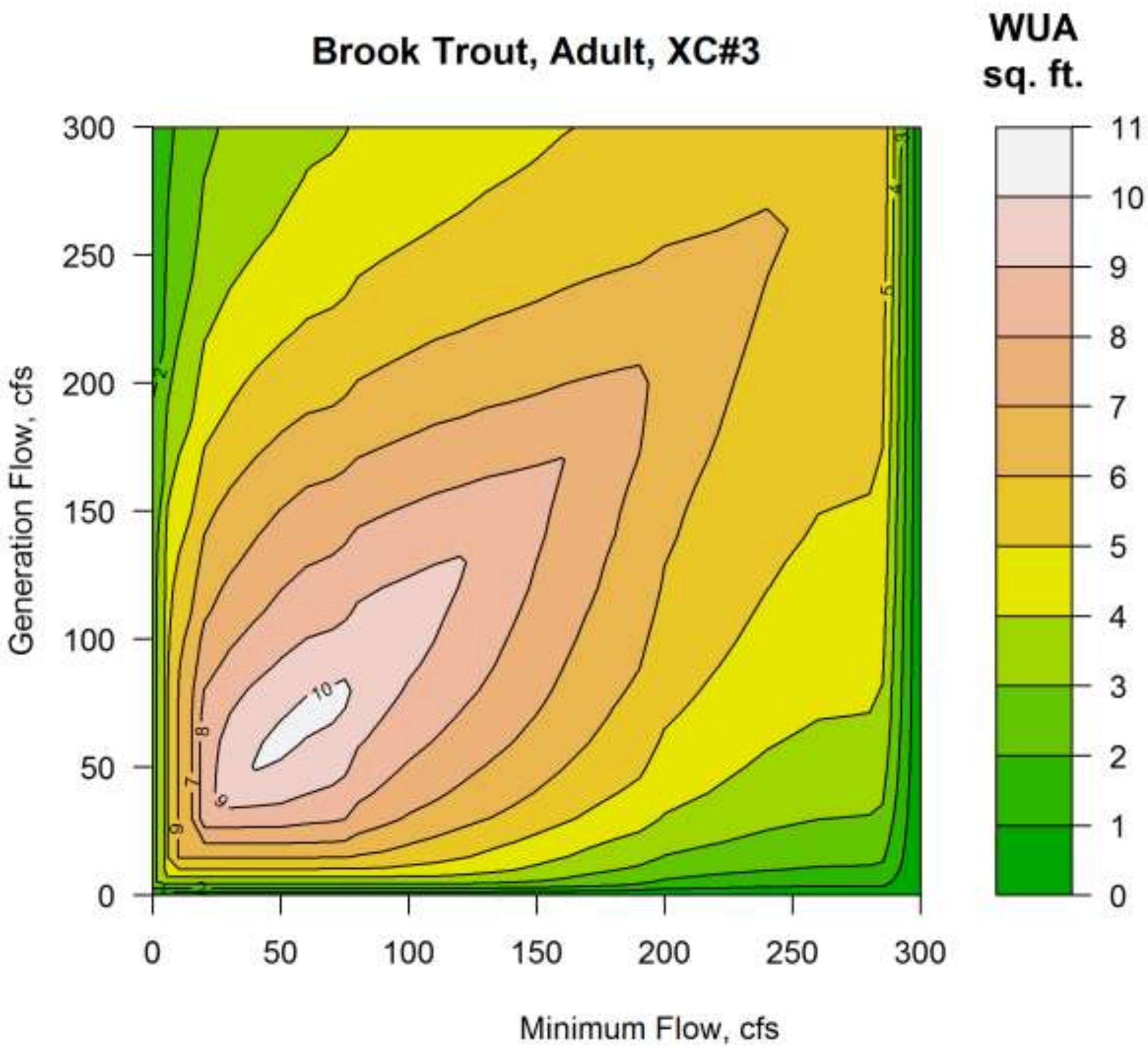

Brook Trout, Juvenile, XC#8
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
16
14
12
10
8
6
4
2
0


Brook Trout, Juvenile, XC#9
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
300
250
200
150
100
50
0
0
50
100
150
200
250
300
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

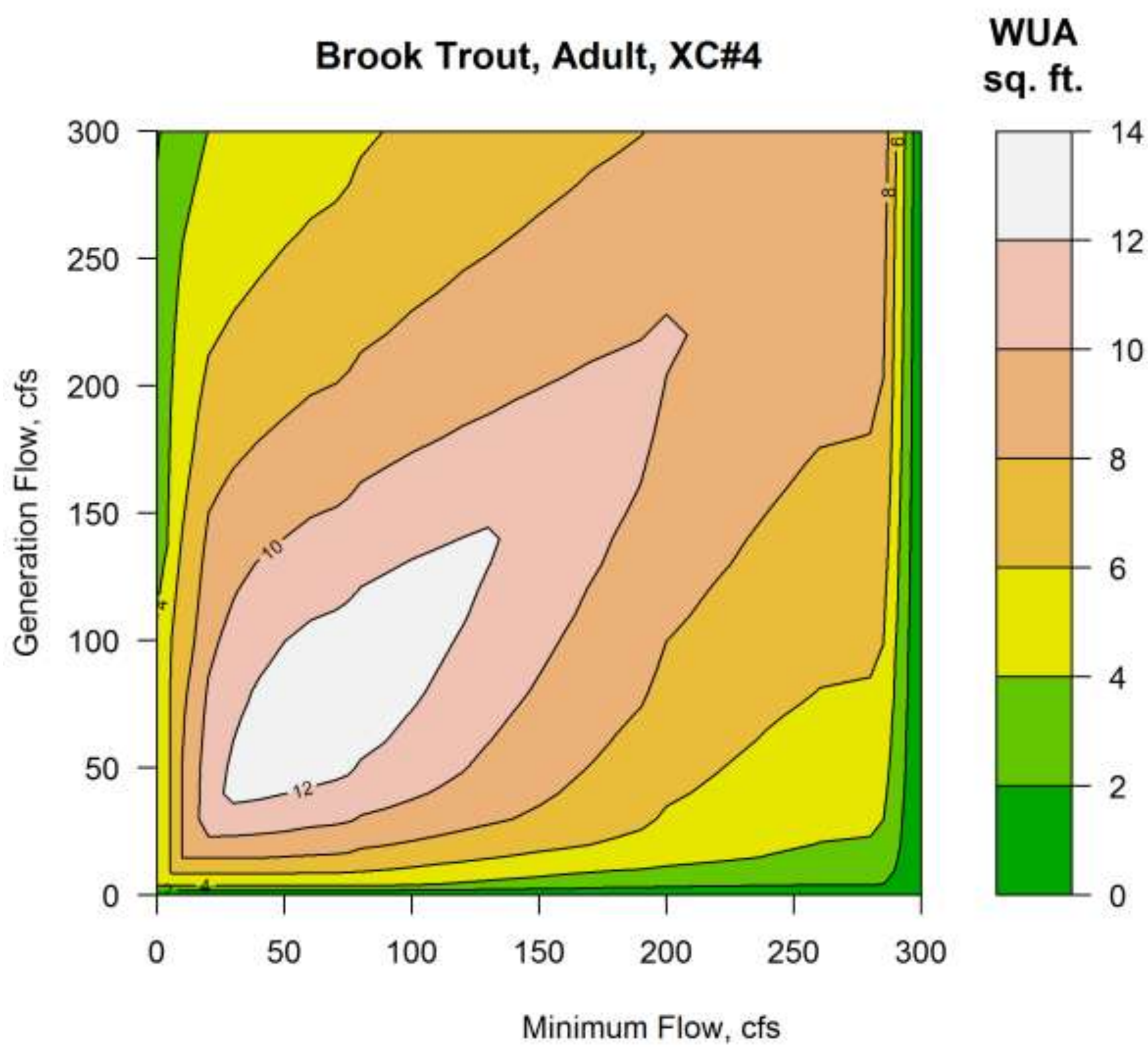

Brook Trout - Adult
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
10
11


Brook Trout, Adult, XC#1
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
12
10
8
6
4
2
0

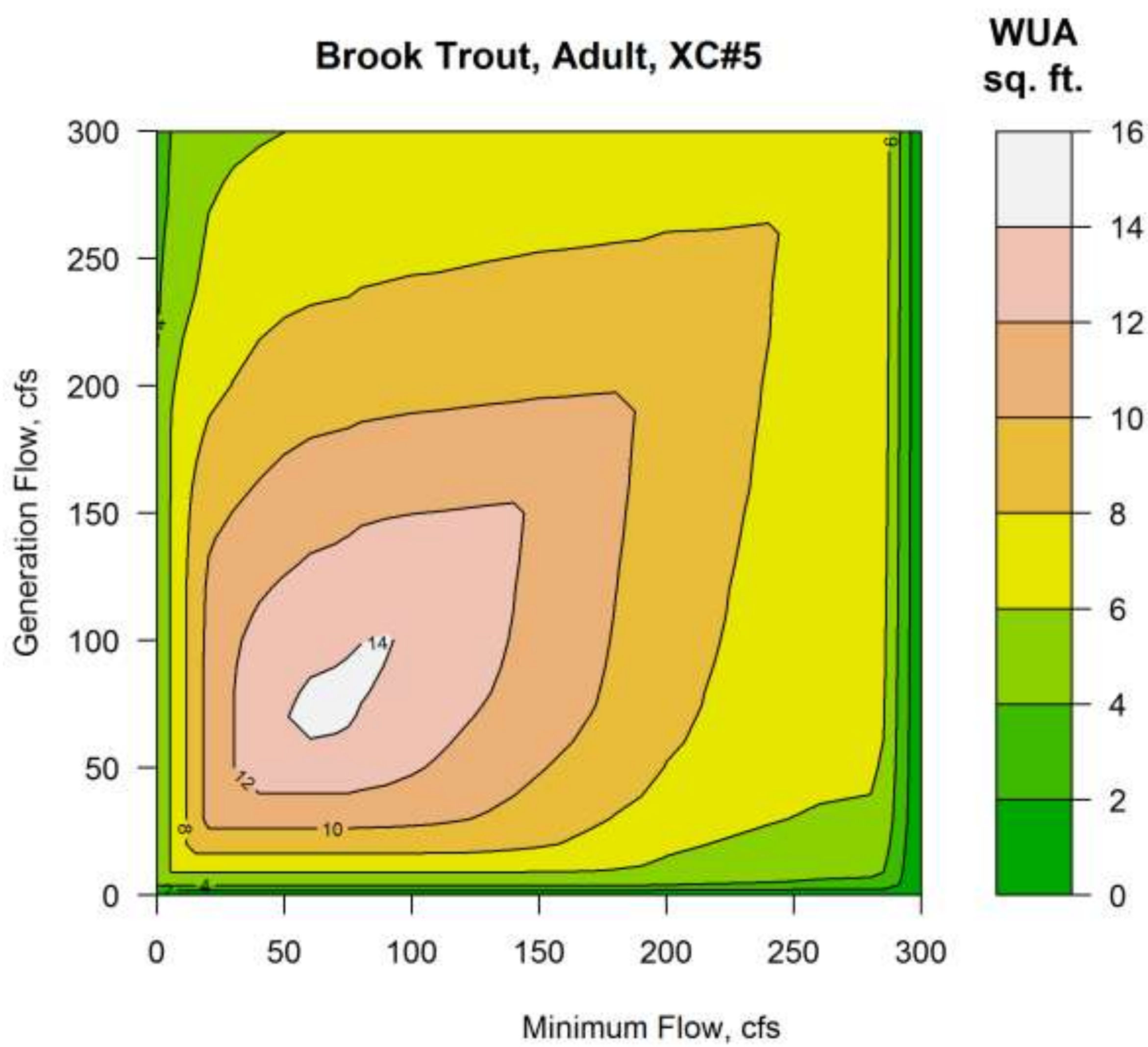

Brook Trout, Adult, XC#2
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8



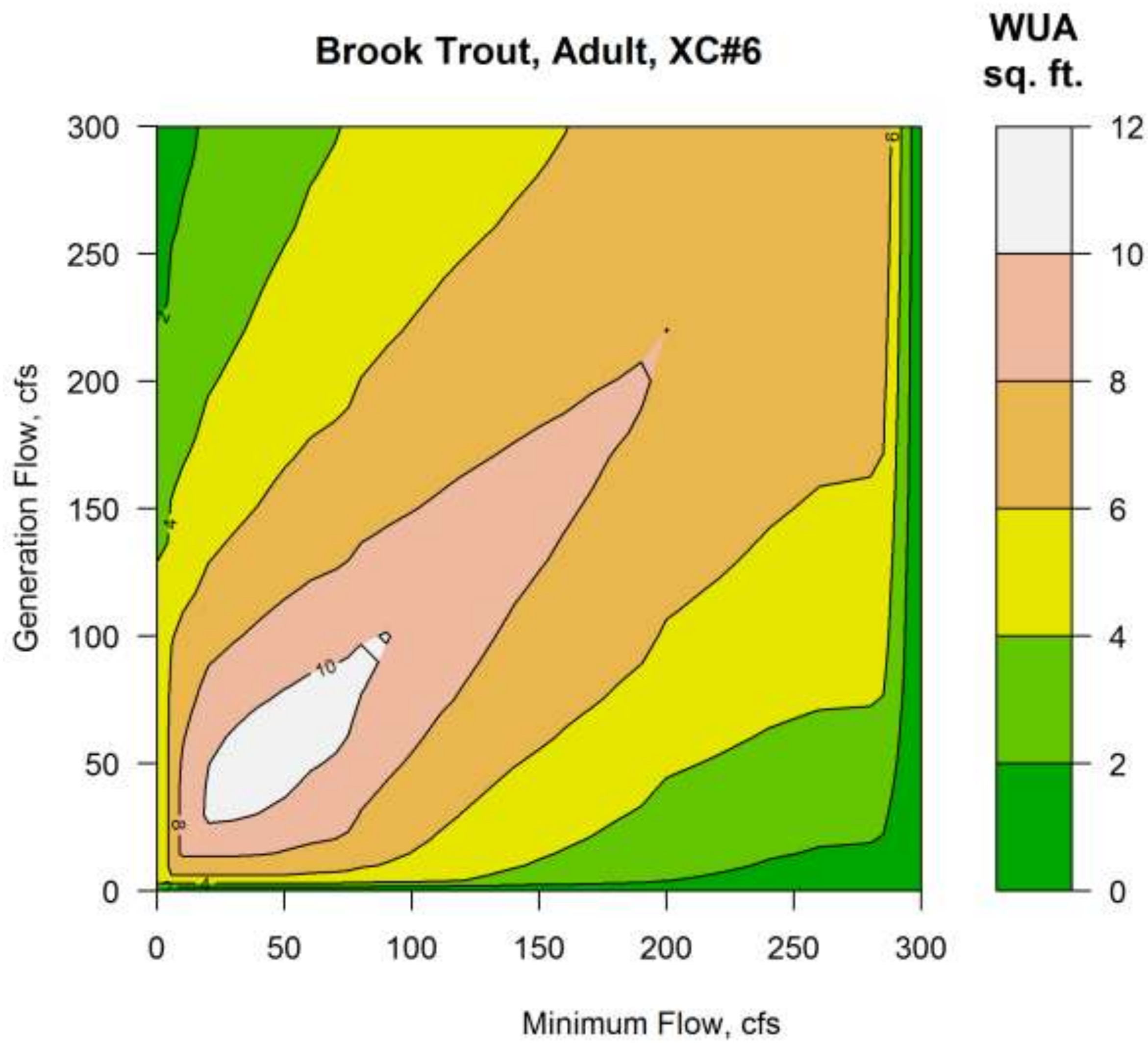
Brook Trout, Adult, XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
0
1
2
3
4
5
6
7
8
9
10
11



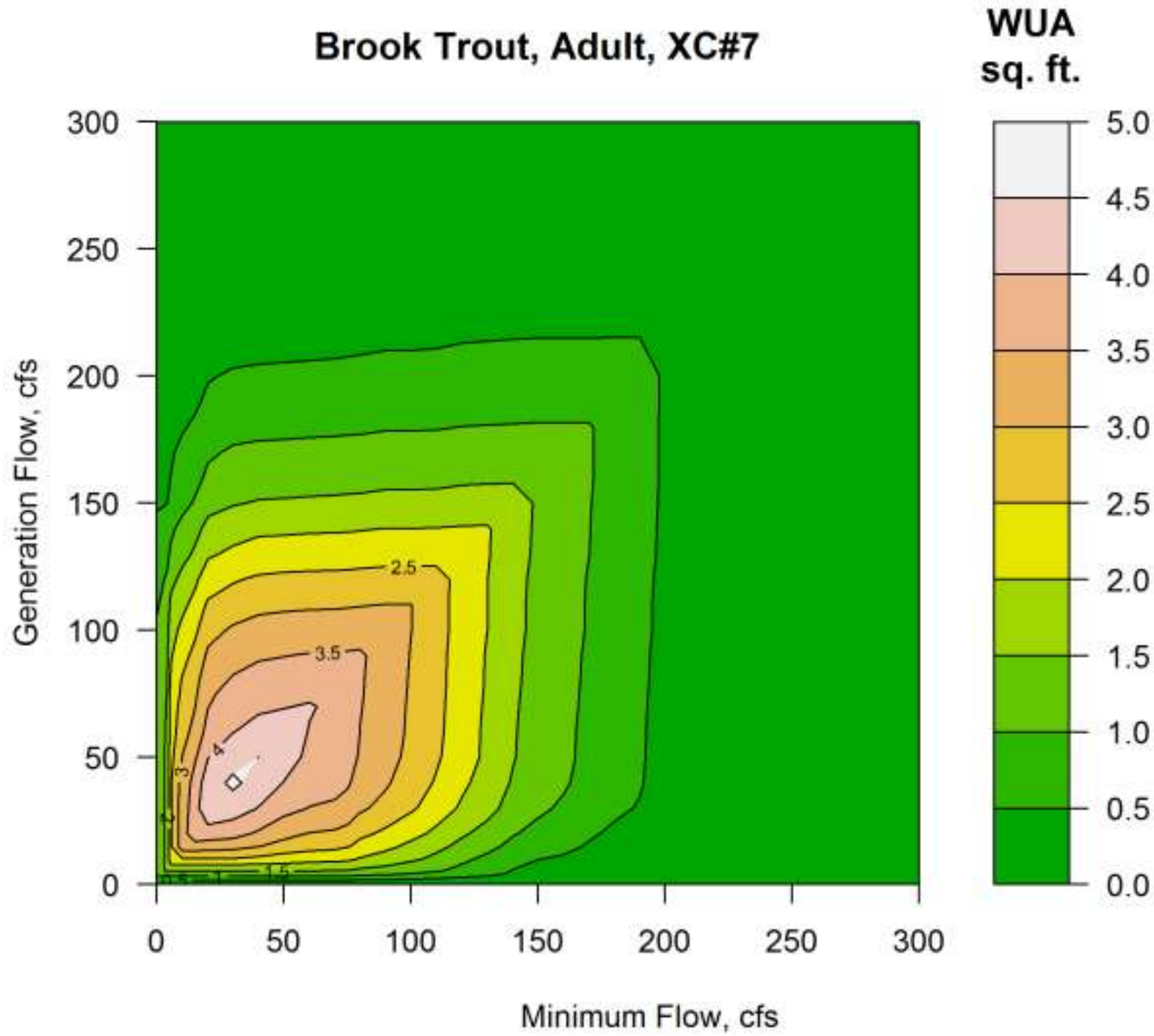
Brook Trout, Adult, XC#4
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
0
2
4
6
8
10
12
14

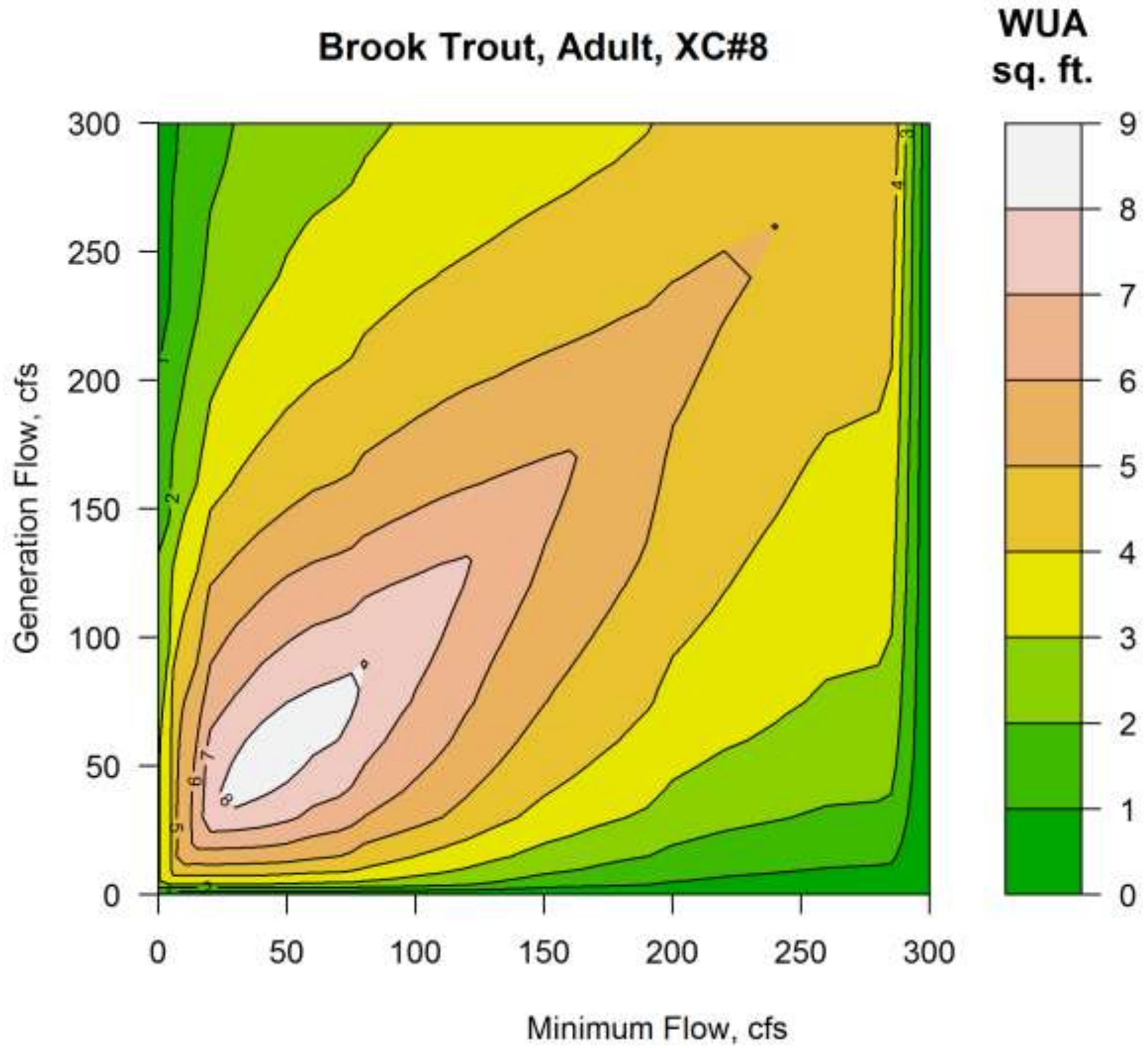


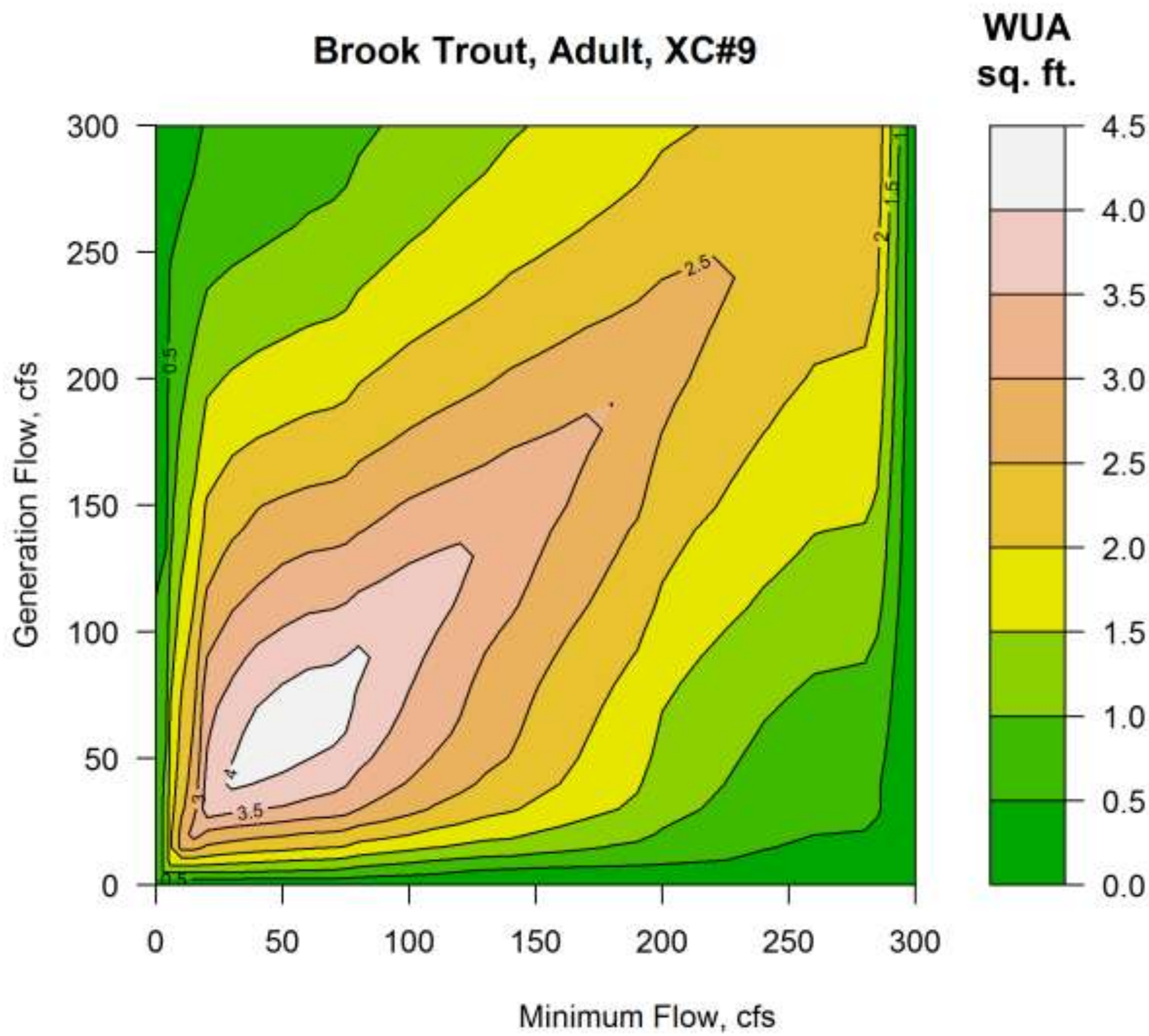
Brook Trout, Adult, XC#5
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
16
14
12
10
8
6
4
2

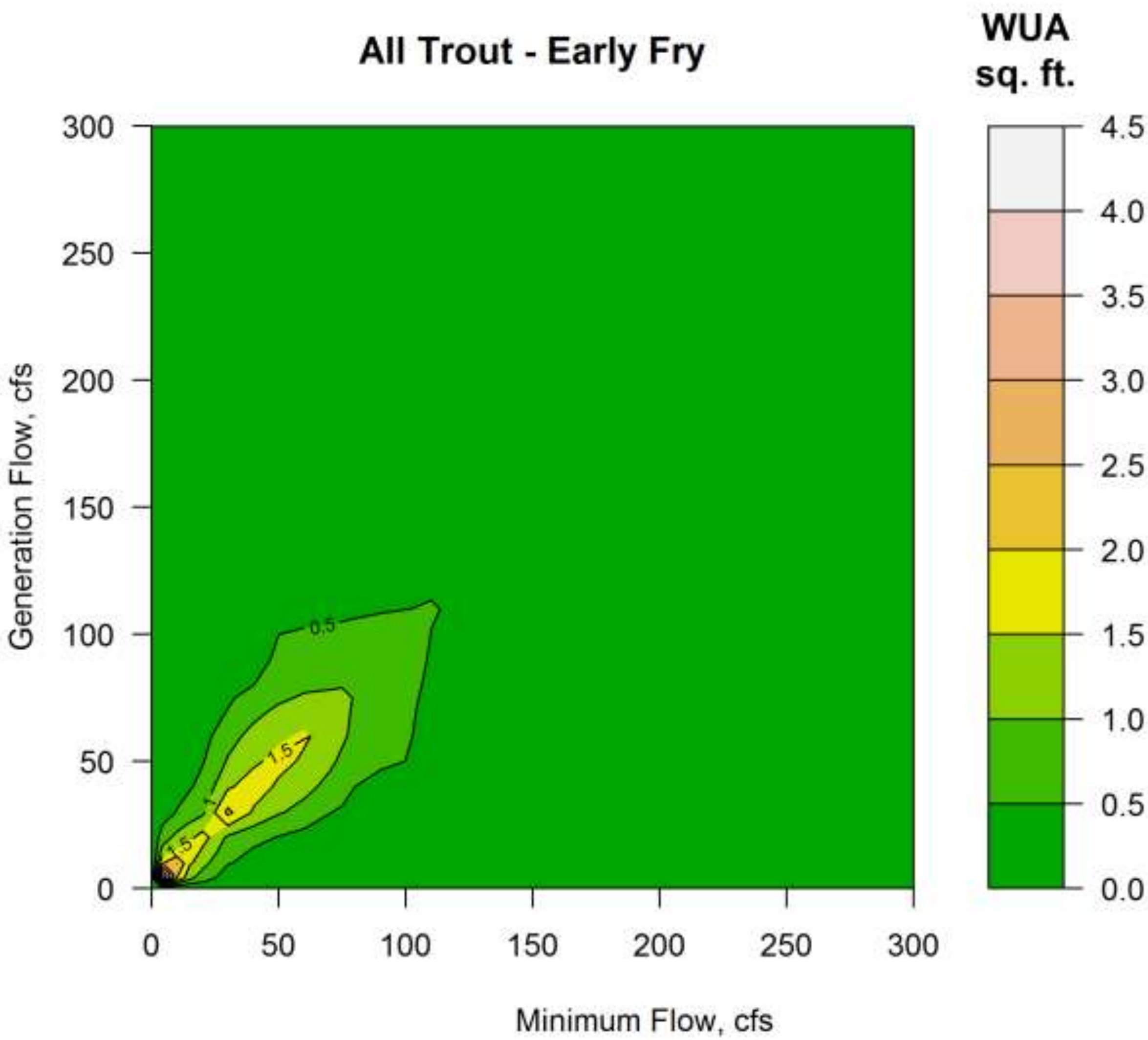


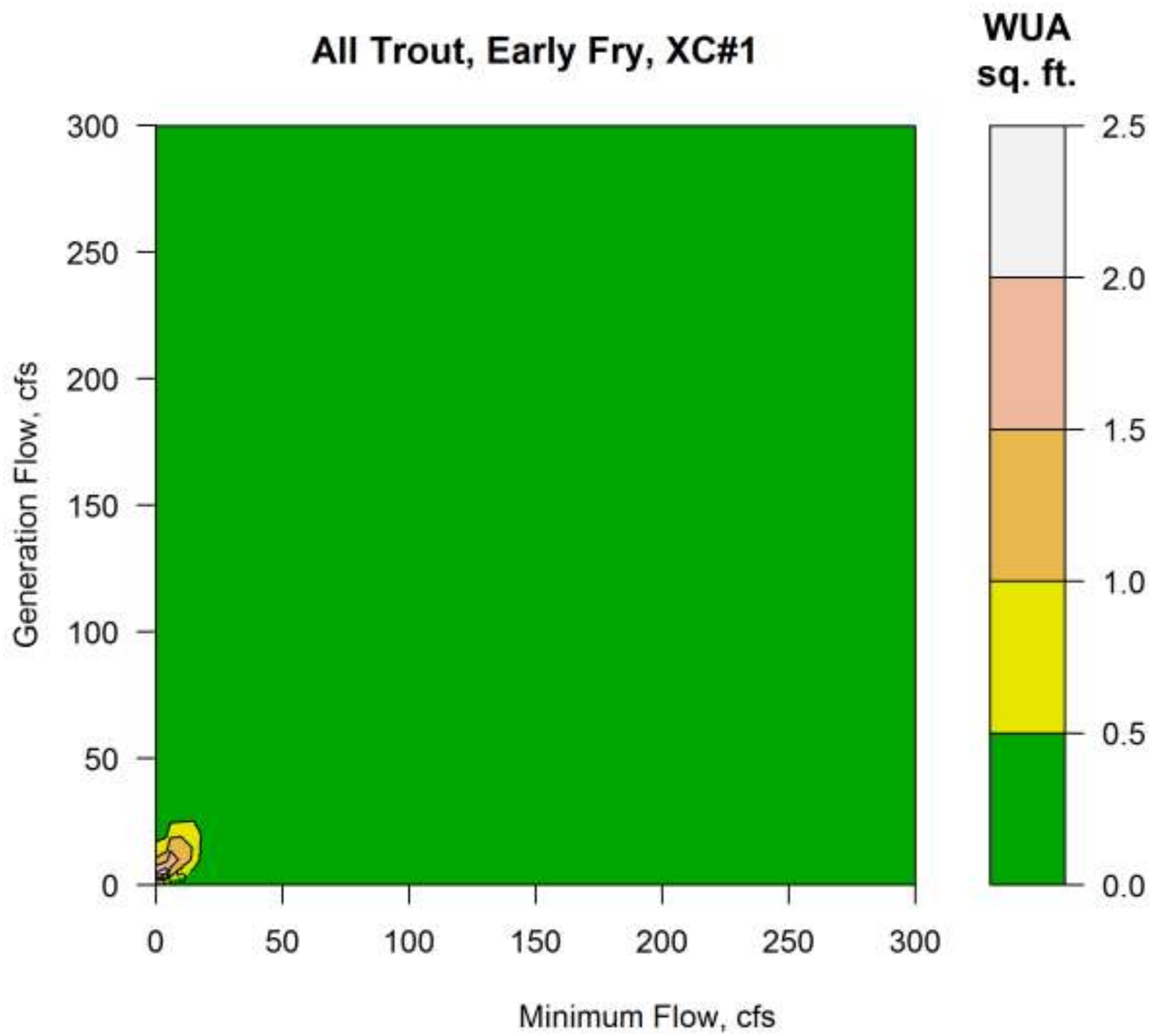
Brook Trout, Adult, XC#6
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
2
4
6
8
10
12

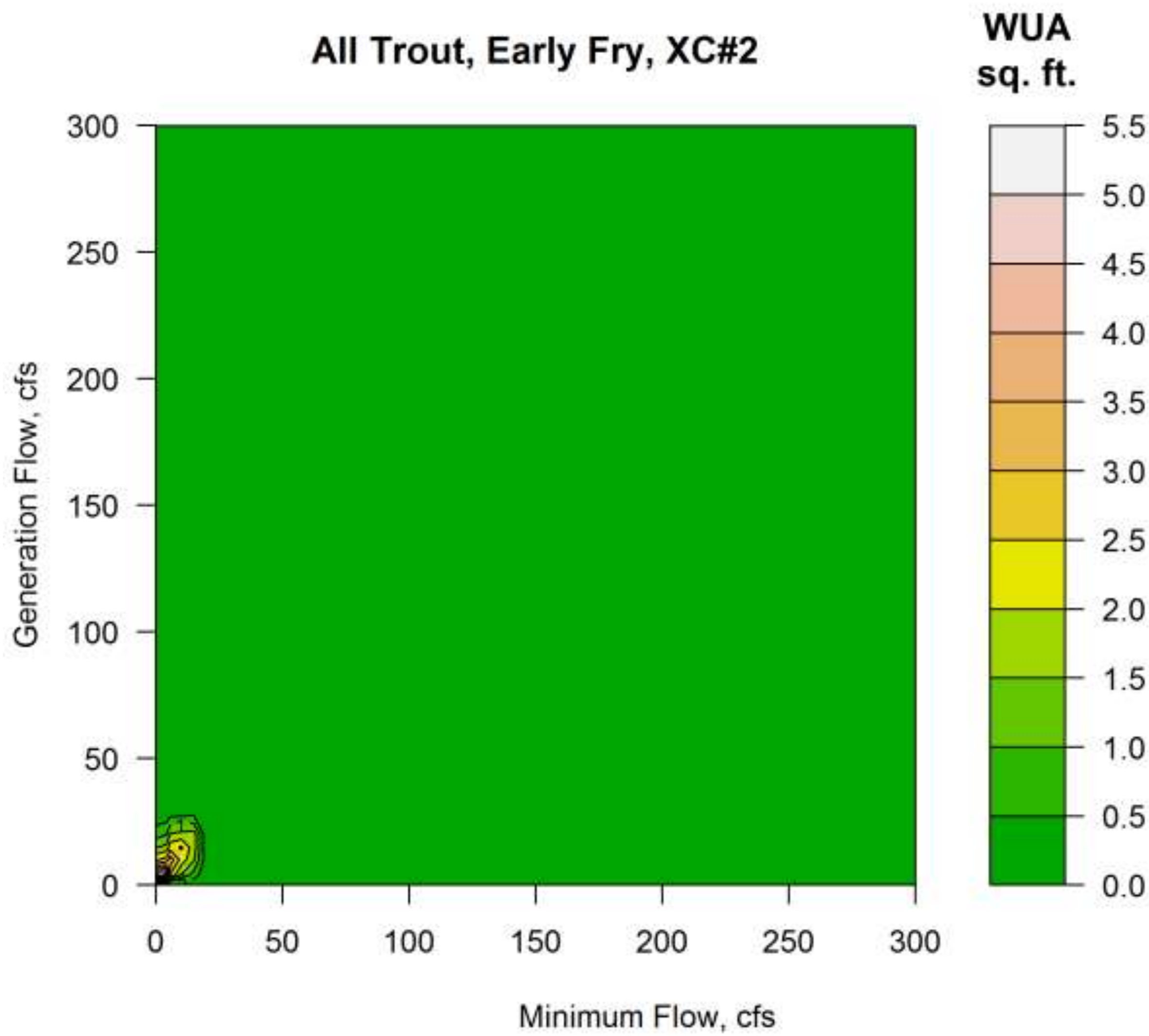

Brook Trout, Adult, XC#7
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

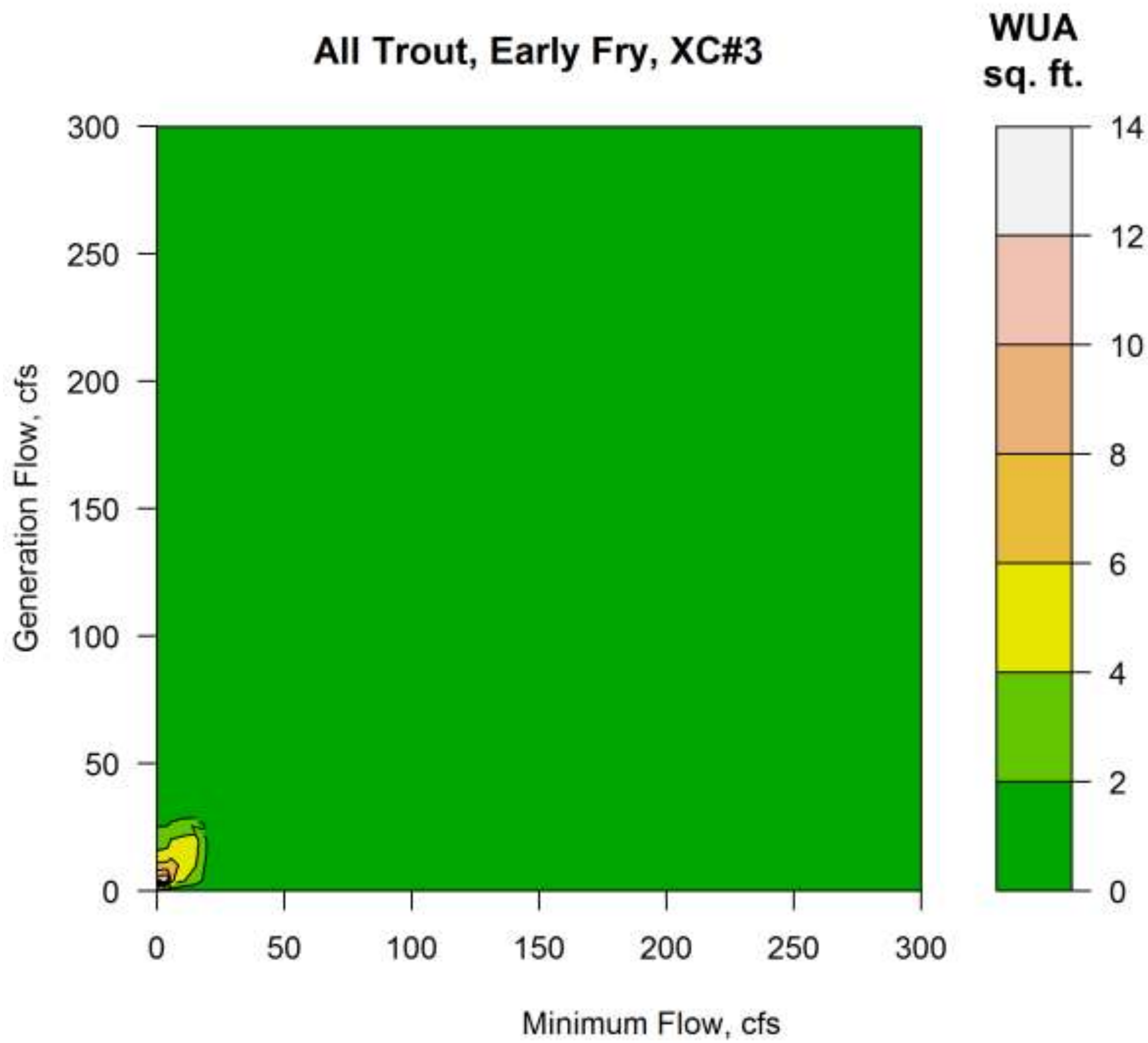

Brook Trout, Adult, XC#8
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9

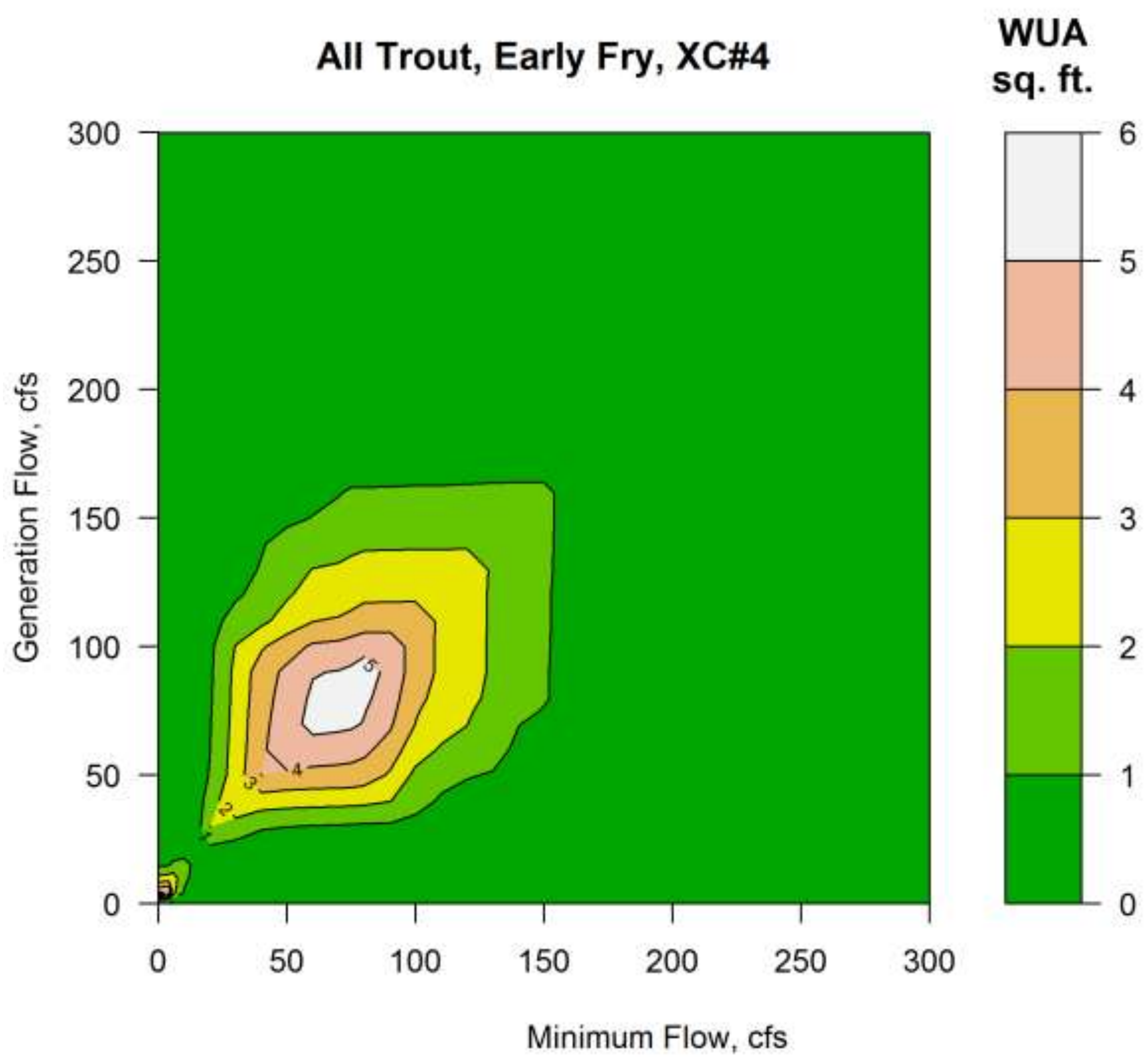

Brook Trout, Adult, XC#9
WUA
sq. ft.
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Generation Flow, cfs
300
250
200
150
100
50
0
Minimum Flow, cfs
0
50
100
150
200
250
300

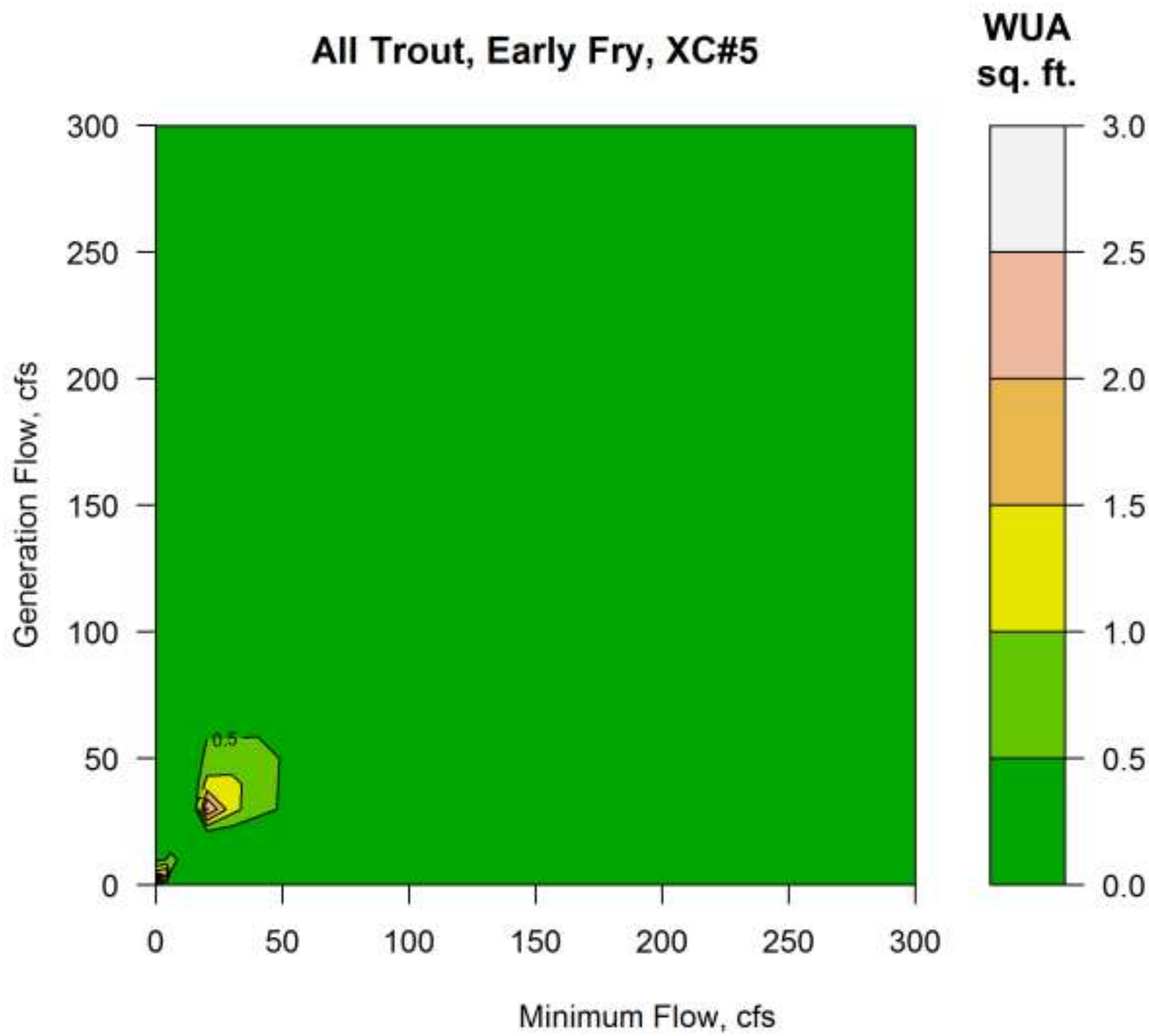

All Trout - Early Fry
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.5
1.5

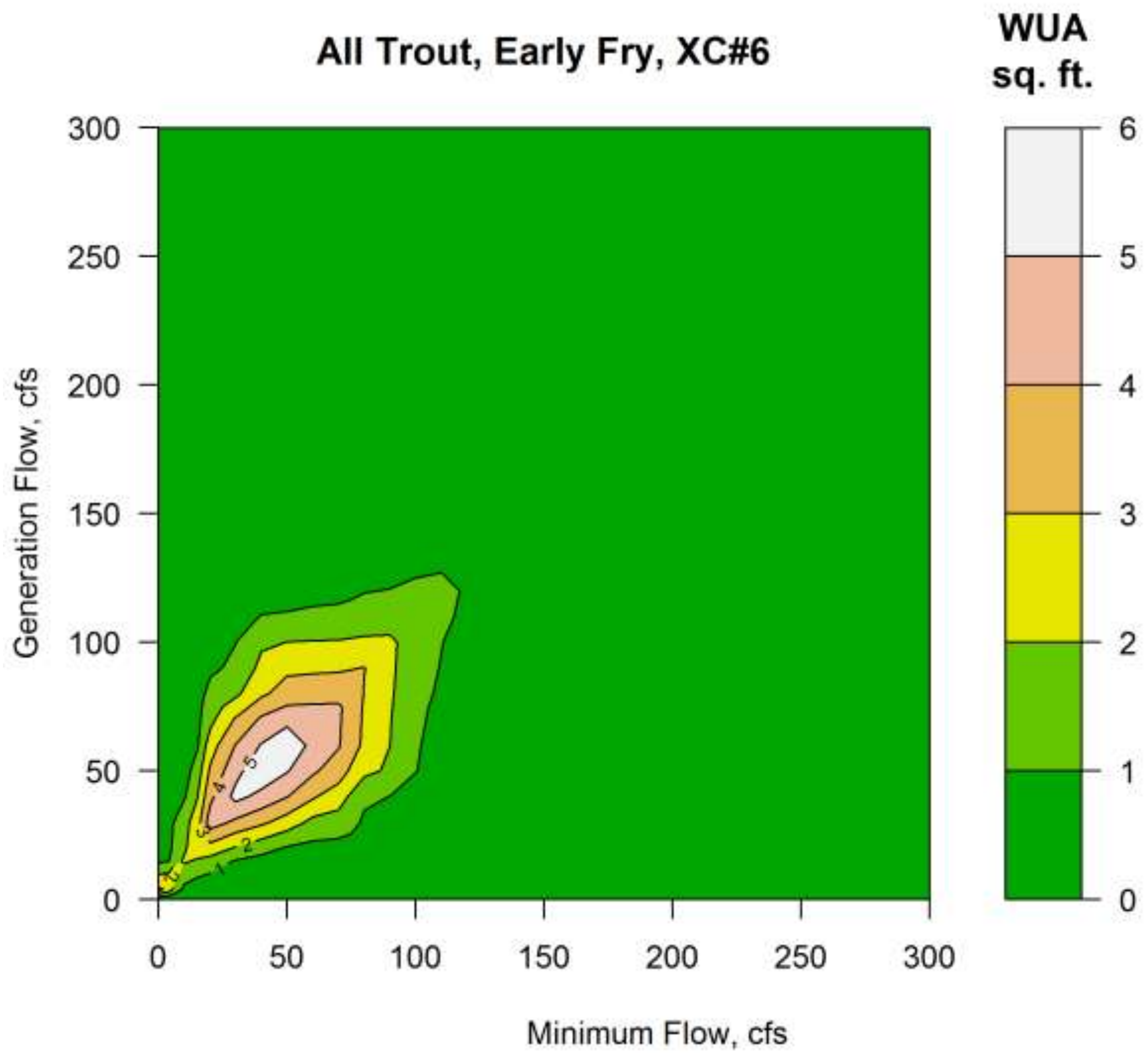

All Trout, Early Fry, XC#1
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
2.5
2.0
1.5
1.0
0.5
0.0

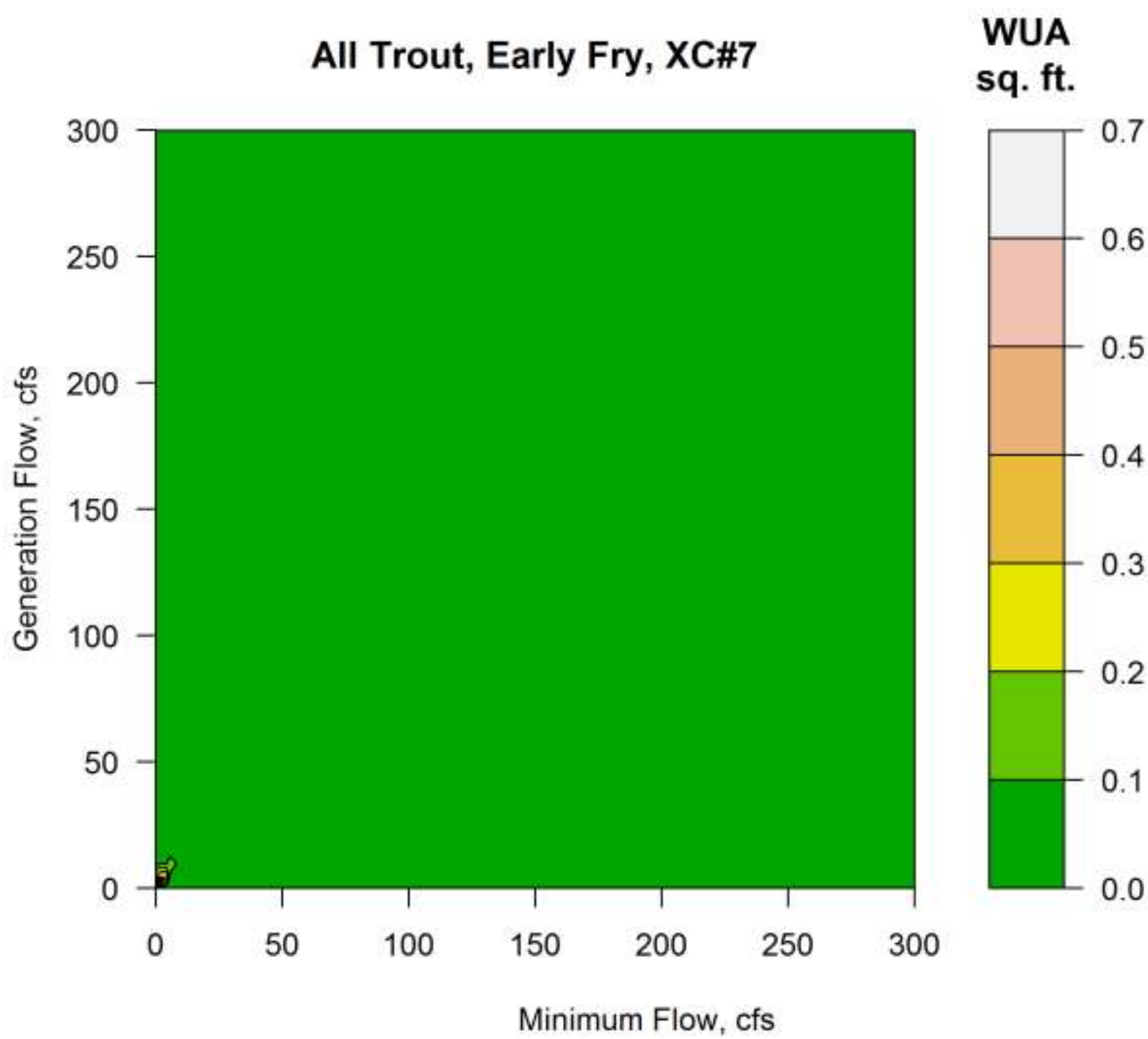

All Trout, Early Fry, XC#2
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0


All Trout, Early Fry, XC#3
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
14
12
10
8
6
4
2
0

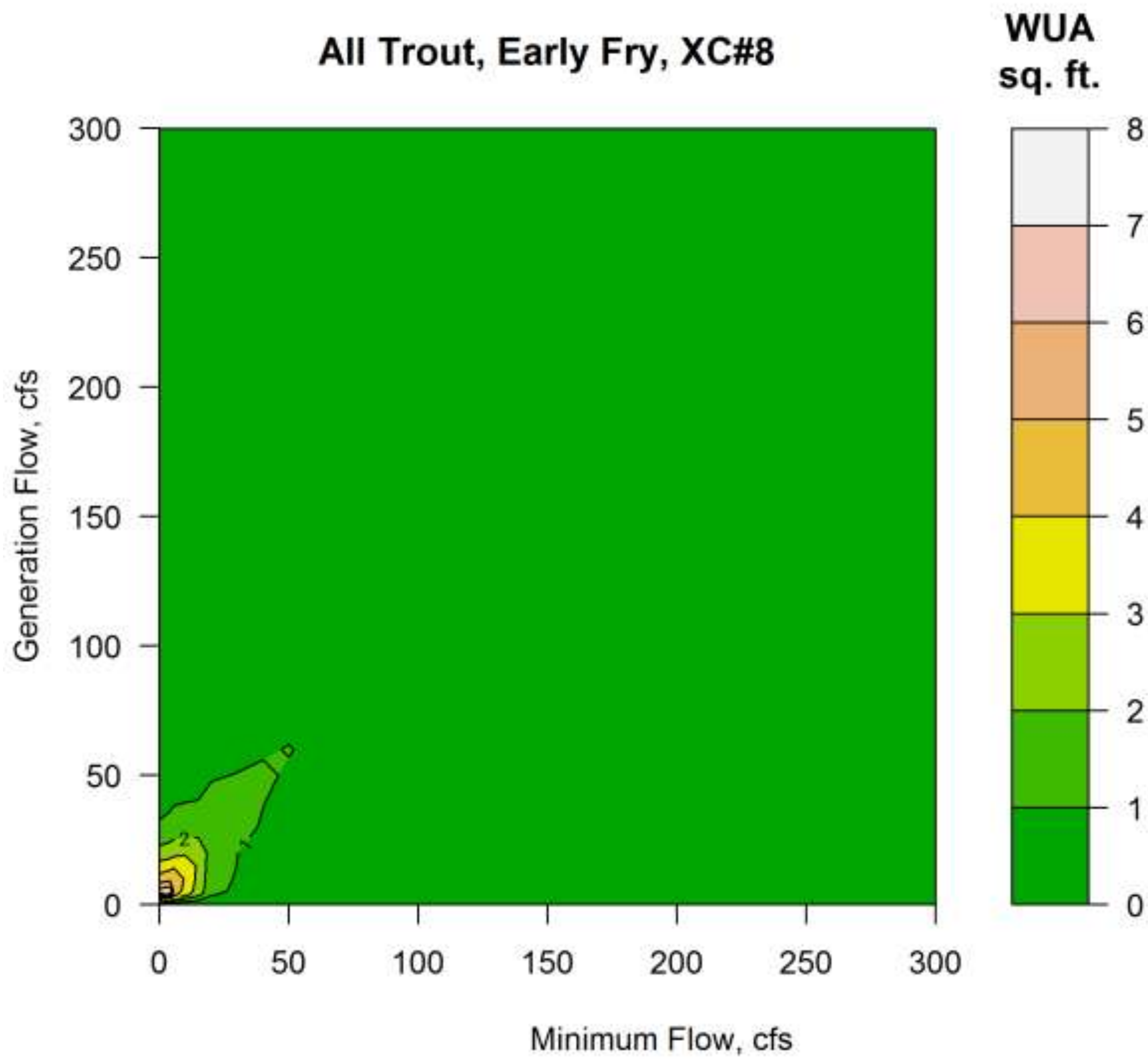

All Trout, Early Fry, XC#4
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
300
250
200
150
100
50
0
0
50
100
150
200
250
300
6
5
4
3
2
1
0

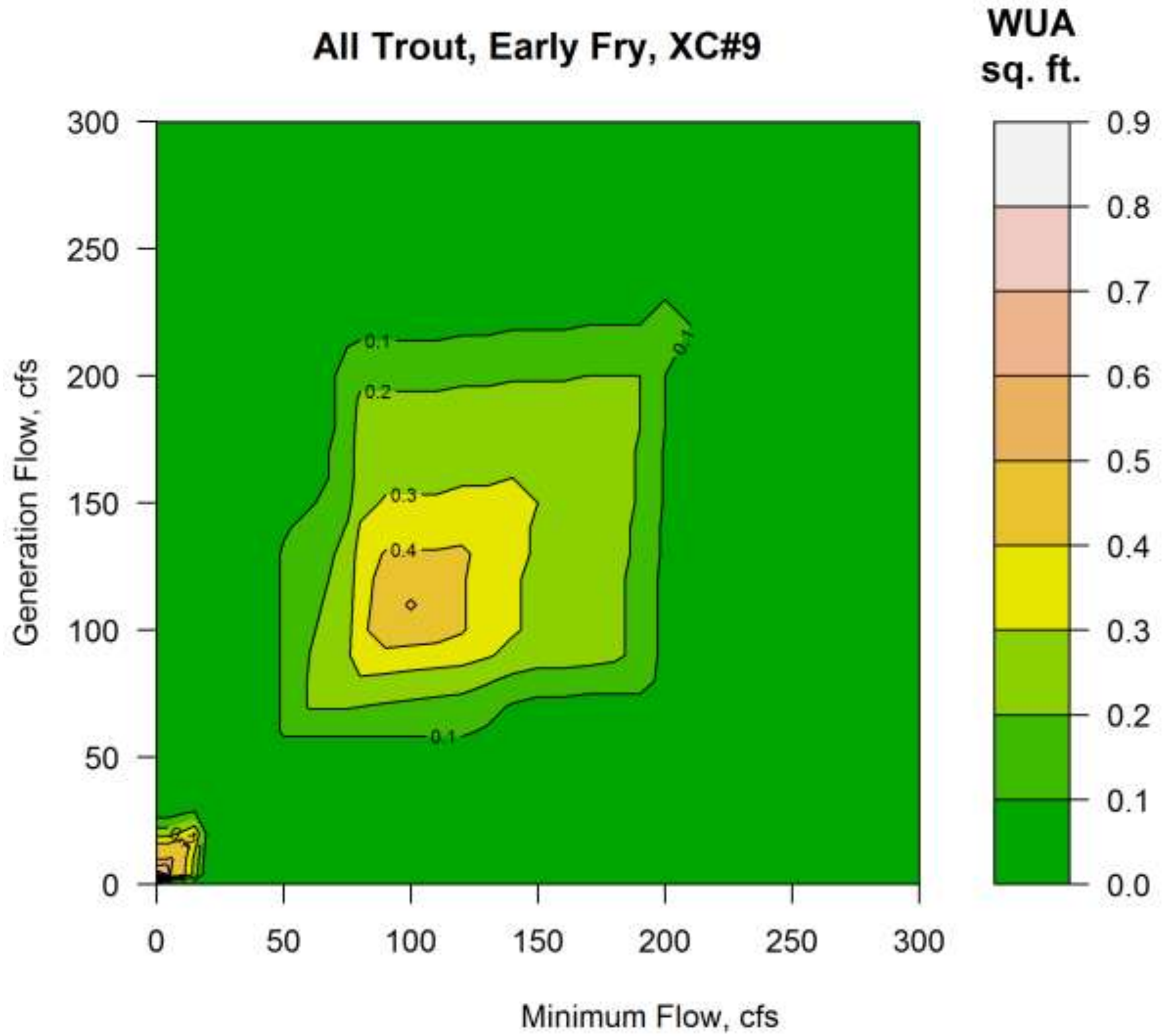

All Trout, Early Fry, XC#5
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
0.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0


All Trout, Early Fry, XC#6
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
0
1
2
3
4
5
6

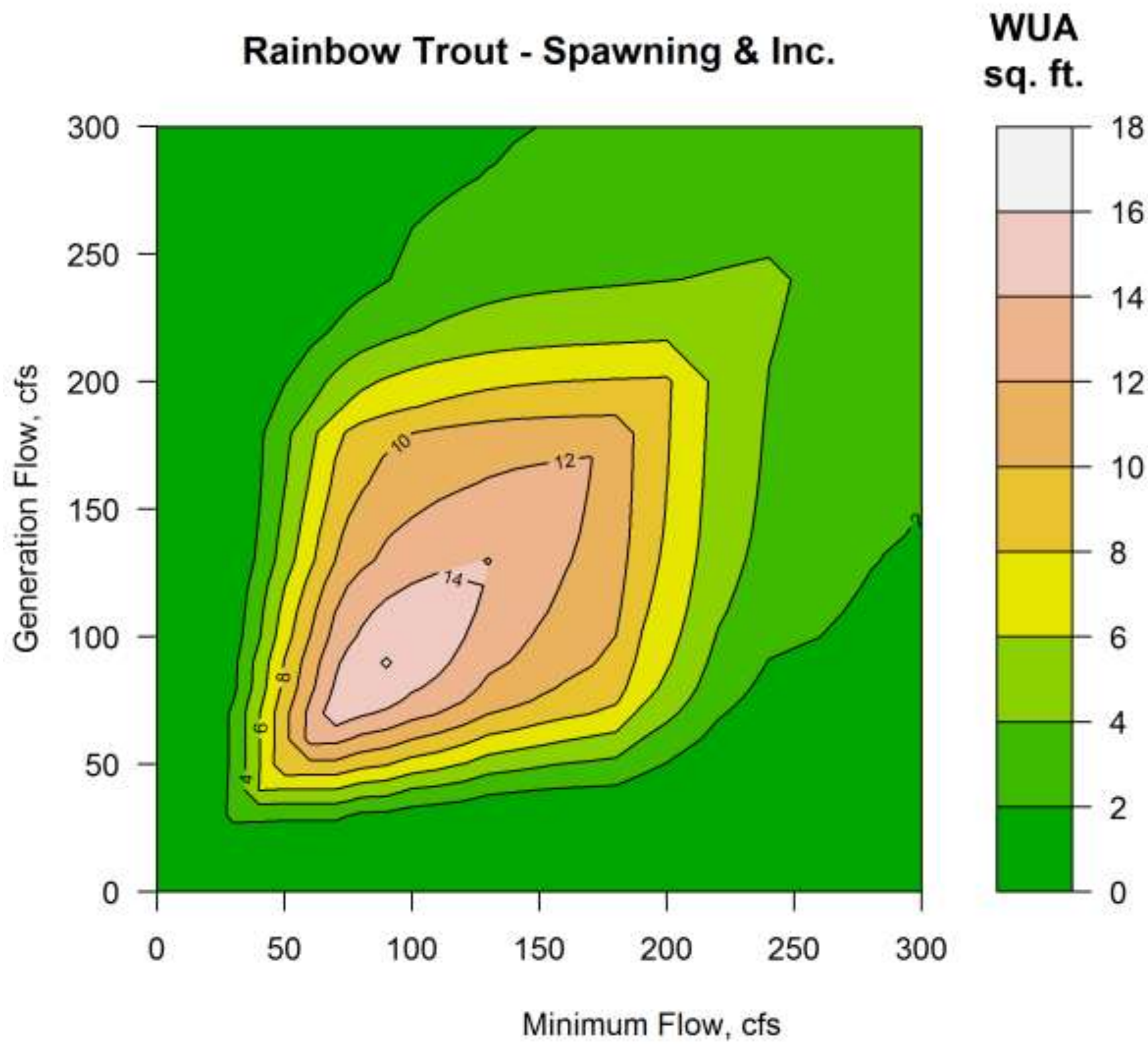


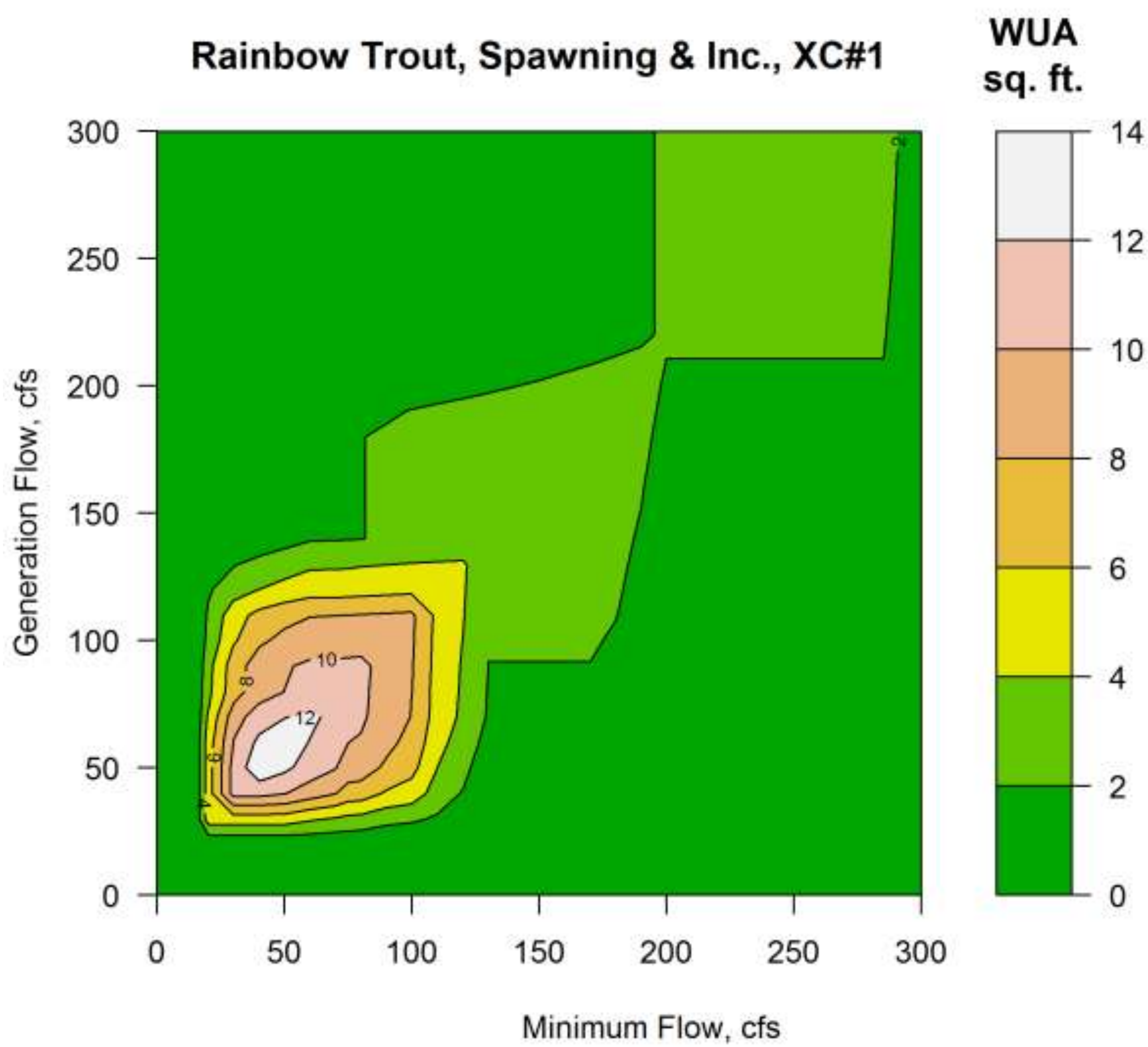
All Trout, Early Fry, XC#7
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

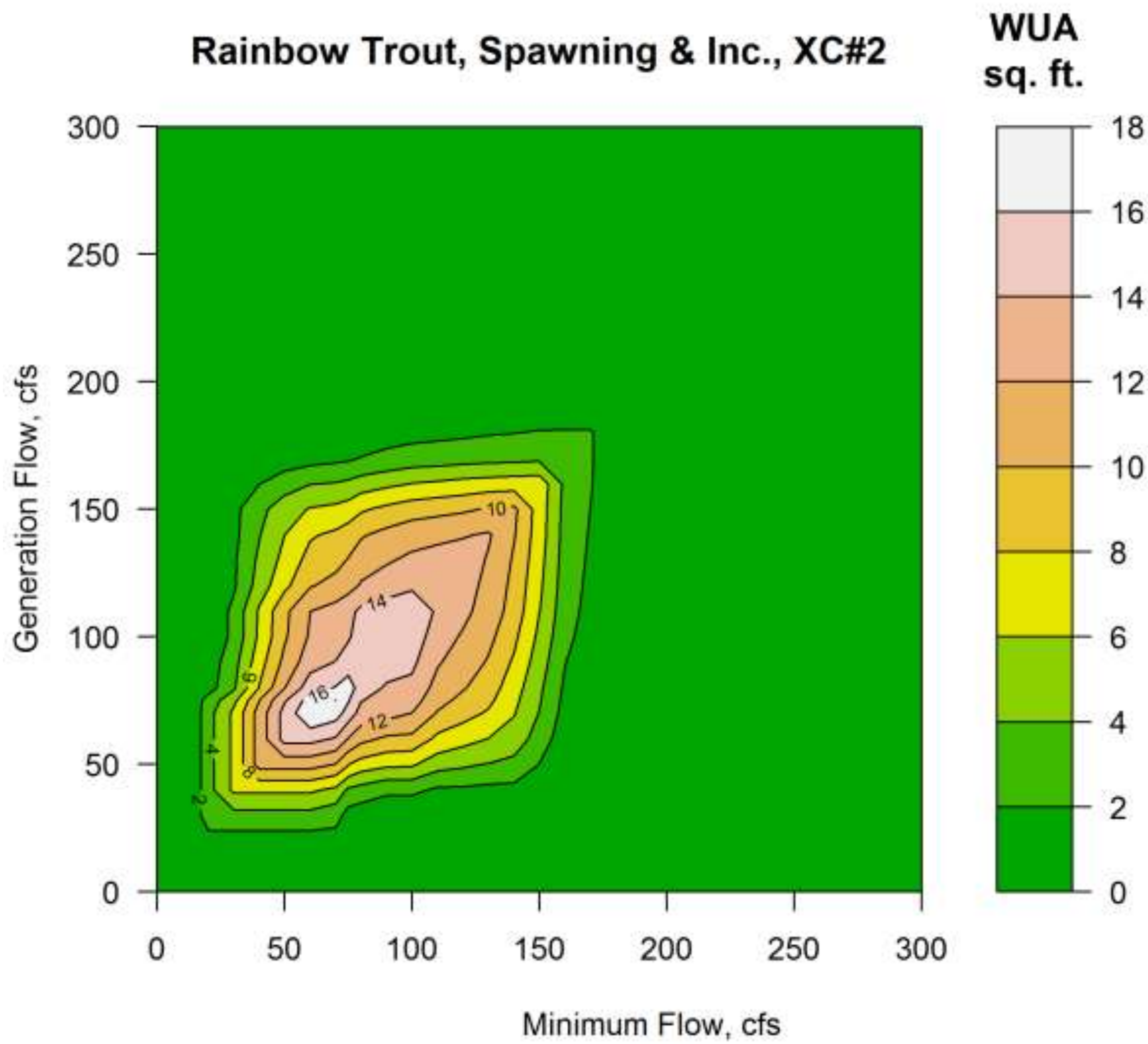

All Trout, Early Fry, XC#8
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8

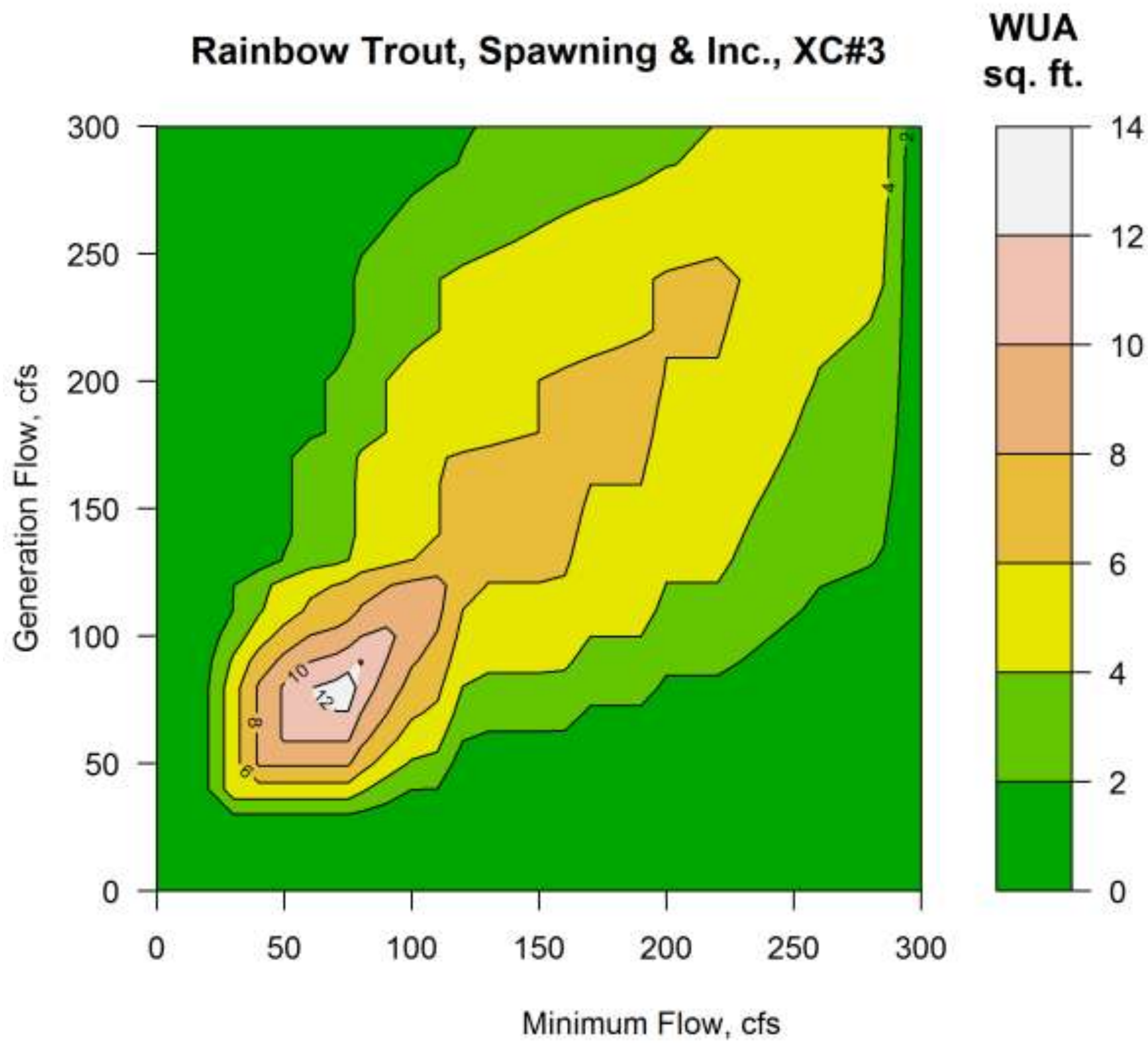


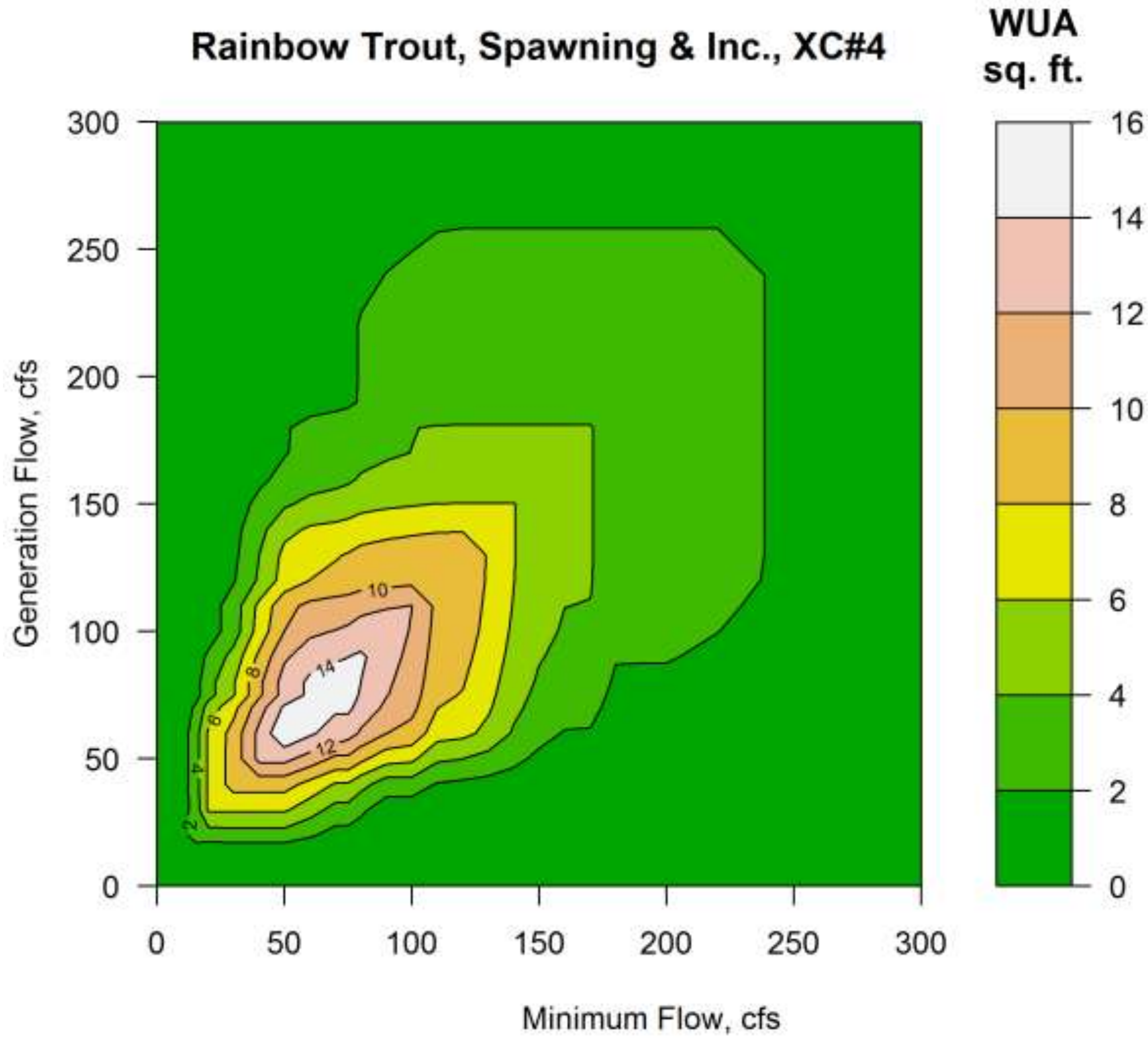
All Trout, Early Fry, XC#9
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

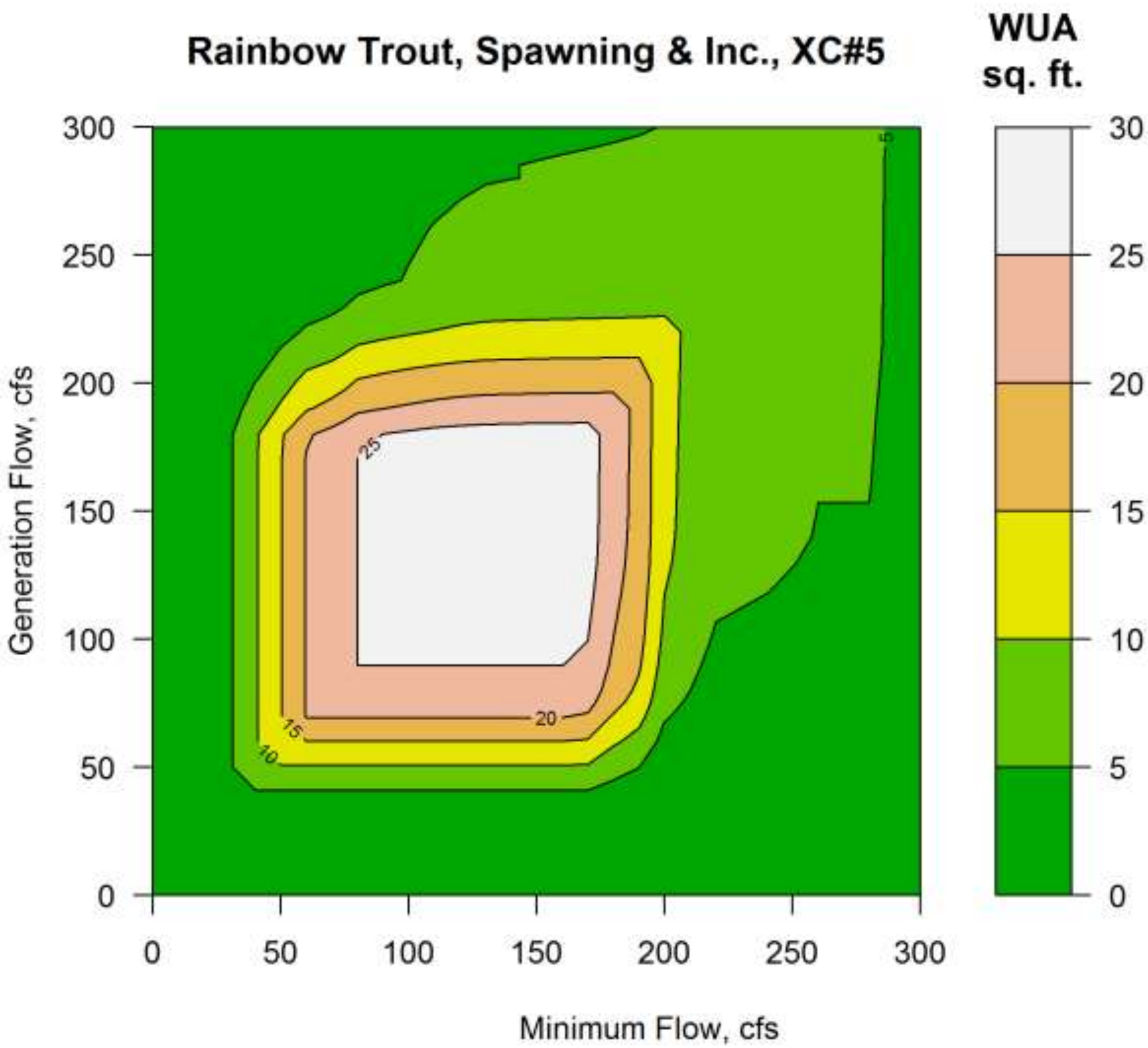

Rainbow Trout - Spawning & Inc.
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
0
2
4
6
8
10
12
14
16
18


Rainbow Trout, Spawning & Inc., XC#1
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
300
250
200
150
100
50
0
0
50
100
150
200
250
300
14
12
10
8
6
4
2
0
10
12
8


Rainbow Trout, Spawning & Inc., XC#2
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
18
16
14
12
10
8
6
4
2
0


Rainbow Trout, Spawning & Inc., XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
14
12
10
8
6
4
2
0


Rainbow Trout, Spawning & Inc., XC#4
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
16
14
12
10
8
6
4
2
0


Rainbow Trout, Spawning & Inc., XC#5
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
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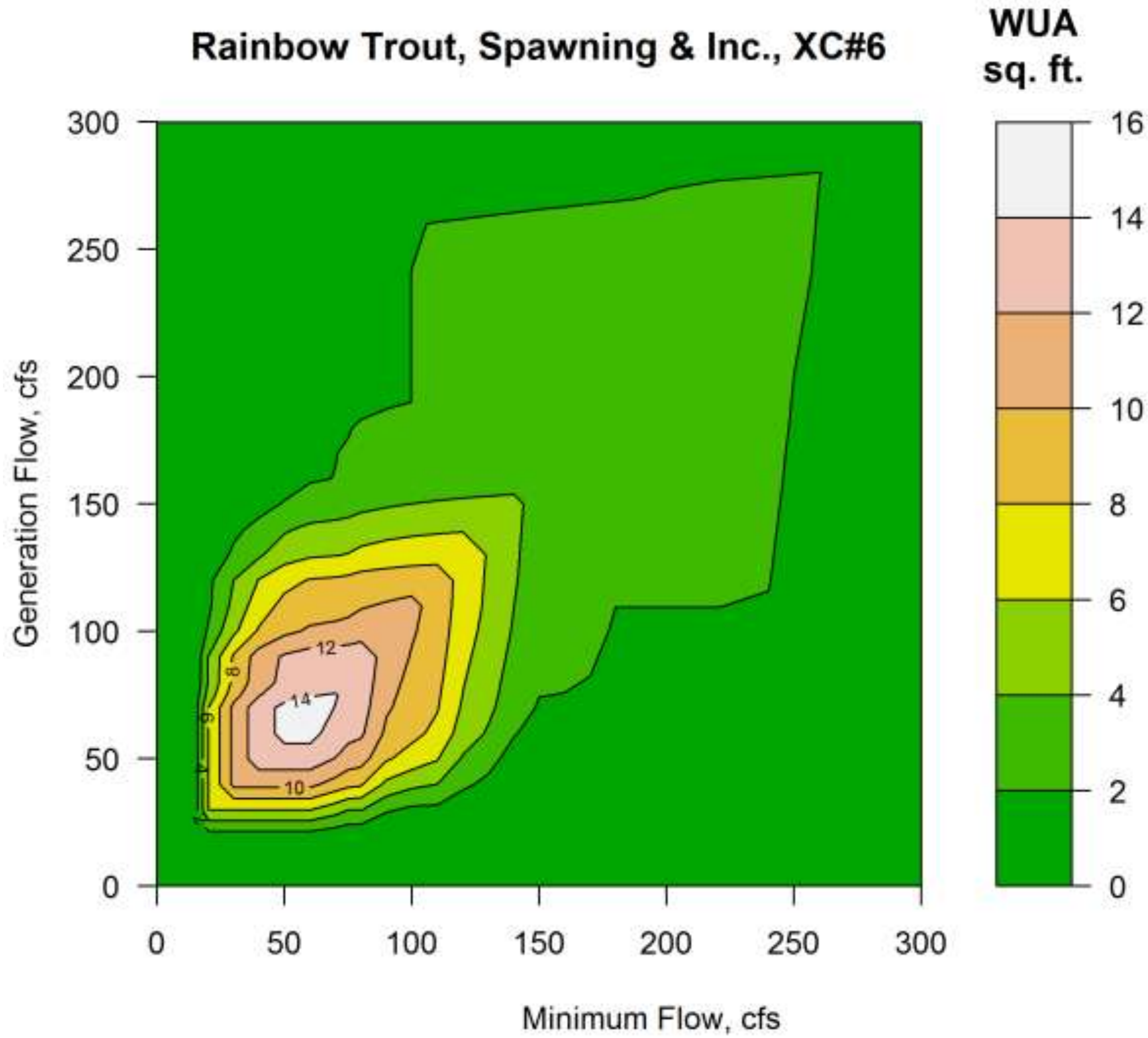
10
15
20
25
30


Rainbow Trout, Spawning & Inc., XC#6
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
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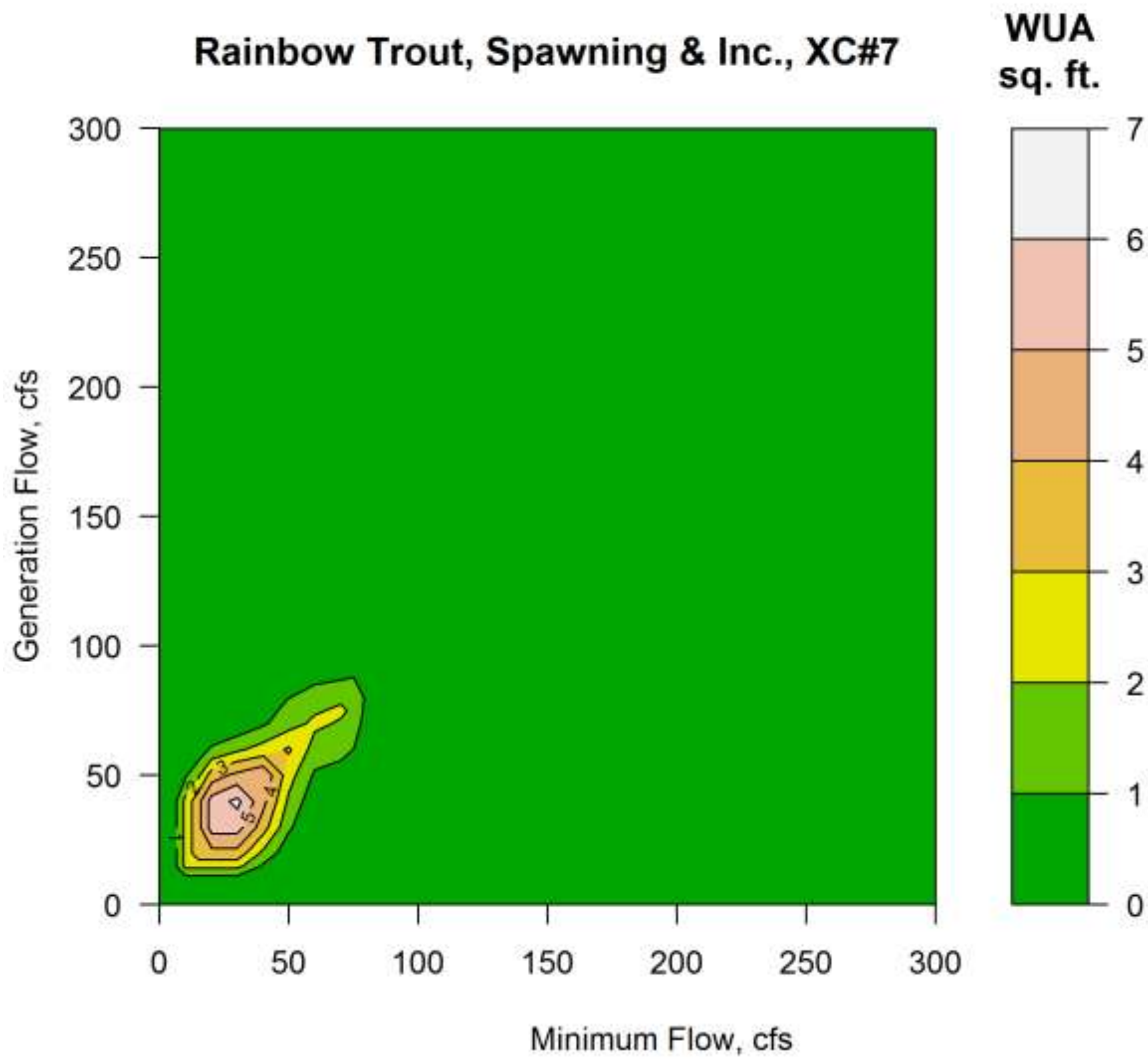
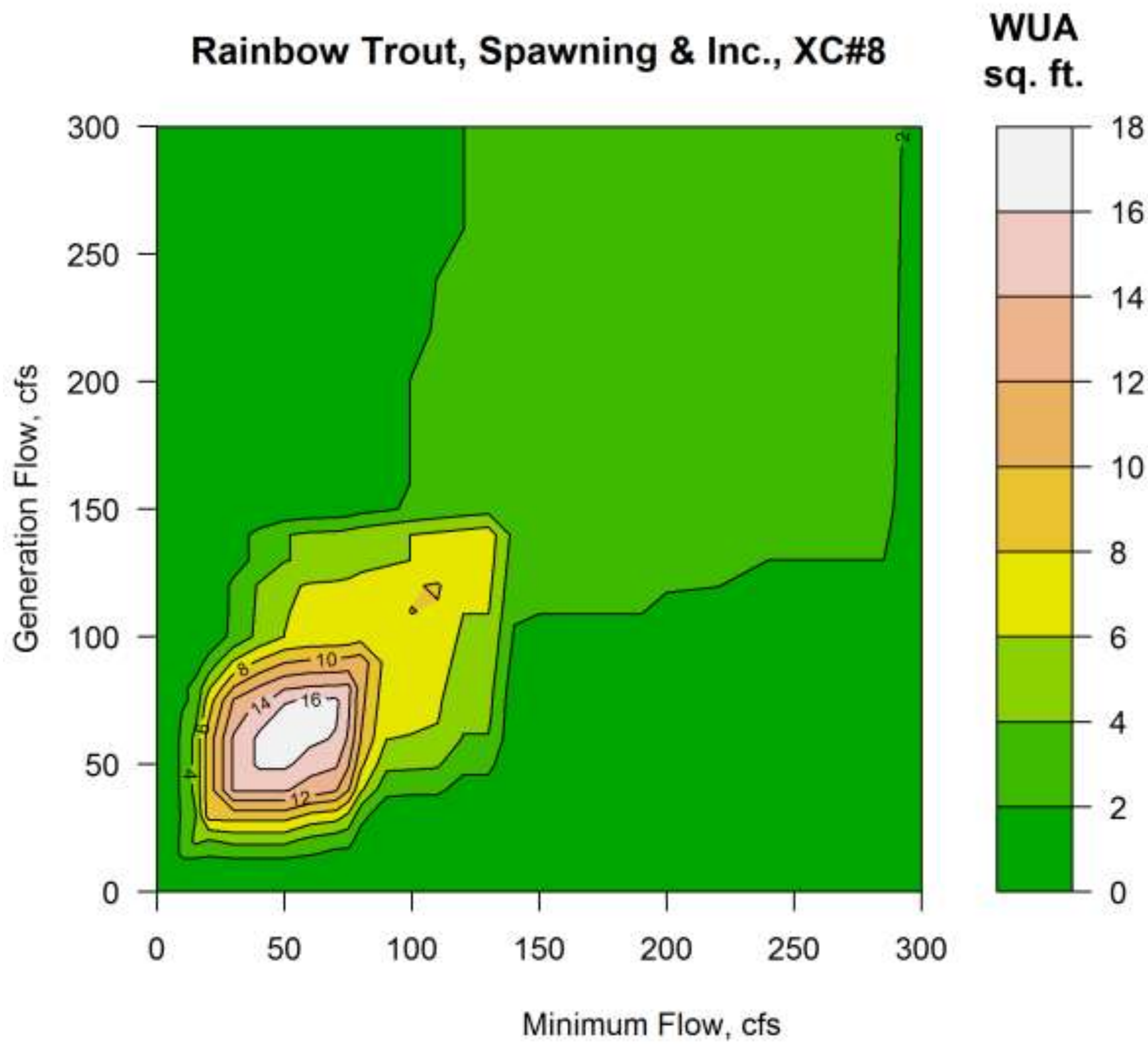
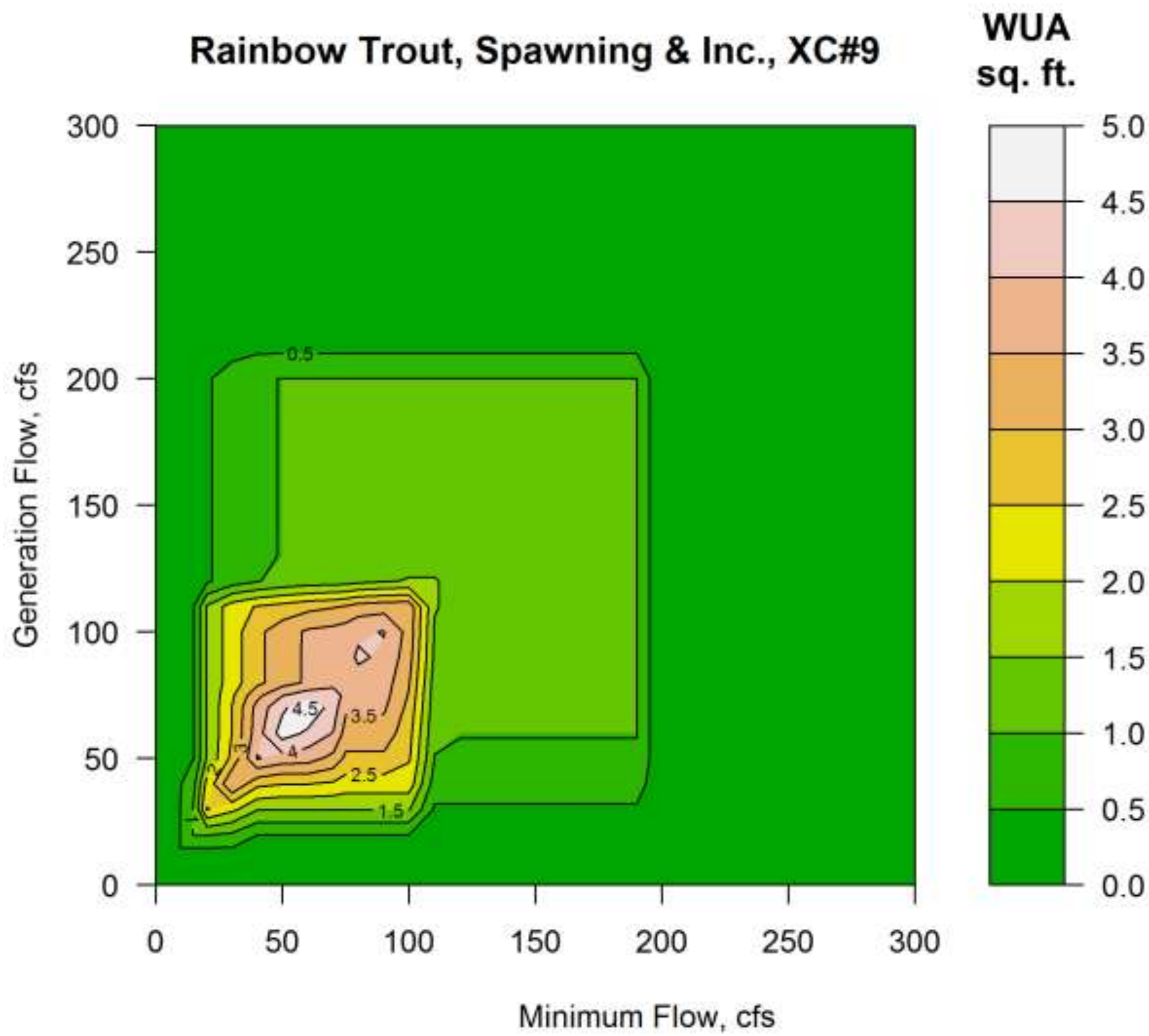
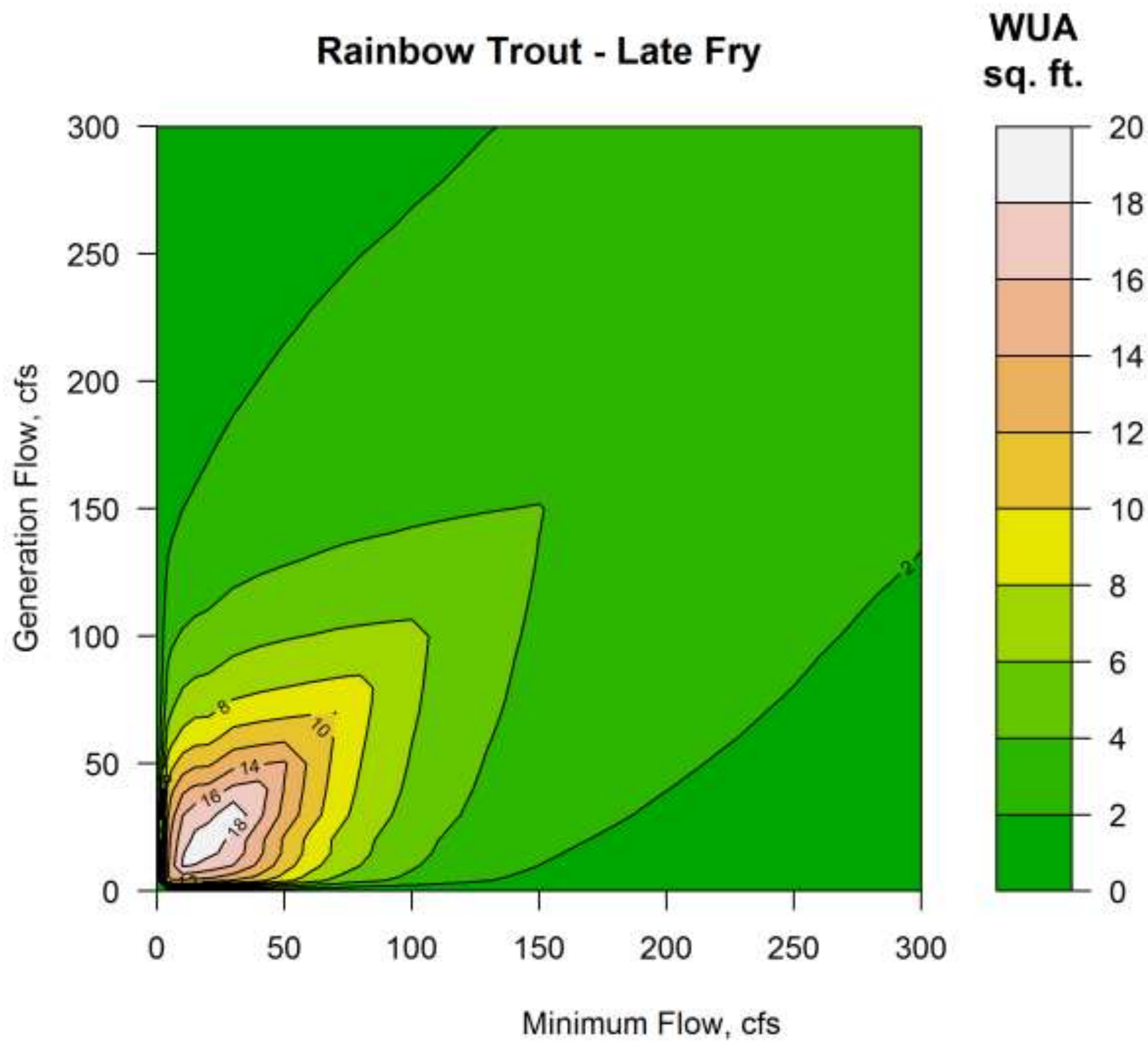
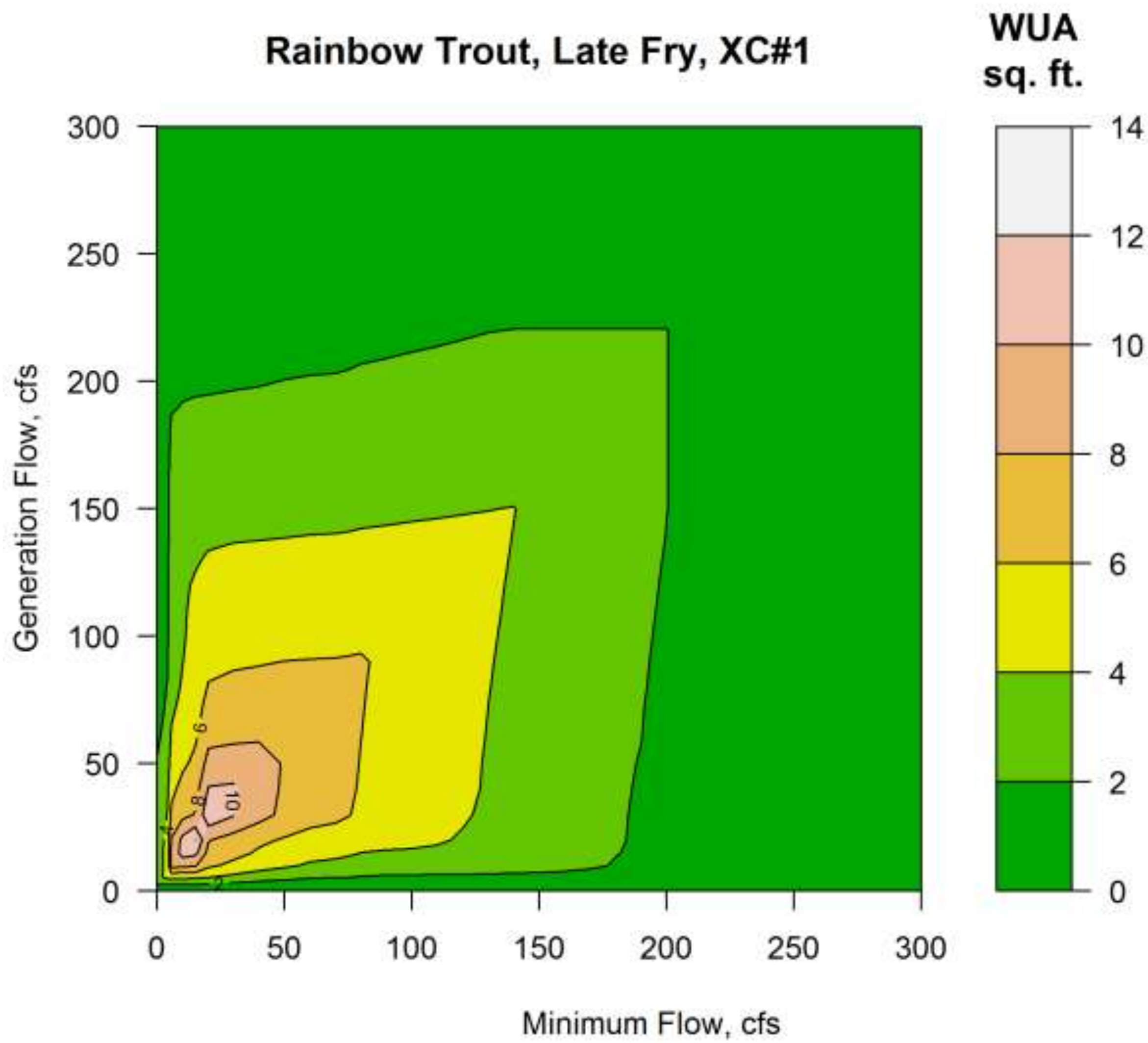
6
8
10
12
14
16

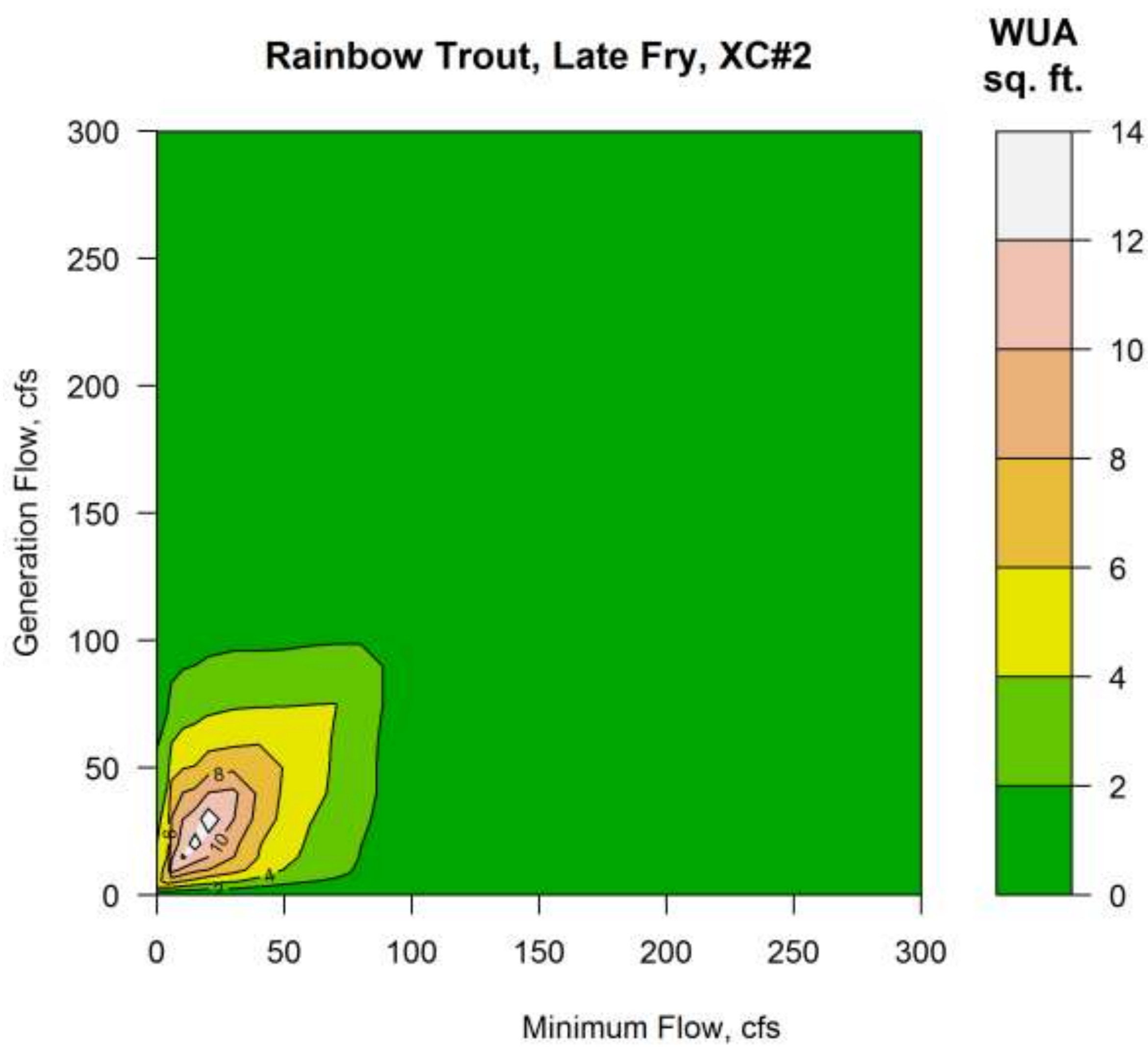

Rainbow Trout, Spawning & Inc., XC#7
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
1
2
3
4
5
6
7

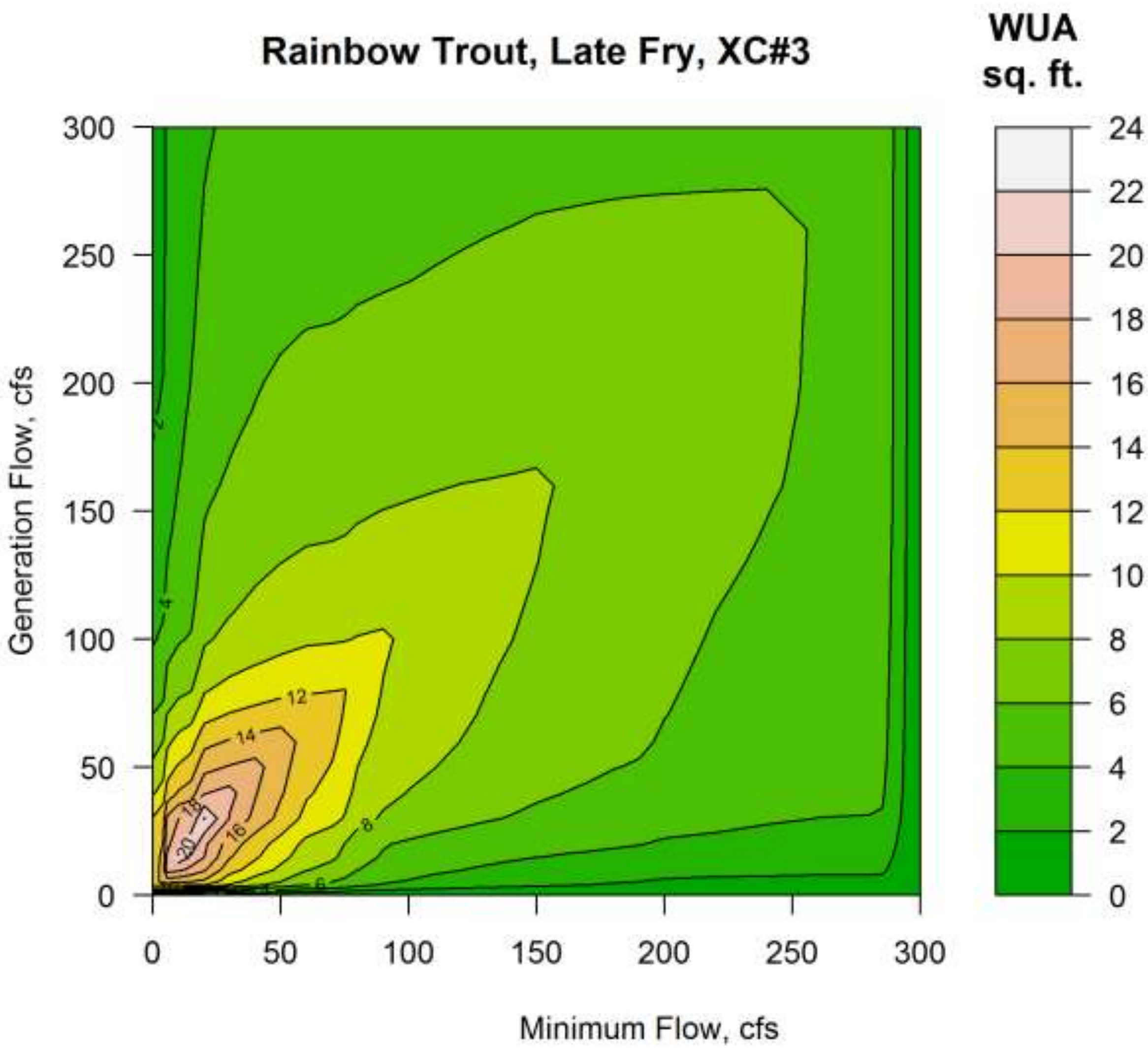

Rainbow Trout, Spawning & Inc., XC#8
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
2
4
6
8
10
12
14
16
18

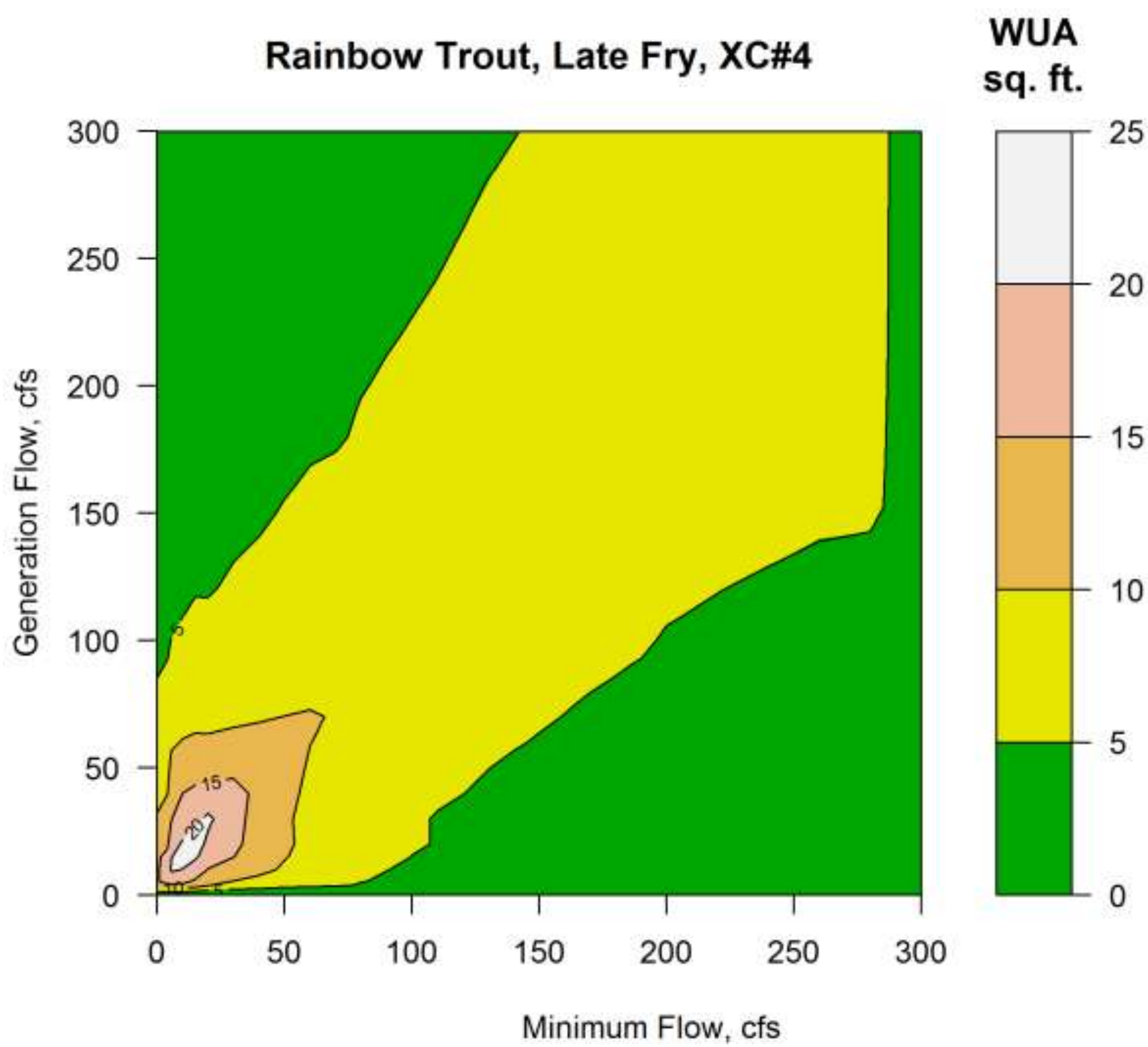

Rainbow Trout, Spawning & Inc., XC#9
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.5
1.5
2.5
3.5
4.5
4

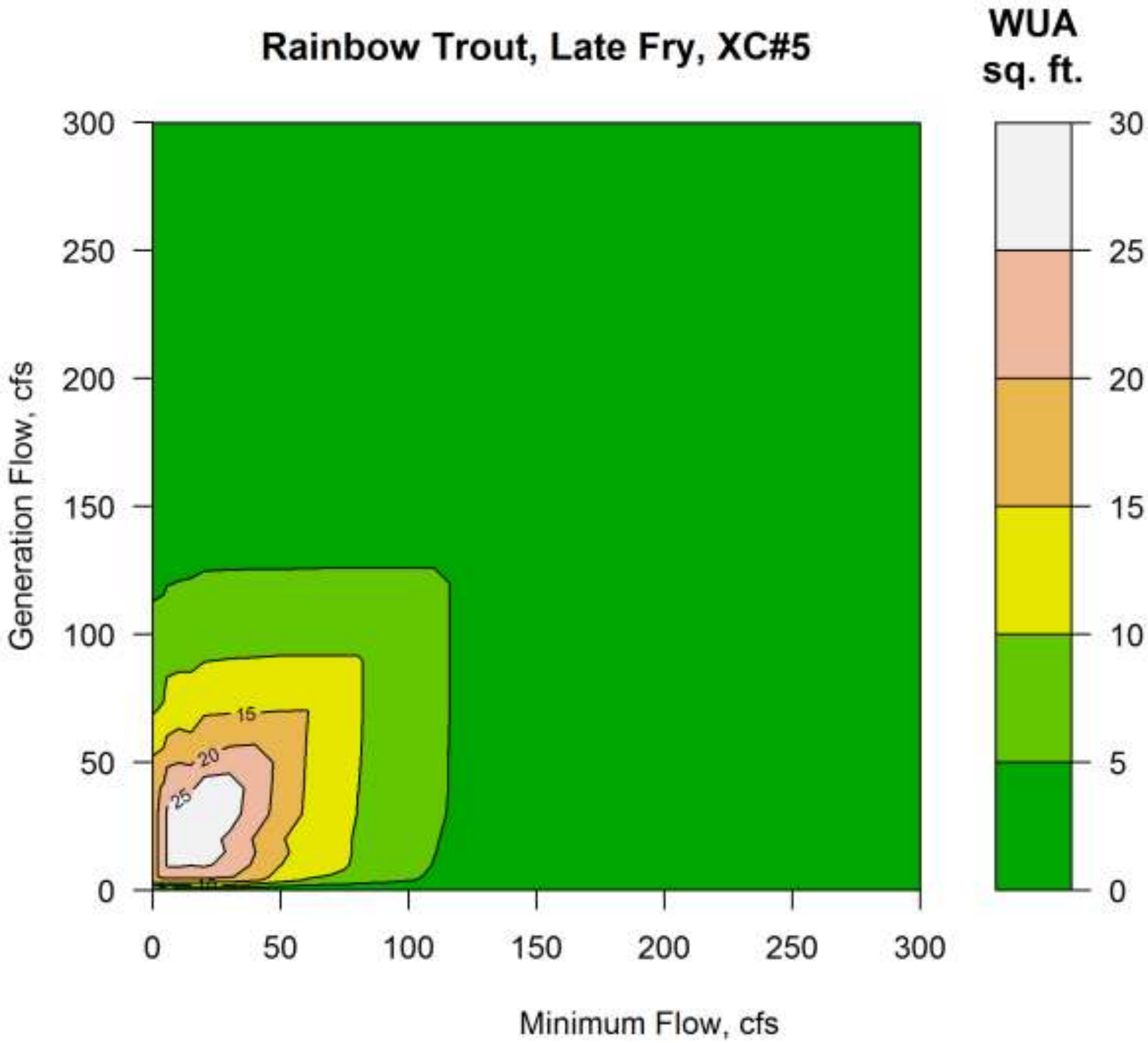

Rainbow Trout - Late Fry
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
20
18
16
14
12
10
8
6
4
2
0

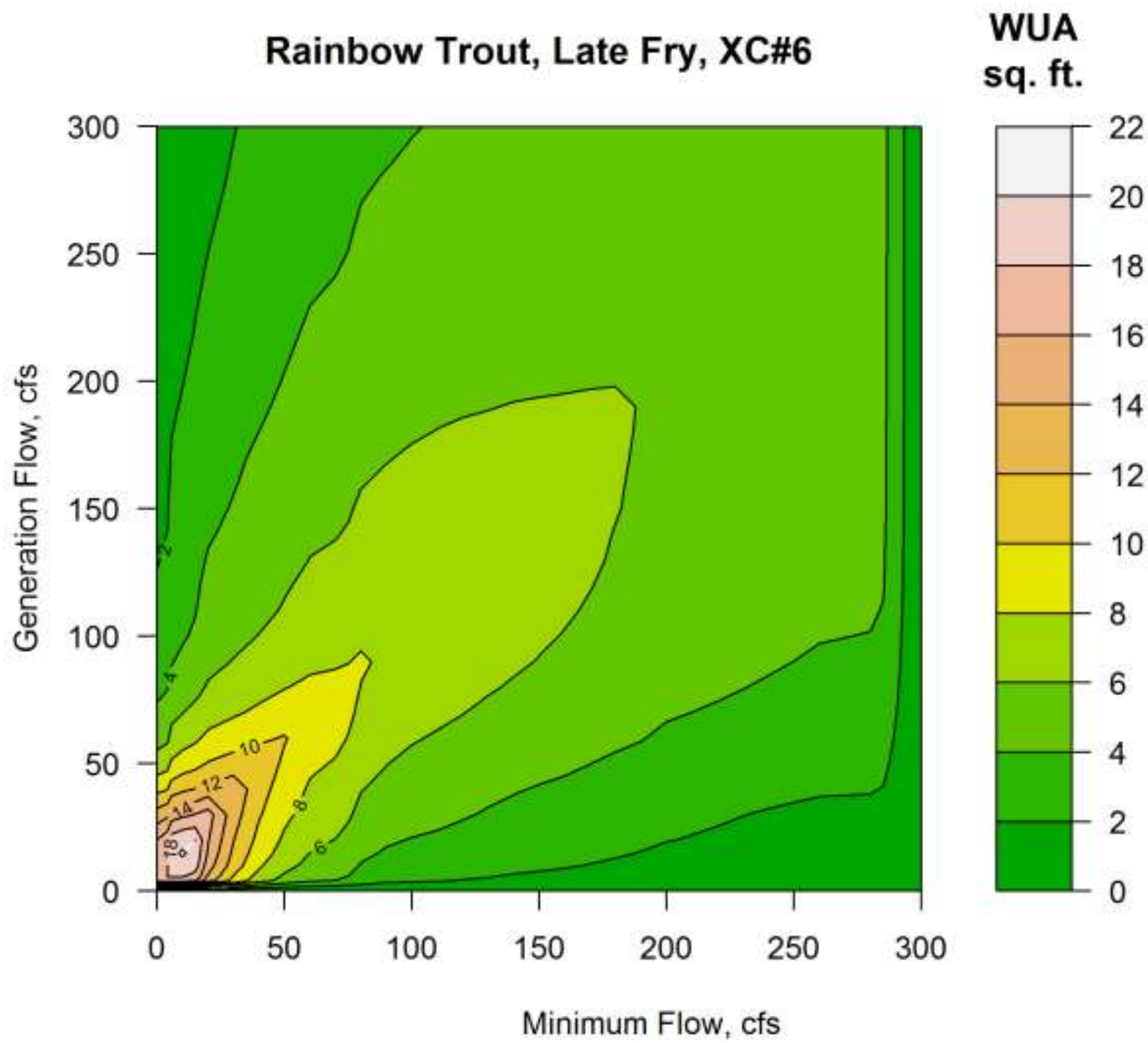

Rainbow Trout, Late Fry, XC#1
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
14
12
10
8
6
4
2
0


Rainbow Trout, Late Fry, XC#2
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
14
12
10
8
6
4
2
0

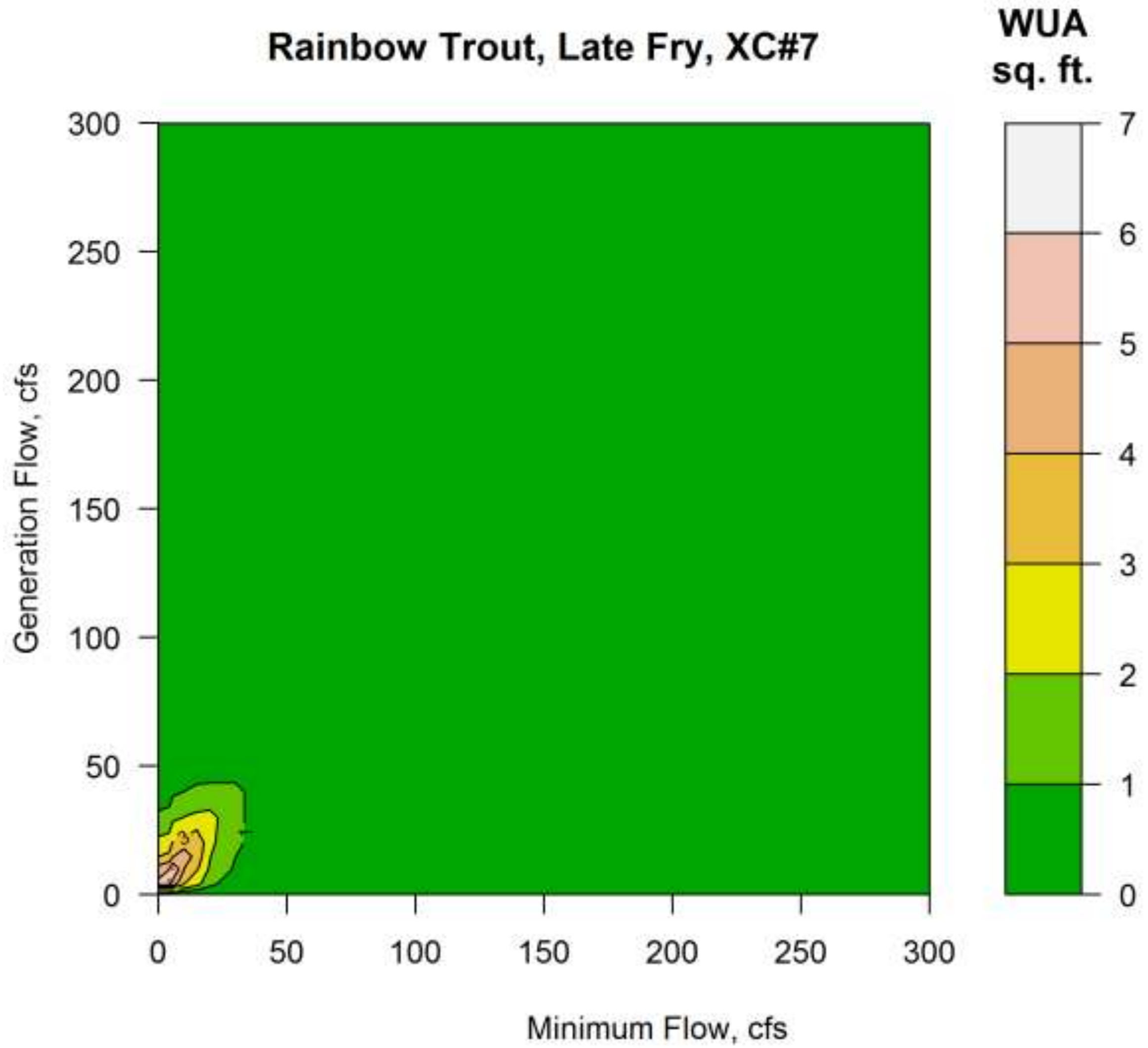

Rainbow Trout, Late Fry, XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
2
4
6
8
10
12
14
16
18
20
22
24

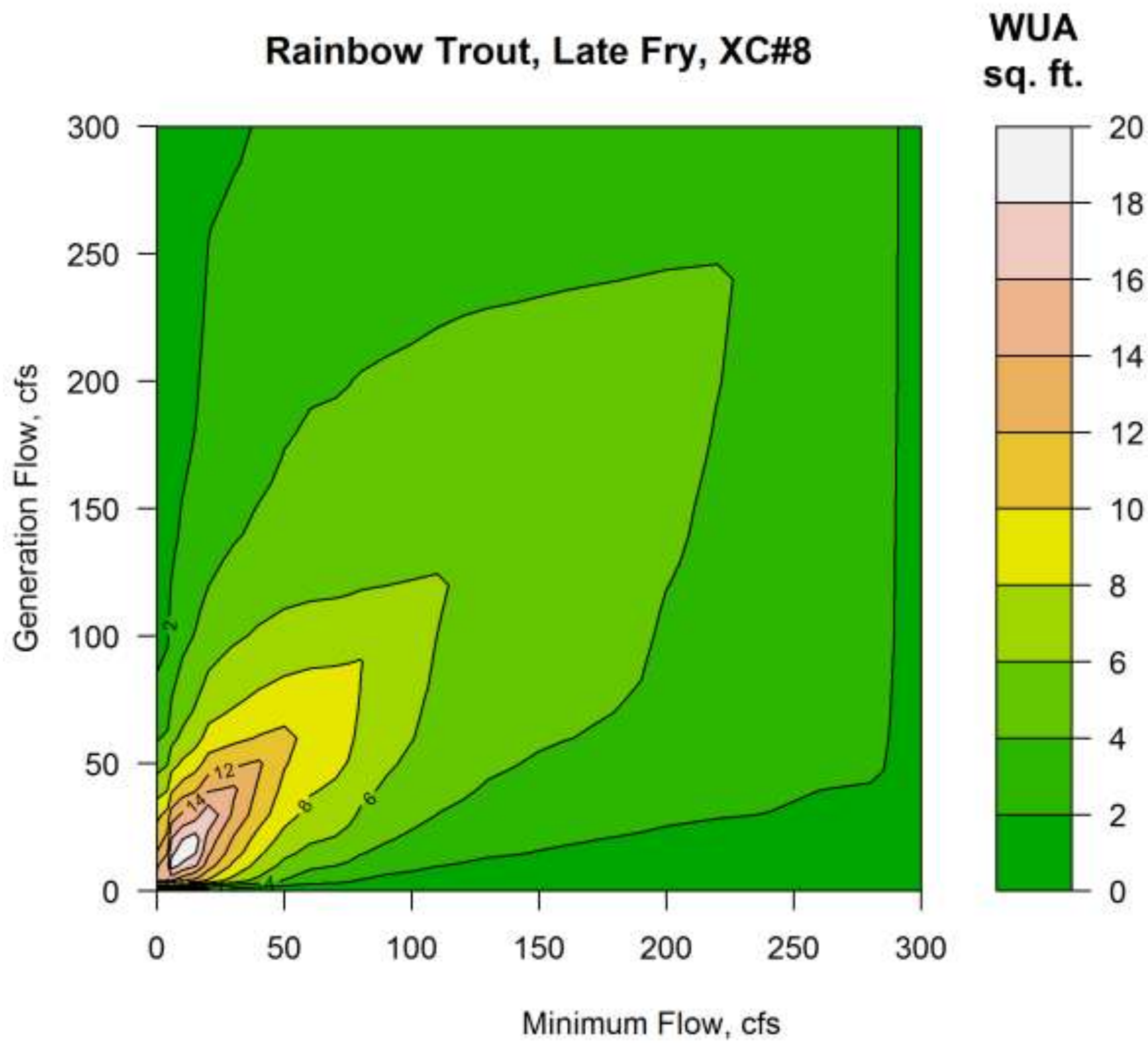

Rainbow Trout, Late Fry, XC#4
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
300
250
200
150
100
50
0
0
50
100
150
200
250
300
25
20
15
10
5
0
15
20
10
5
5

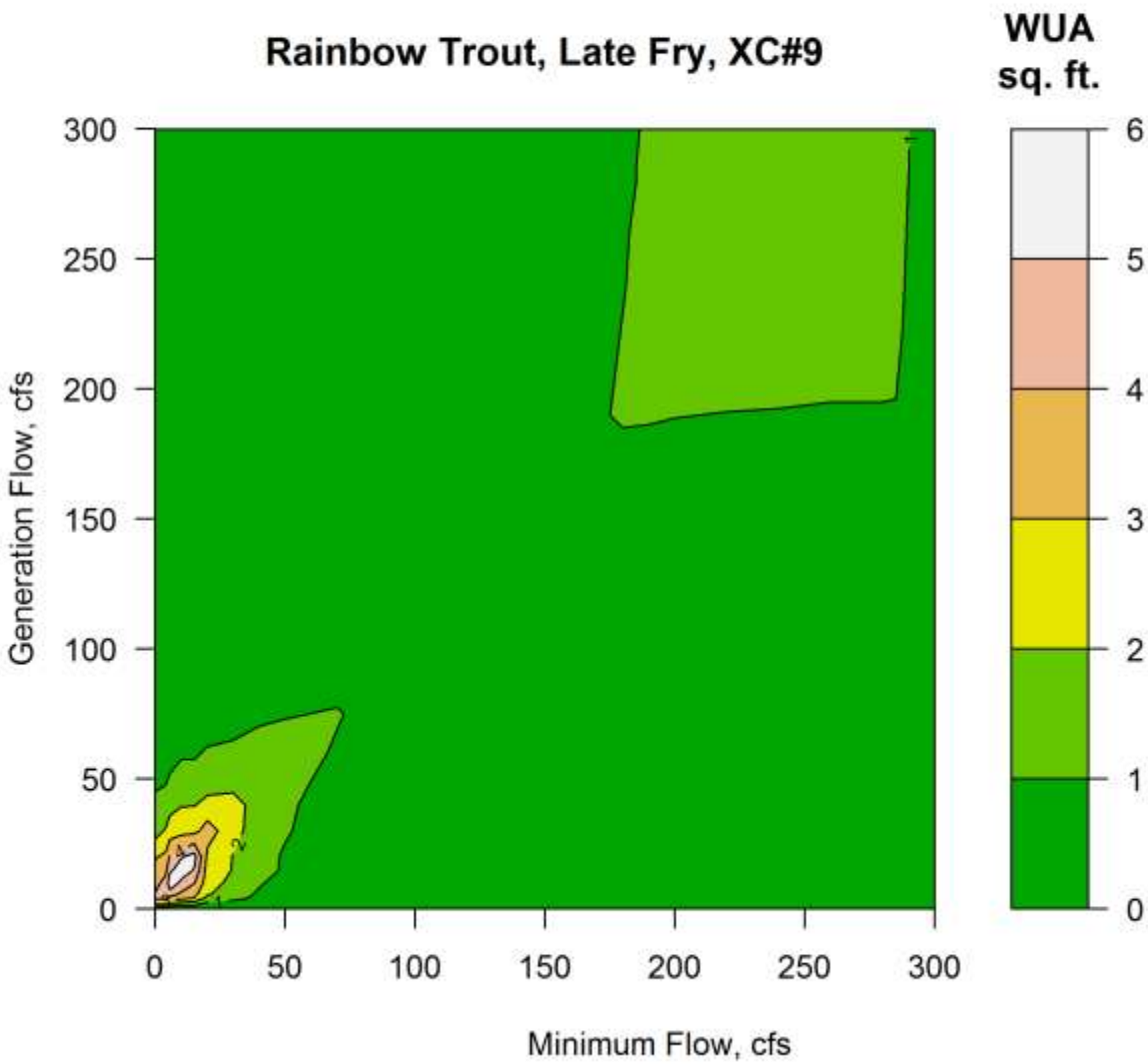

Rainbow Trout, Late Fry, XC#5
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
15
20
25
30
25
20
15
10
5
0

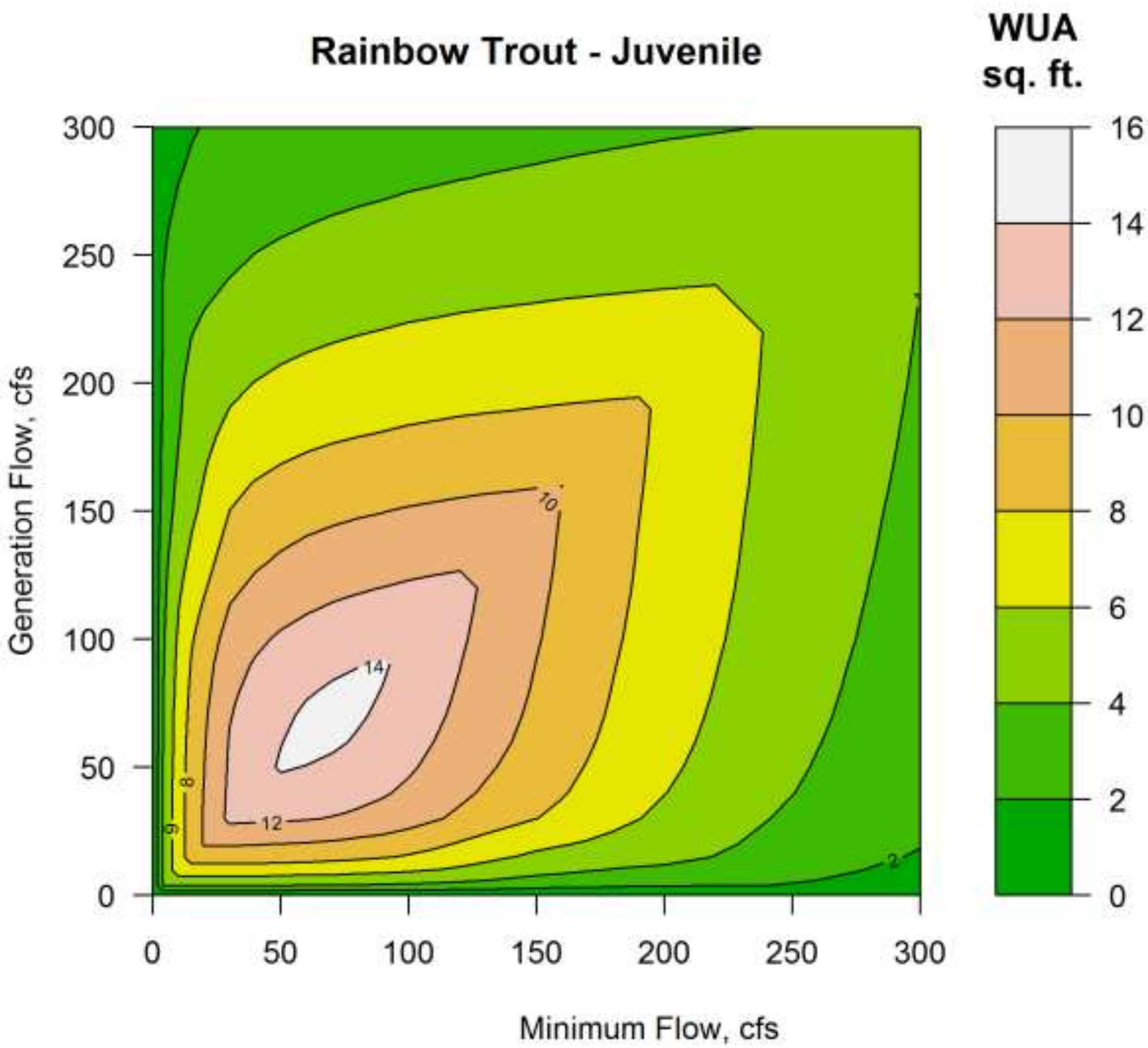


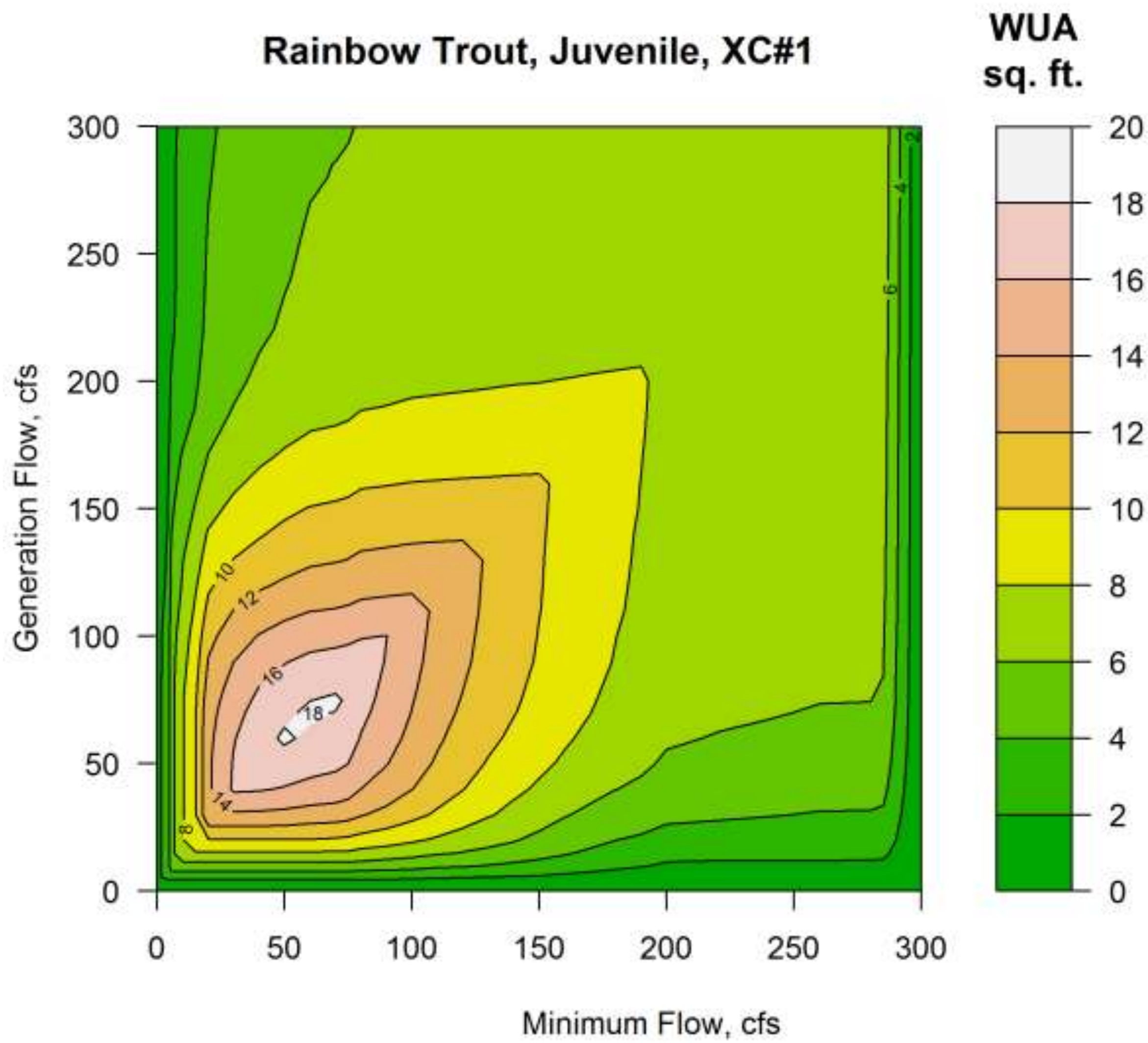
Rainbow Trout, Late Fry, XC#6
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
22
20
18
16
14
12
10
8
6
4
2
0


Rainbow Trout, Late Fry, XC#7
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
7
6
5
4
3
2
1
0


Rainbow Trout, Late Fry, XC#8
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
20
18
16
14
12
10
8
6
4
2
0
2
12
14
8
6


Rainbow Trout, Late Fry, XC#9
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
0
1
2
3
4
5
6


Rainbow Trout - Juvenile
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
300
250
200
150
100
50
0
0
50
100
150
200
250
300
16
14
12
10
8
6
4
2
0


Rainbow Trout, Juvenile, XC#1
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
300
250
200
150
100
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100
150
200
250
300
20
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14
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6
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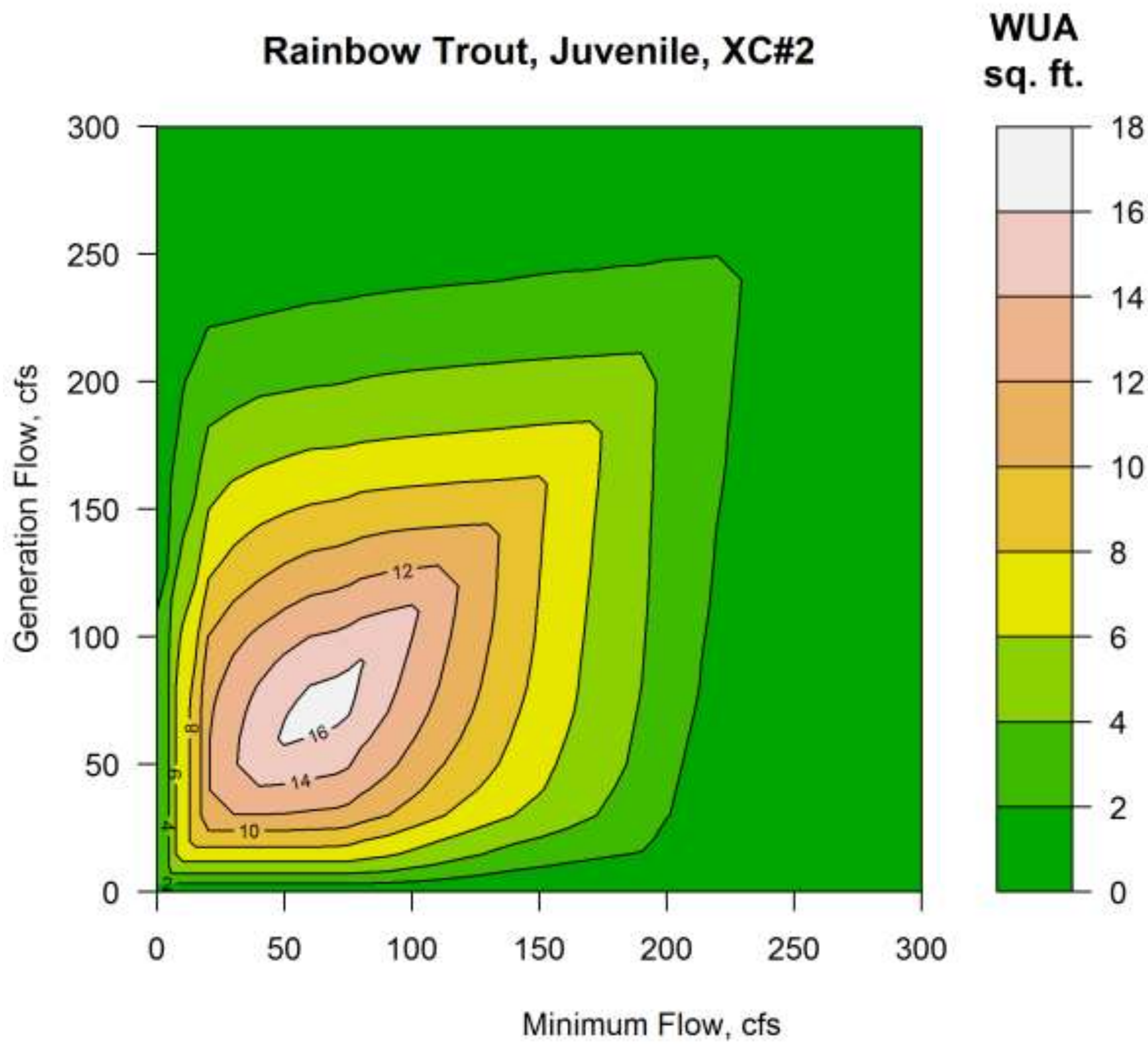
Rainbow Trout, Juvenile, XC#2
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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50
100
150
200
250
300
0
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4
6
8
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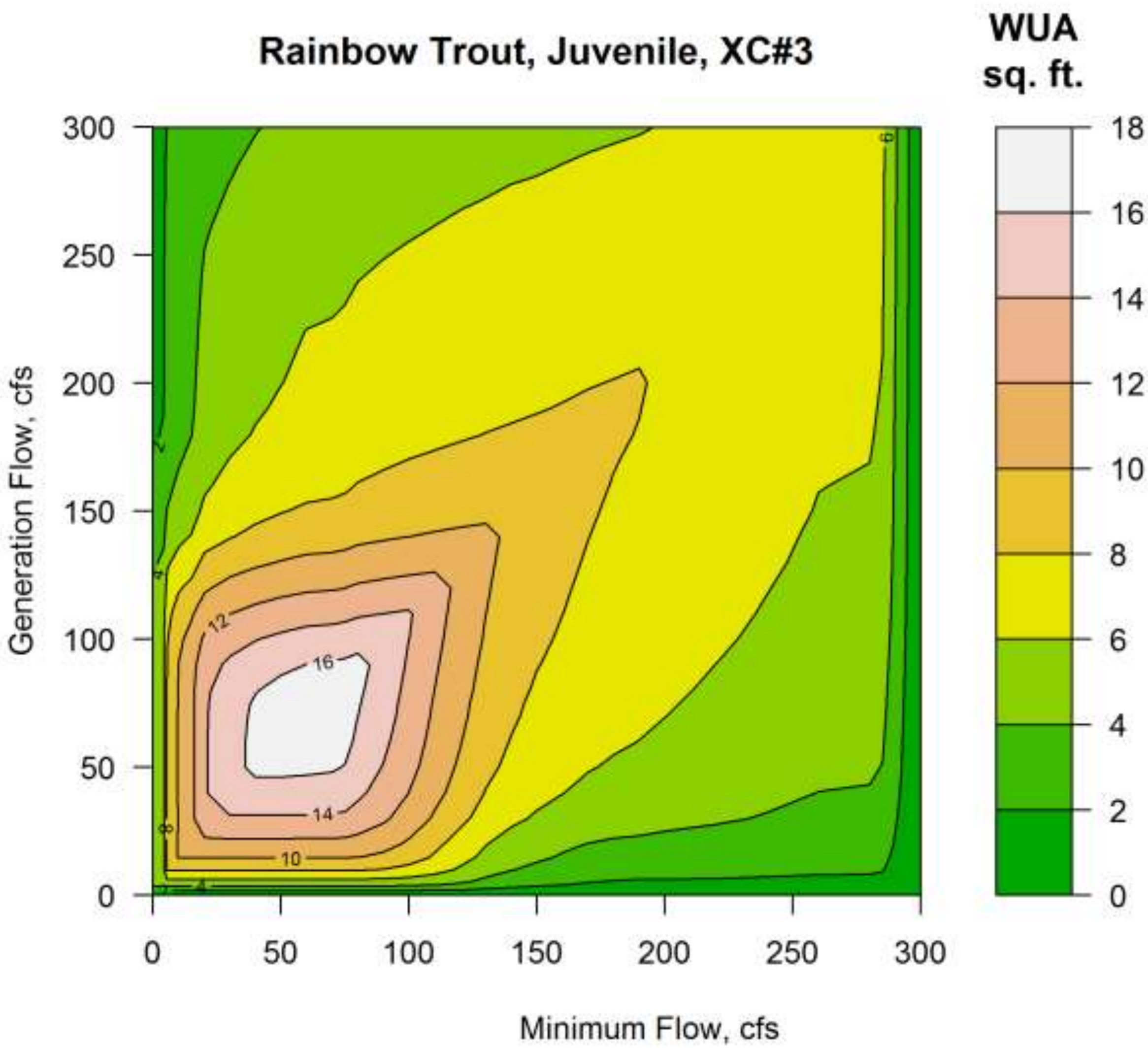
12
14
16
18


Rainbow Trout, Juvenile, XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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200
250
300
18
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14
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8
6
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2
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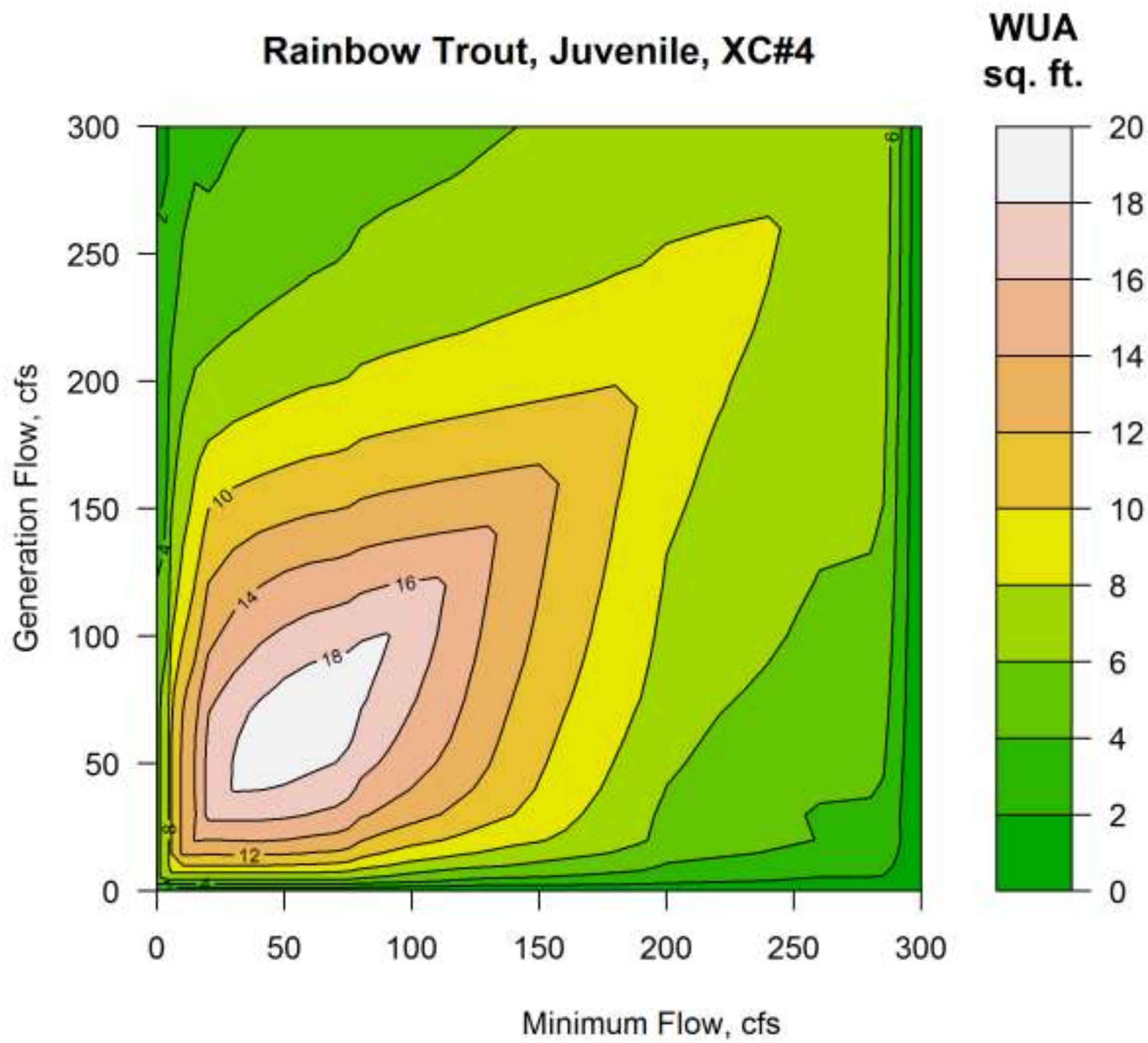
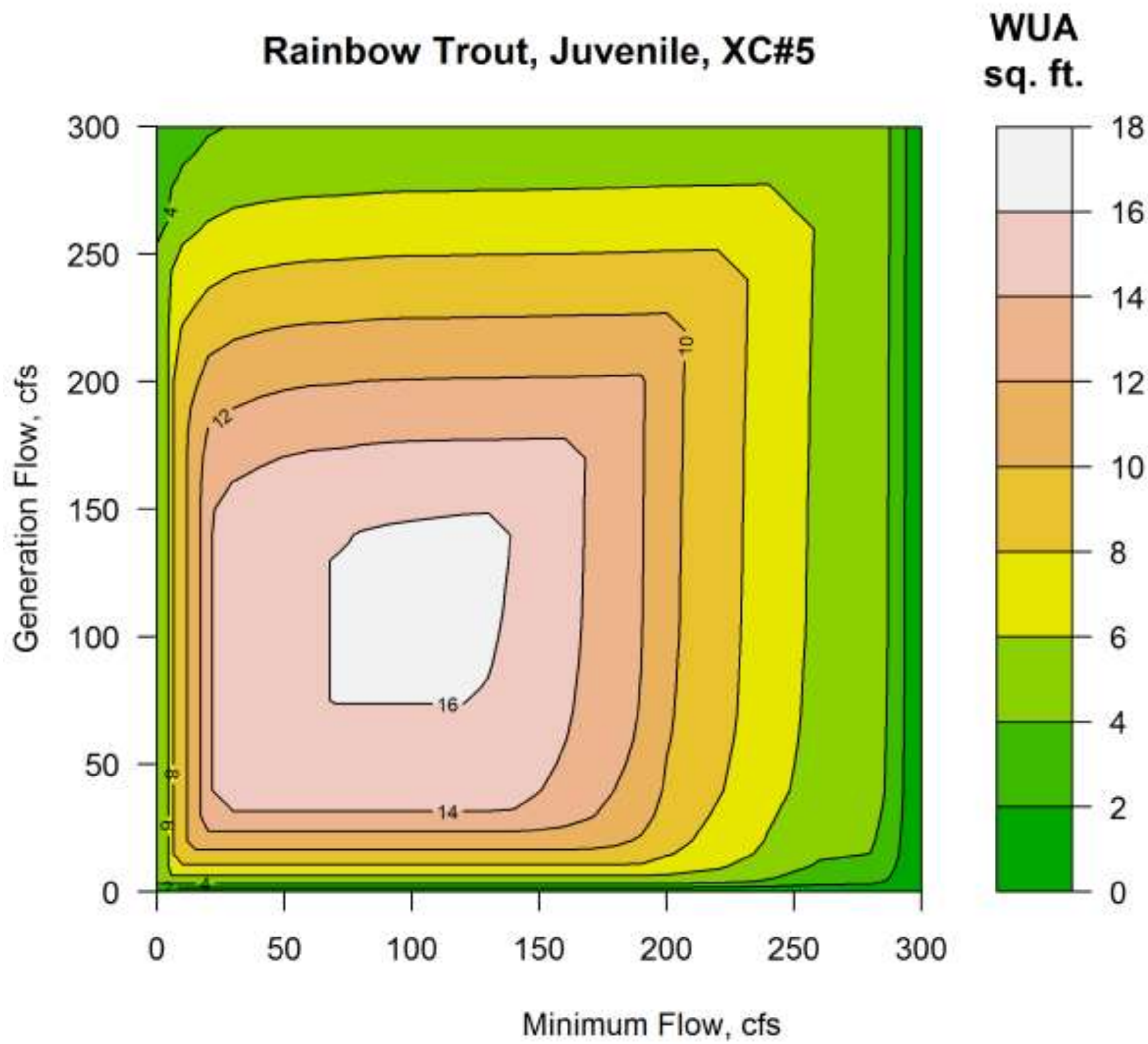


Rainbow Trout, Juvenile, XC#4
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
10
12
14
16
18
8
20
18
16
14
12
10
8
6
4
2
0



Rainbow Trout, Juvenile, XC#5
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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100
150
200
250
300
0
2
4
6
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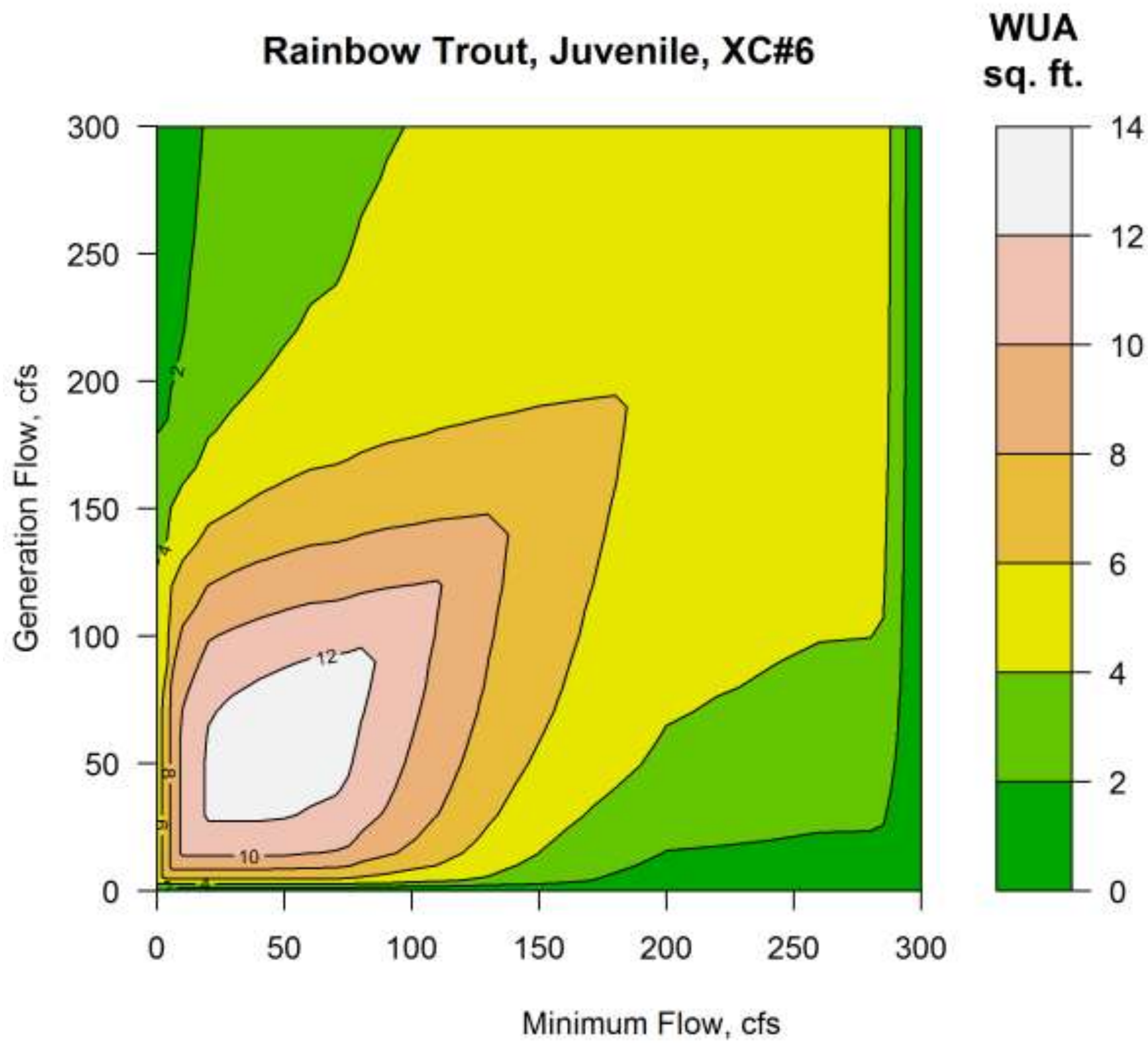
10
12
14
16
18


Rainbow Trout, Juvenile, XC#6
WUA
sq. ft.
14
12
10
8
6
4
2
0
300
250
200
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Generation Flow, cfs
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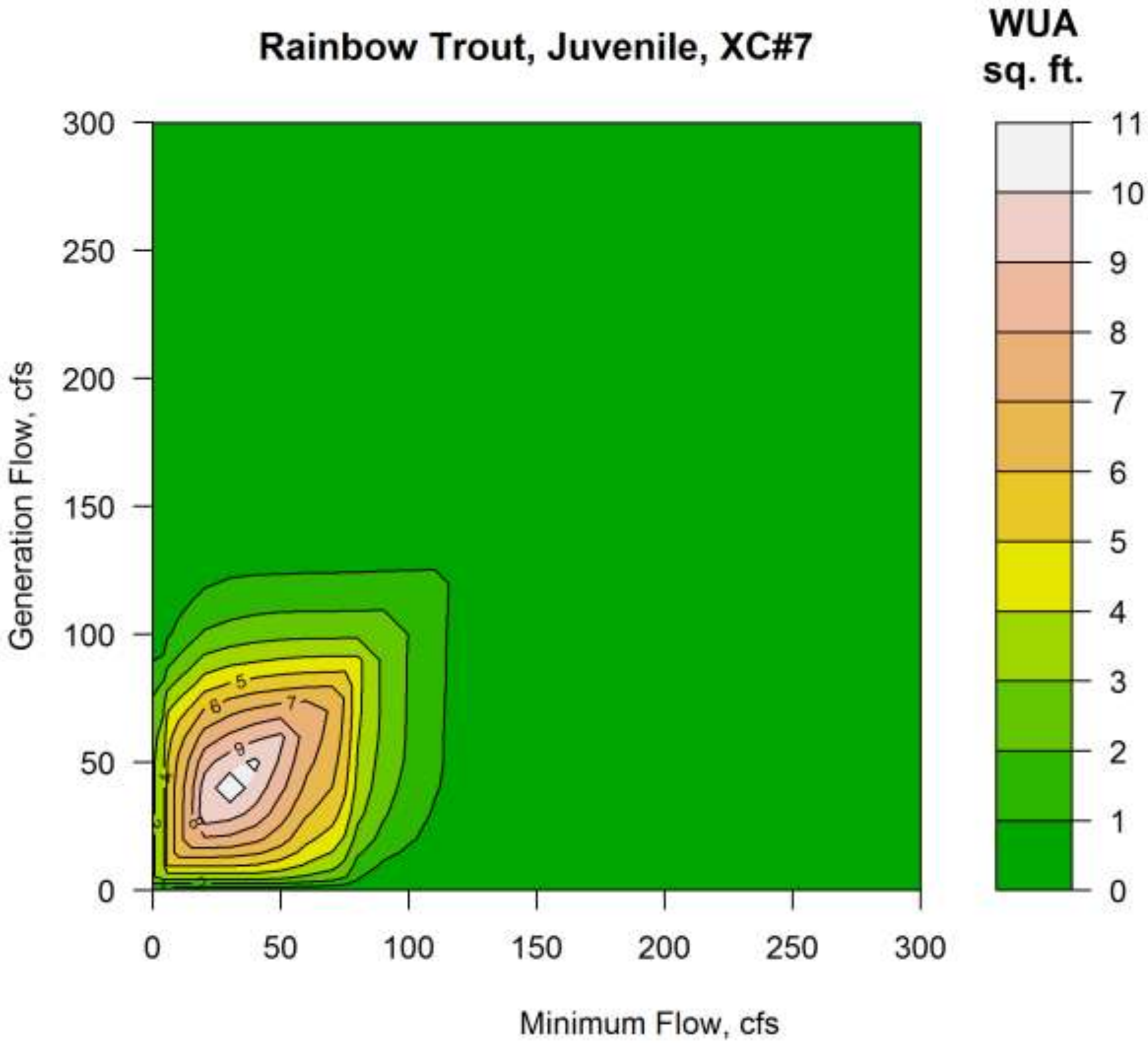
100
150
200
250
300
Minimum Flow, cfs
12
10
8
2
4


Rainbow Trout, Juvenile, XC#7
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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200
250
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8
9
10
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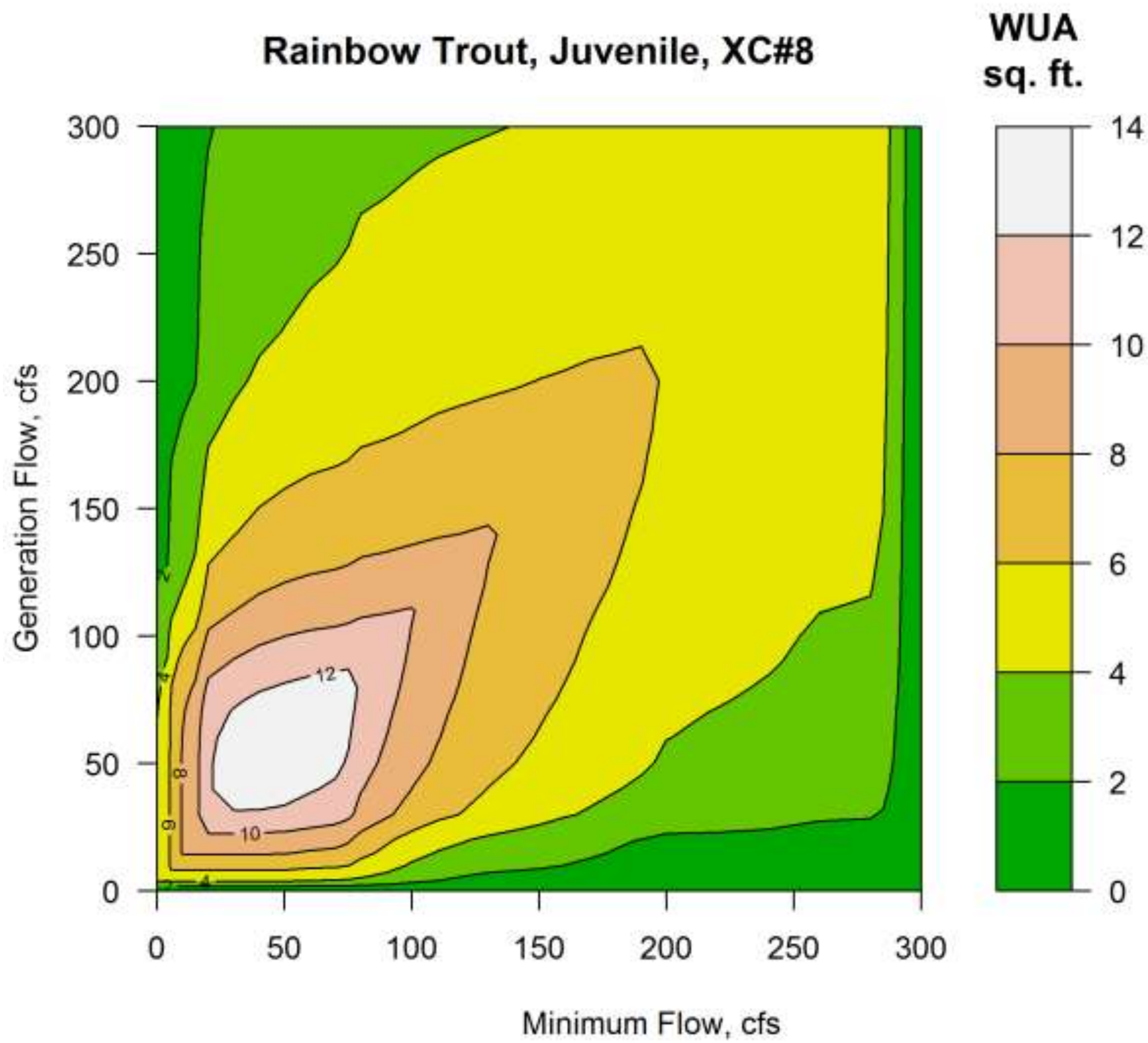
Rainbow Trout, Juvenile, XC#8
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
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100
150
200
250
300
Minimum Flow, cfs
14
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6
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2
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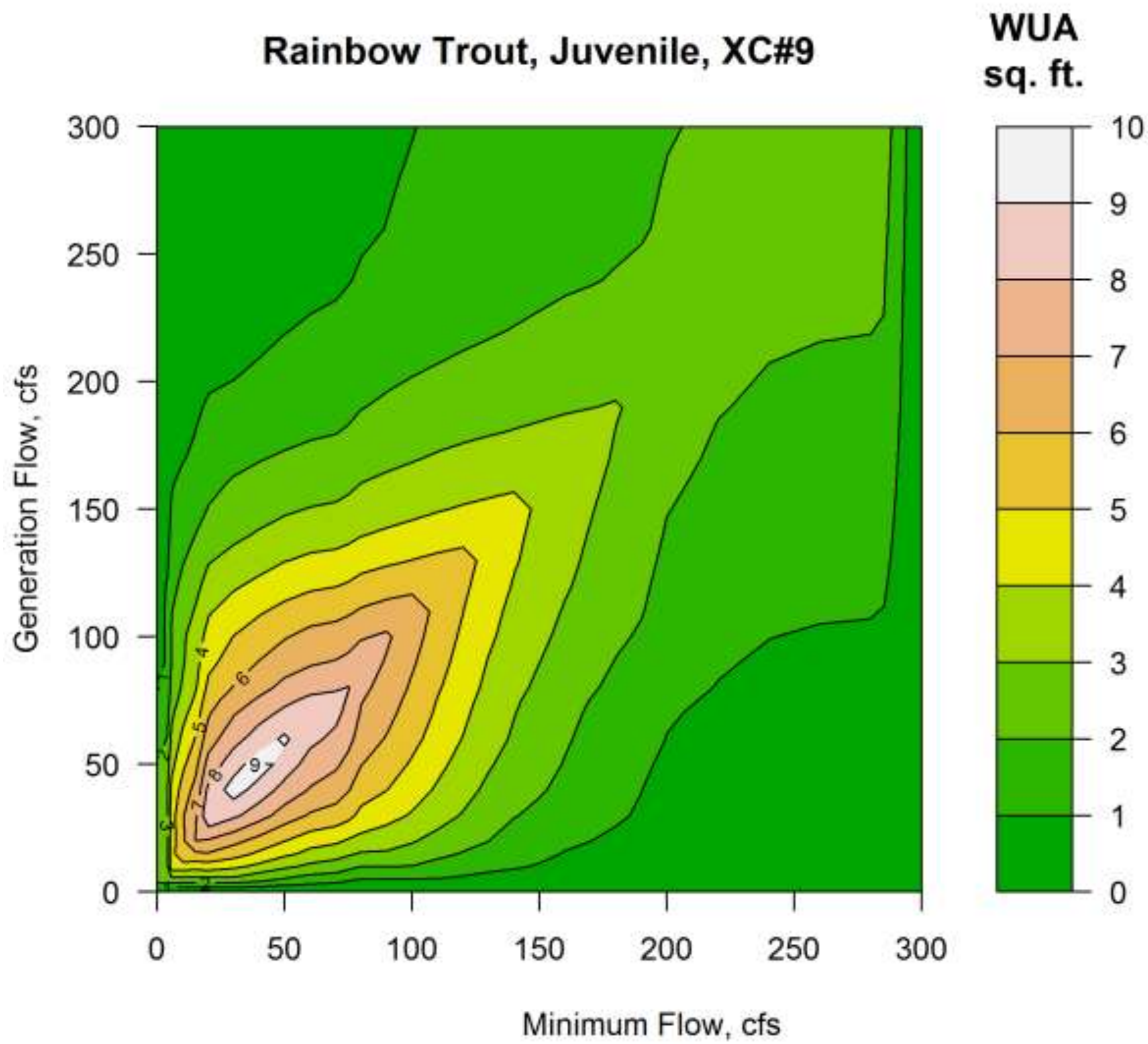
Rainbow Trout, Juvenile, XC#9
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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100
150
200
250
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7
8
9
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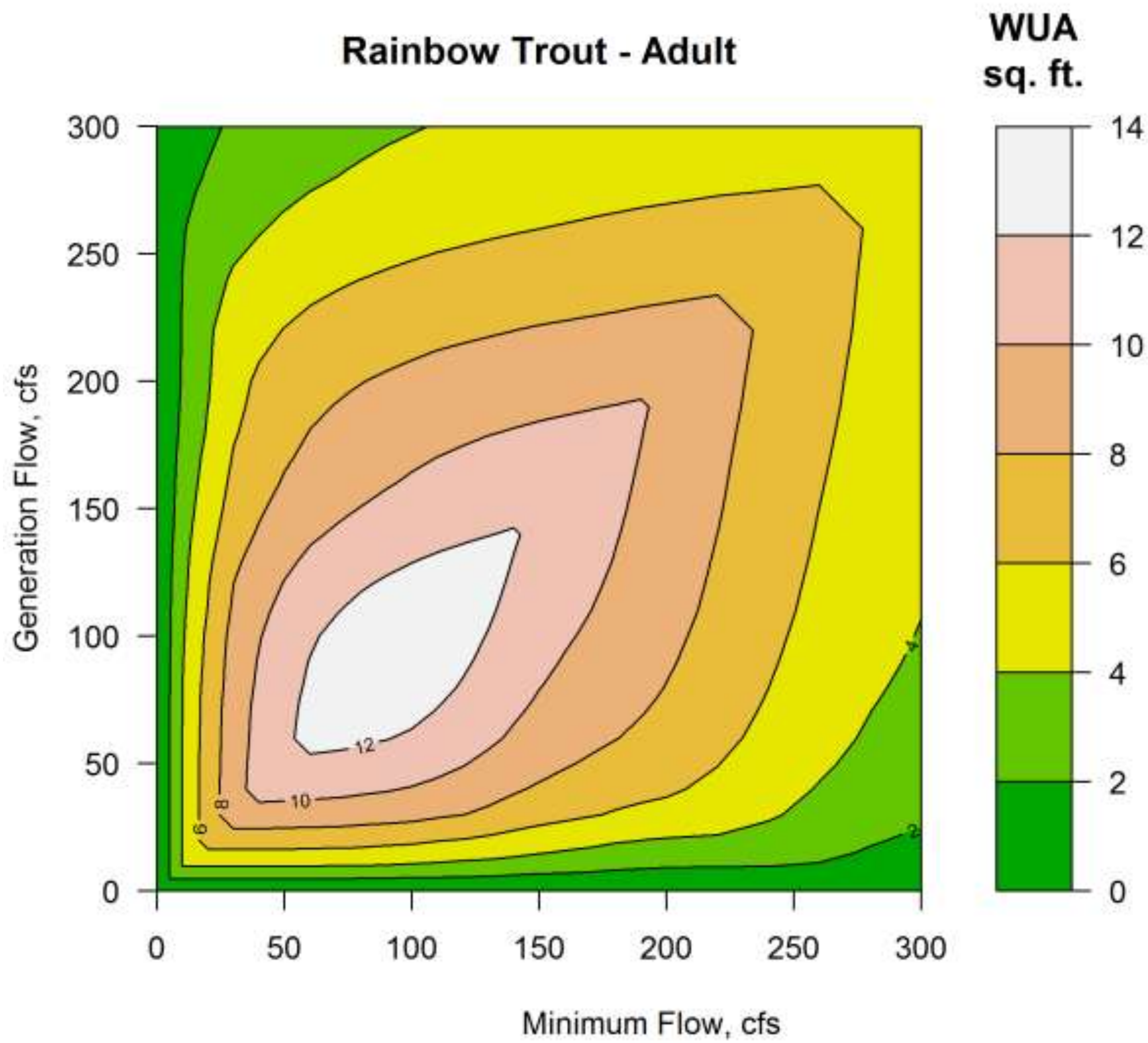
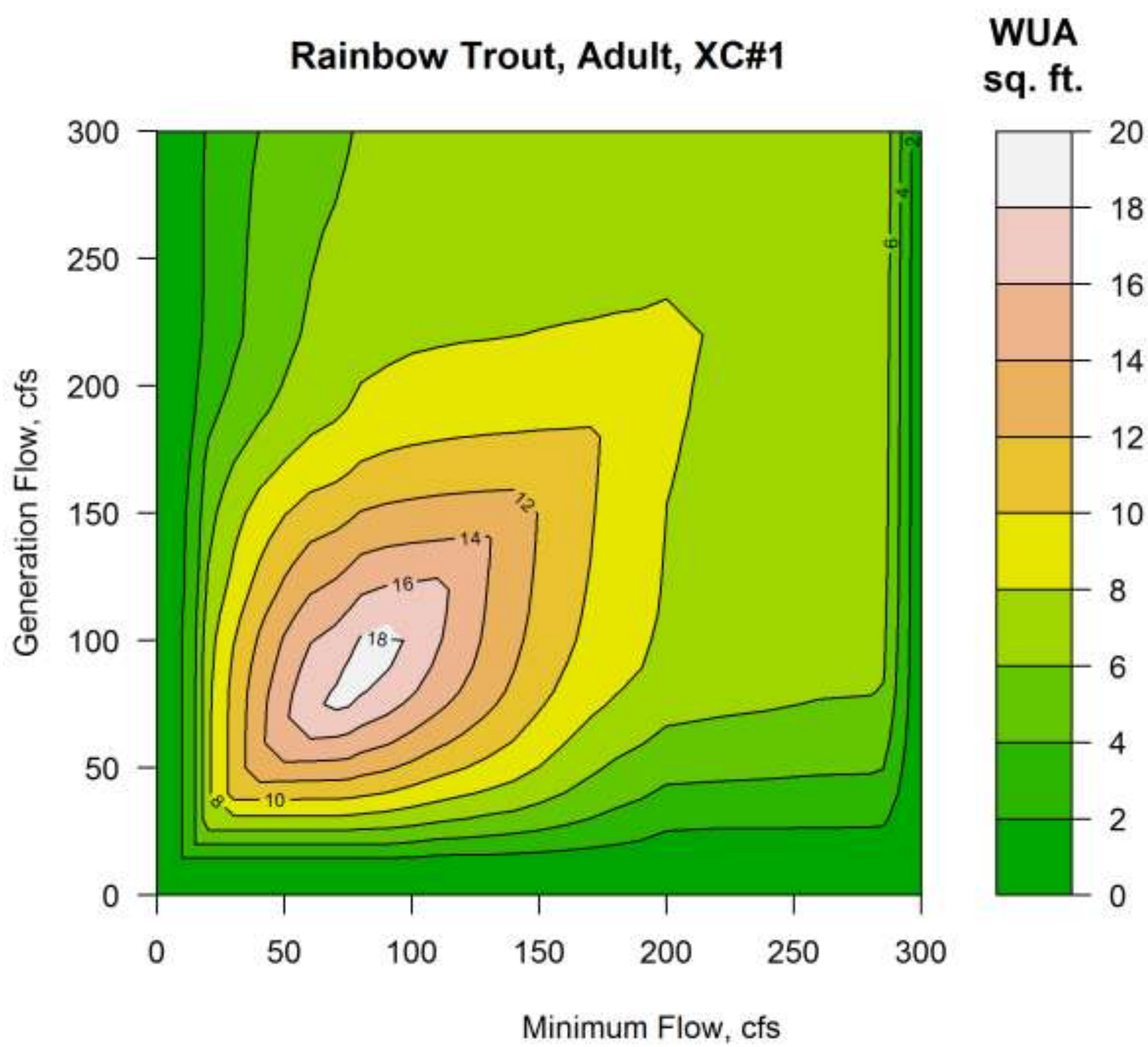

Rainbow Trout - Adult
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
14
12
10
8
6
4
2
0


Rainbow Trout, Adult, XC#1
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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100
150
200
250
300
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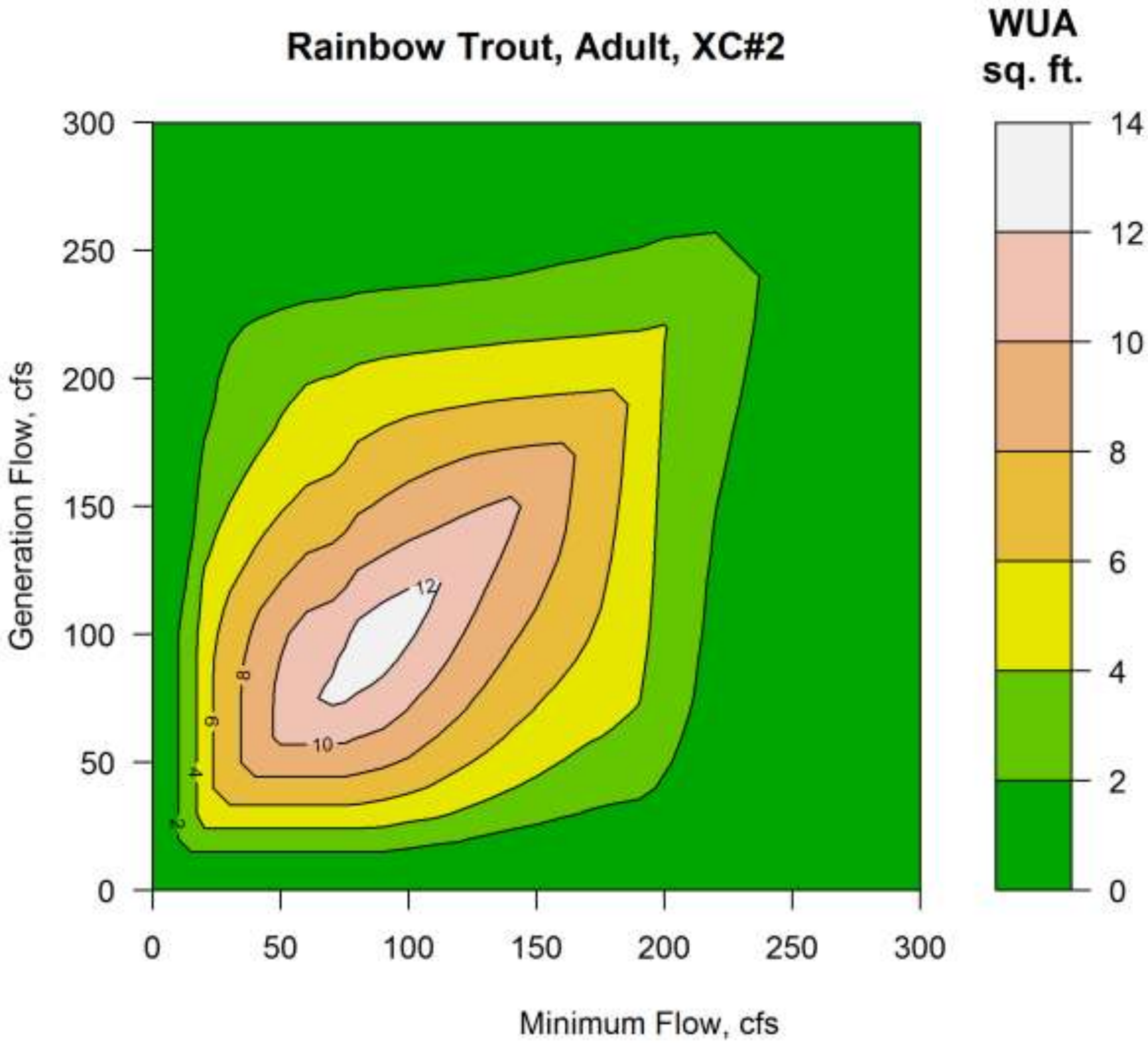
12
14
16
18
20


Rainbow Trout, Adult, XC#2
WUA
sq. ft.
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250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
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Minimum Flow, cfs
14
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10
8
6
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2
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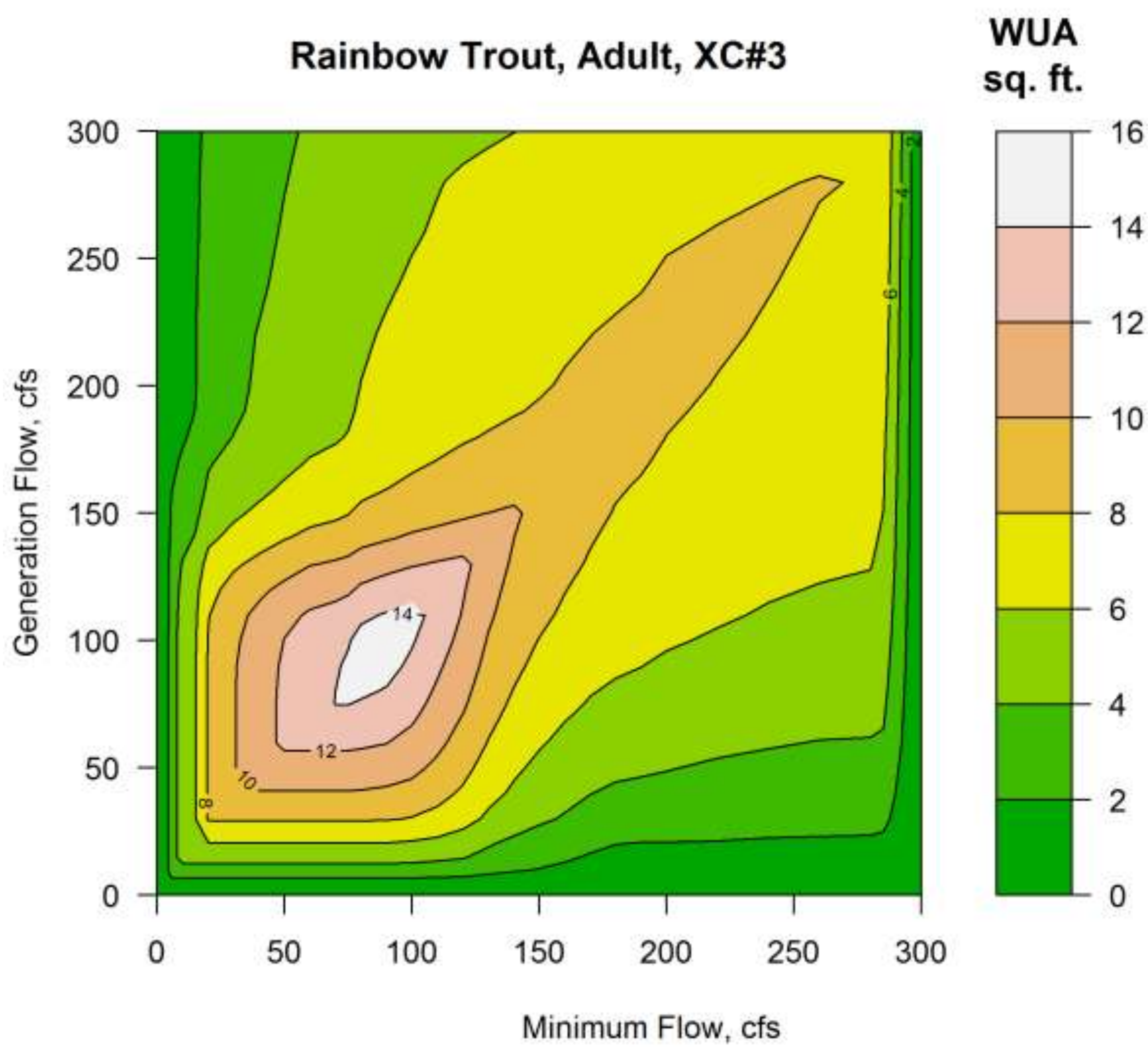
8
6
4
2


Rainbow Trout, Adult, XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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100
150
200
250
300
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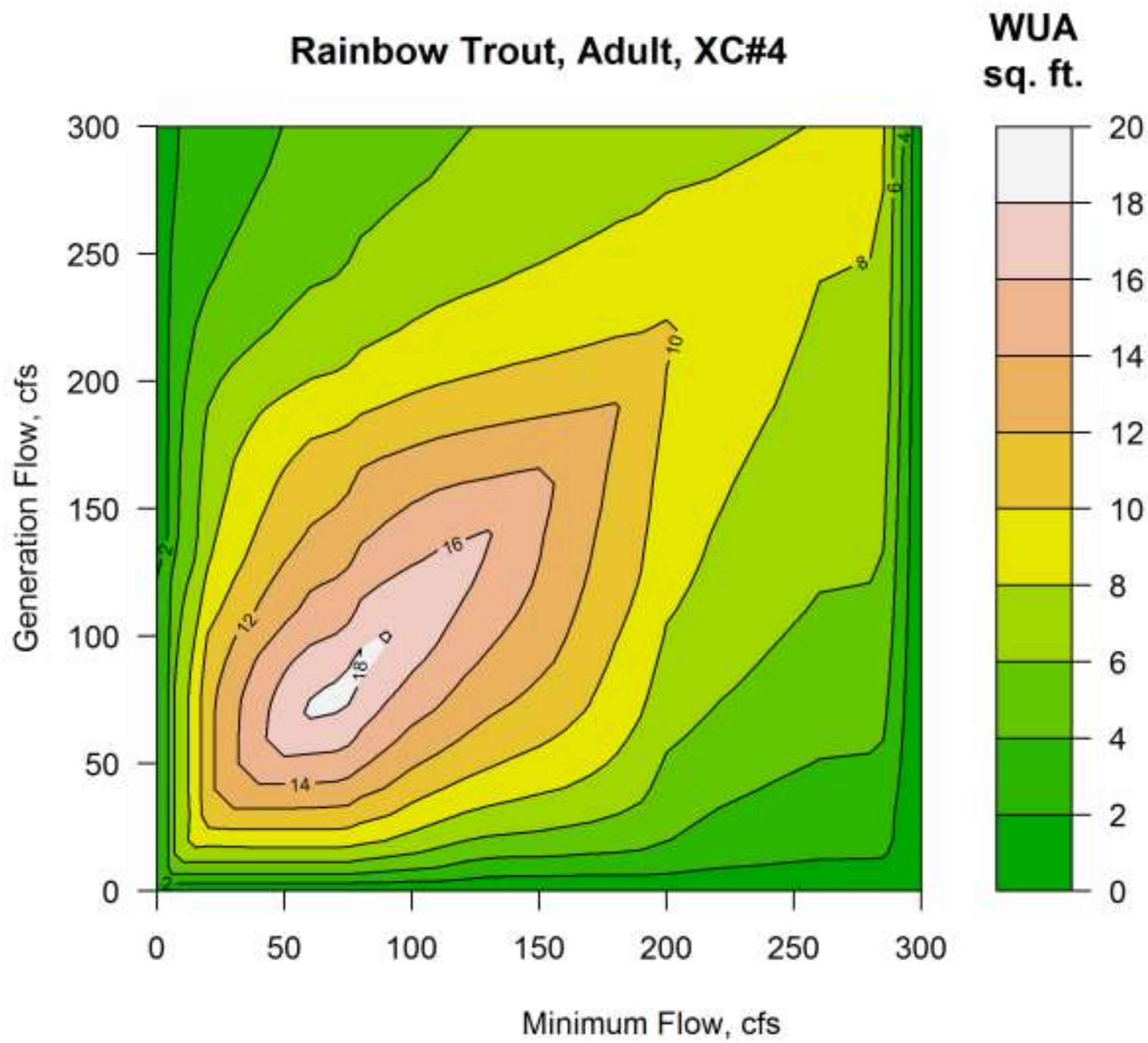
8
10
12
14
16


Rainbow Trout, Adult, XC#4
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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200
250
300
2
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6
8
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14
16
18
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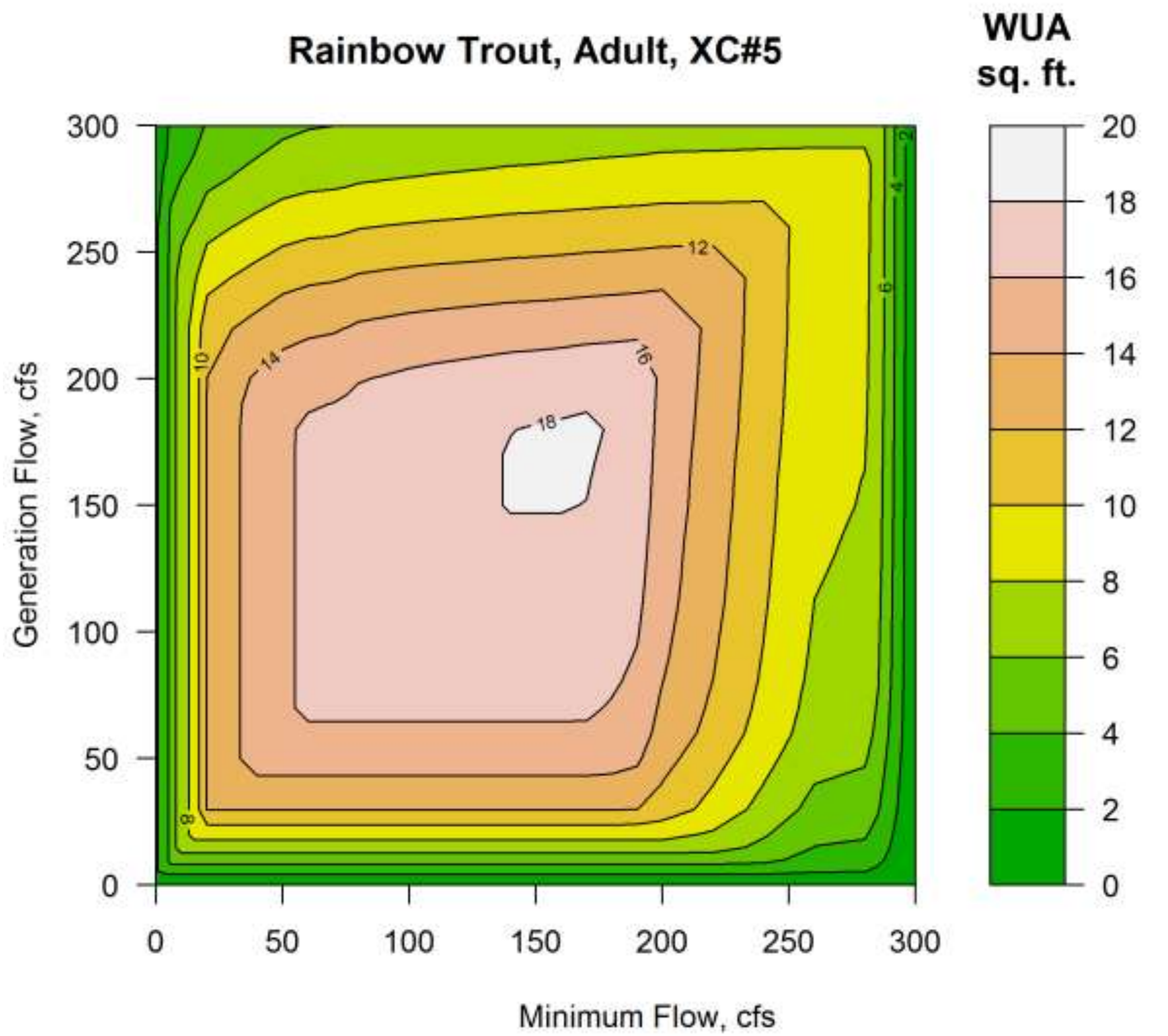
Rainbow Trout, Adult, XC#5
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
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150
200
250
300
Minimum Flow, cfs
20
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14
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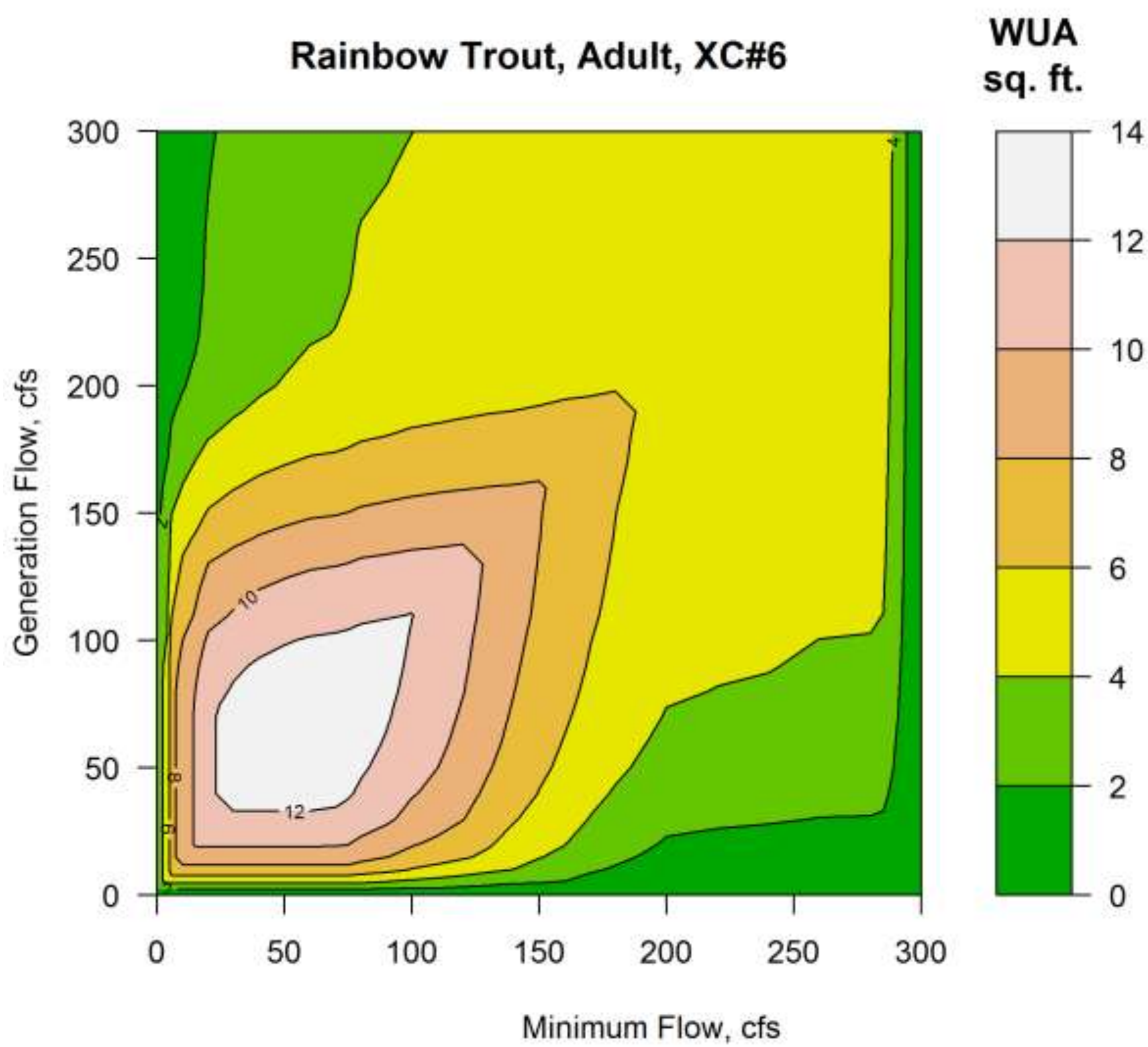
8
6
4
2
0



Rainbow Trout, Adult, XC#6
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
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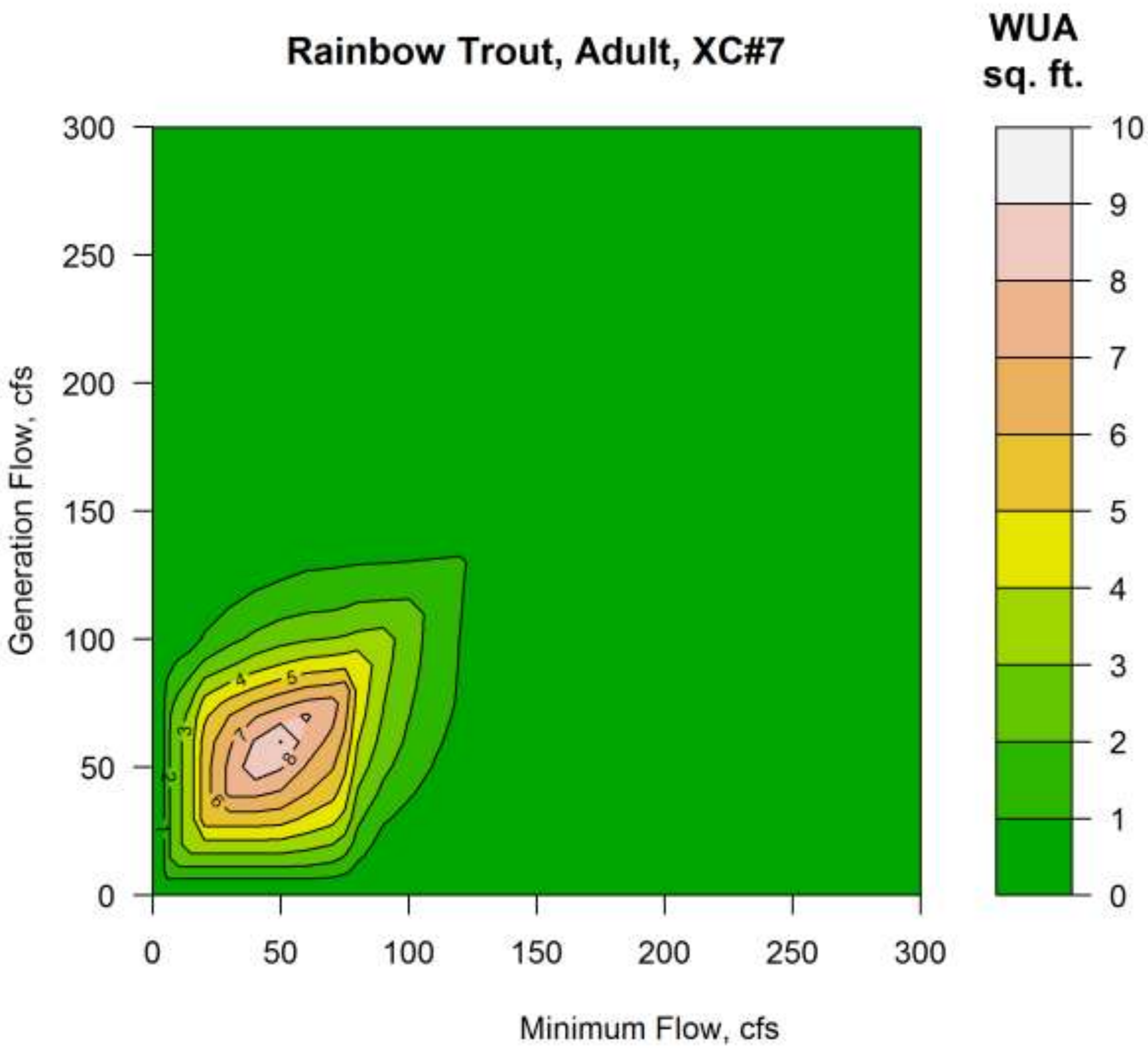
50
100
150
200
250
300
Minimum Flow, cfs
14
12
10
8
6
4
2
0


Rainbow Trout, Adult, XC#7
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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100
150
200
250
300
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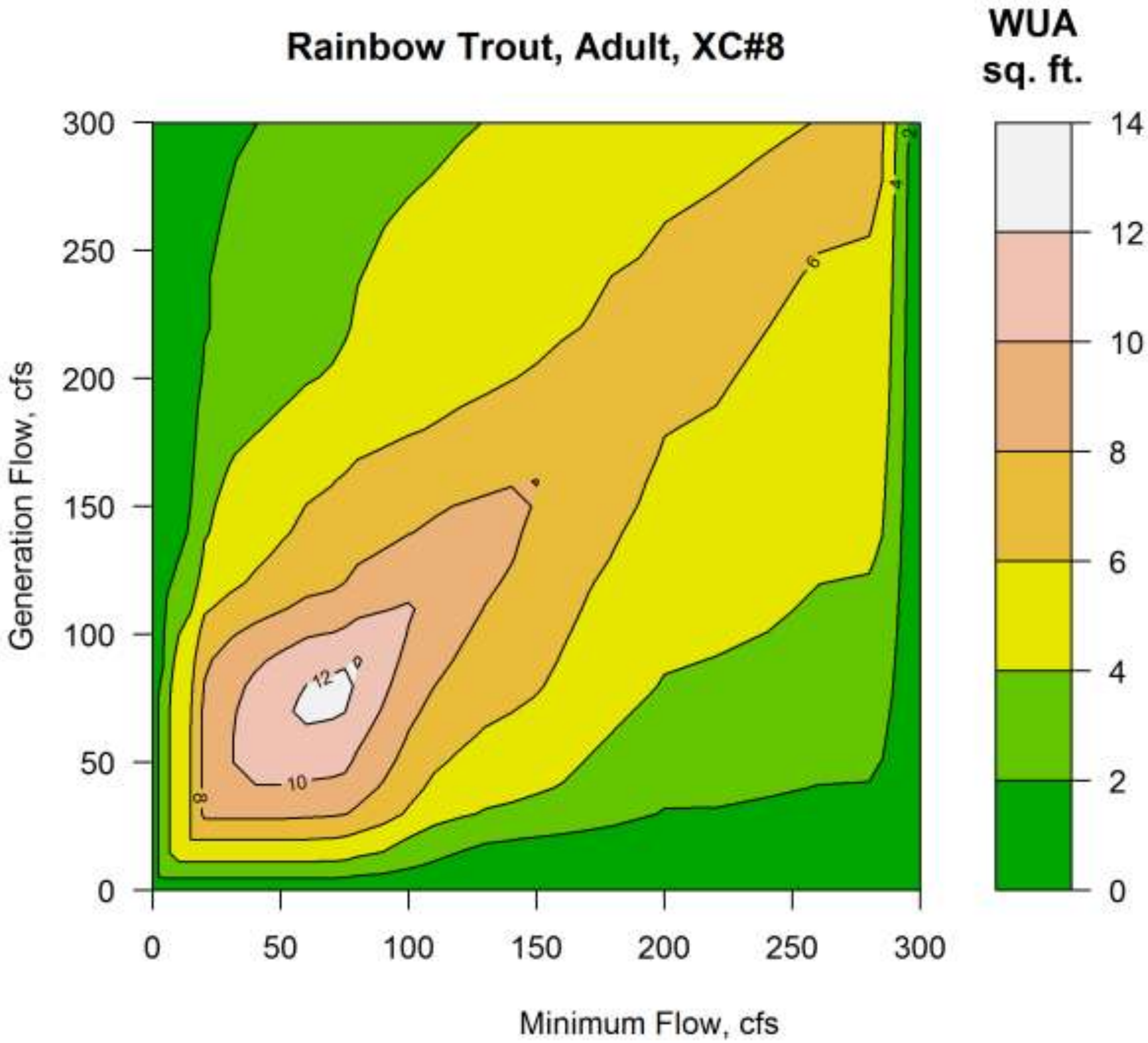
6
7
8
9
10


Rainbow Trout, Adult, XC#8
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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100
150
200
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300
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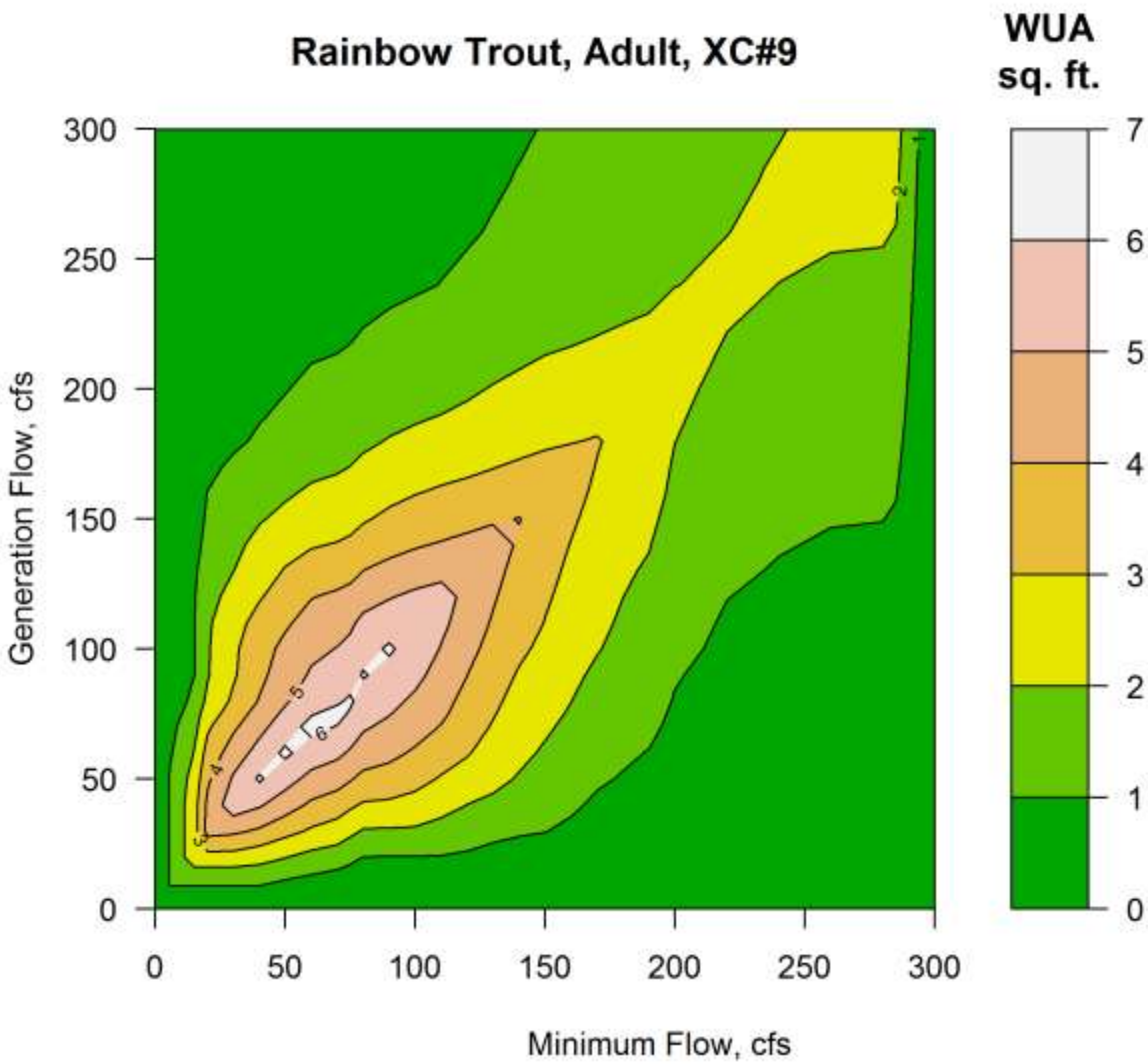
6
8
10
12
14


Rainbow Trout, Adult, XC#9
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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100
150
200
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300
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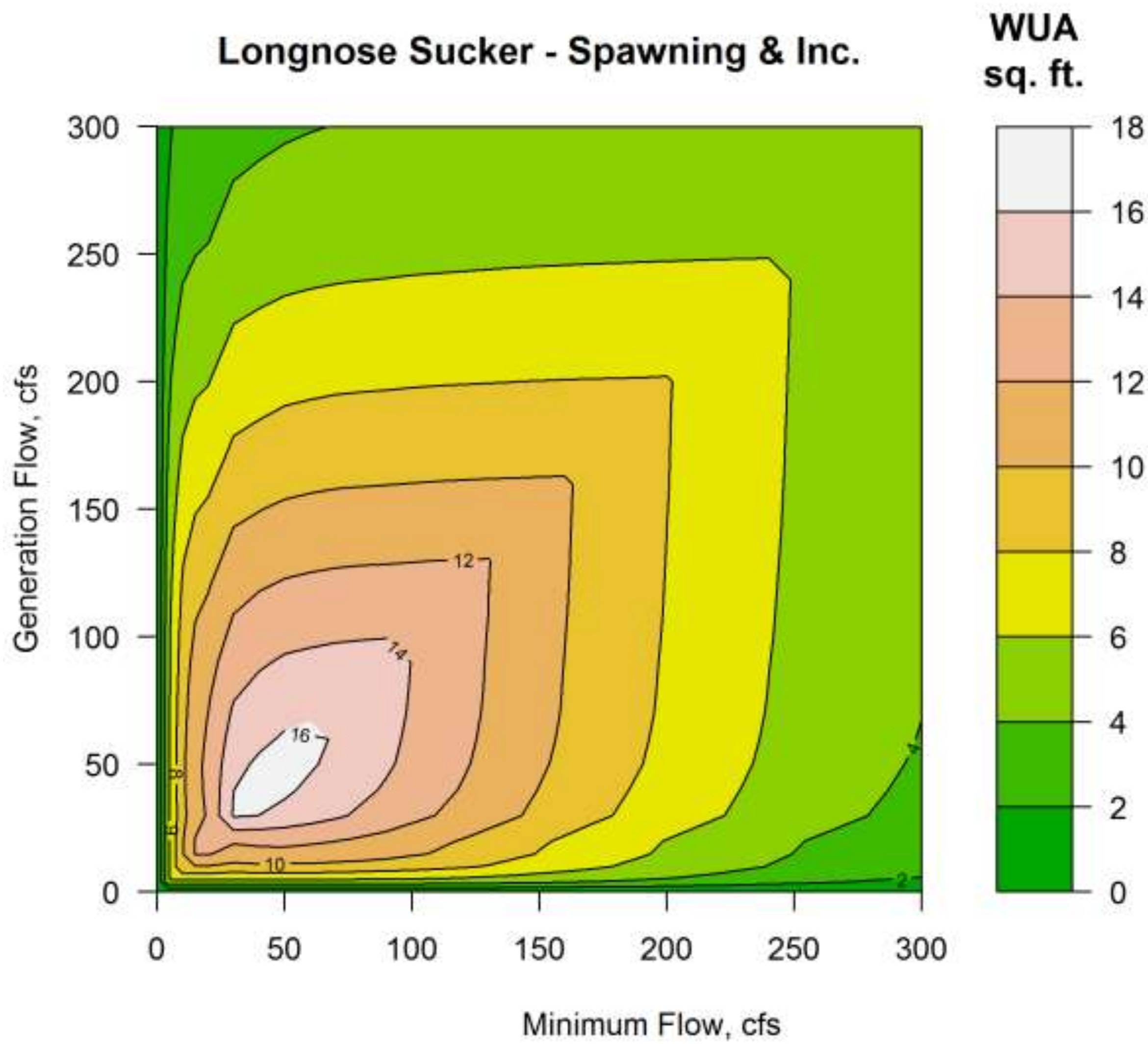
3
4
5
6
7


Longnose Sucker - Spawning & Inc.
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
0
50
100
150
200
250
300
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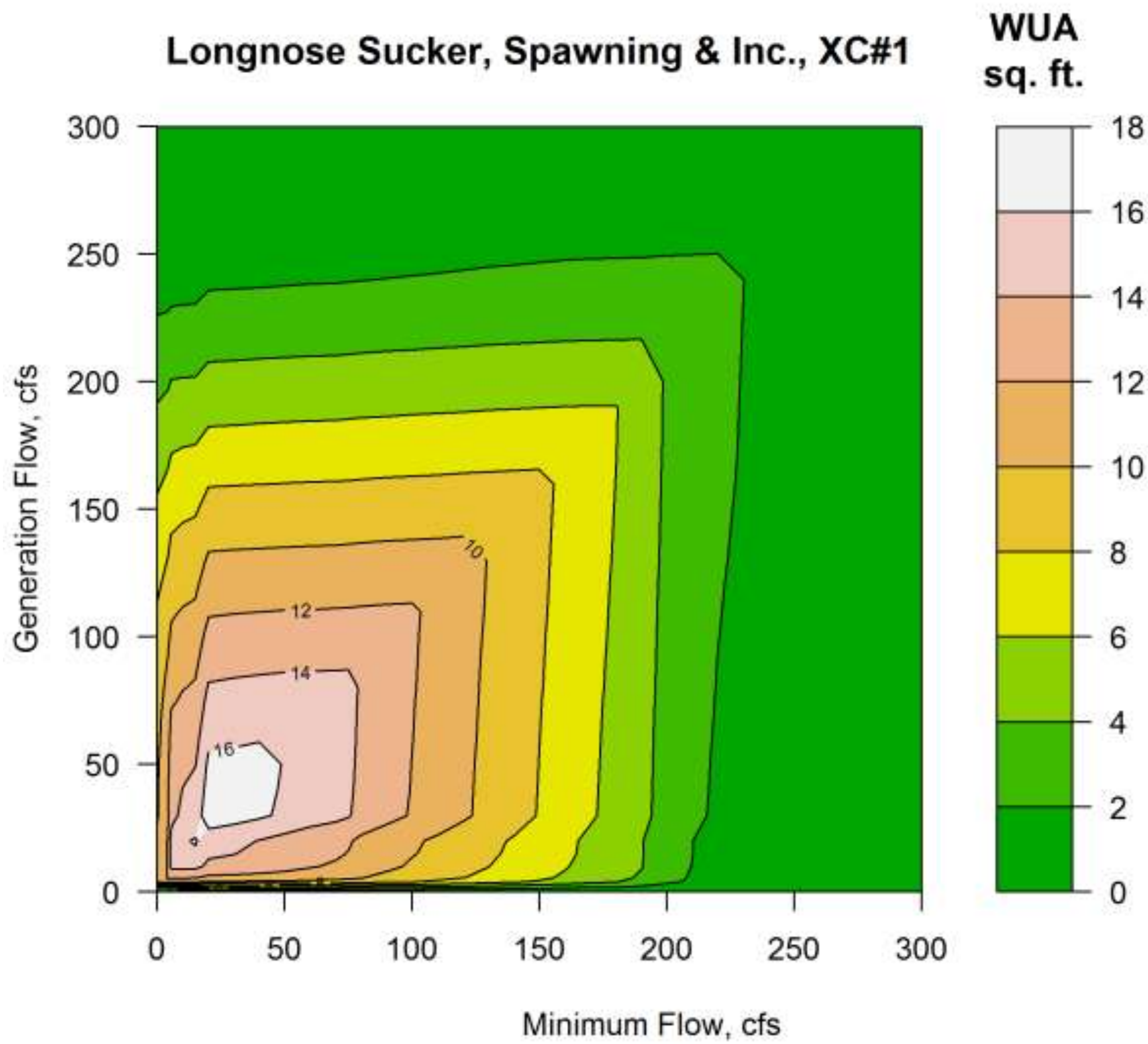
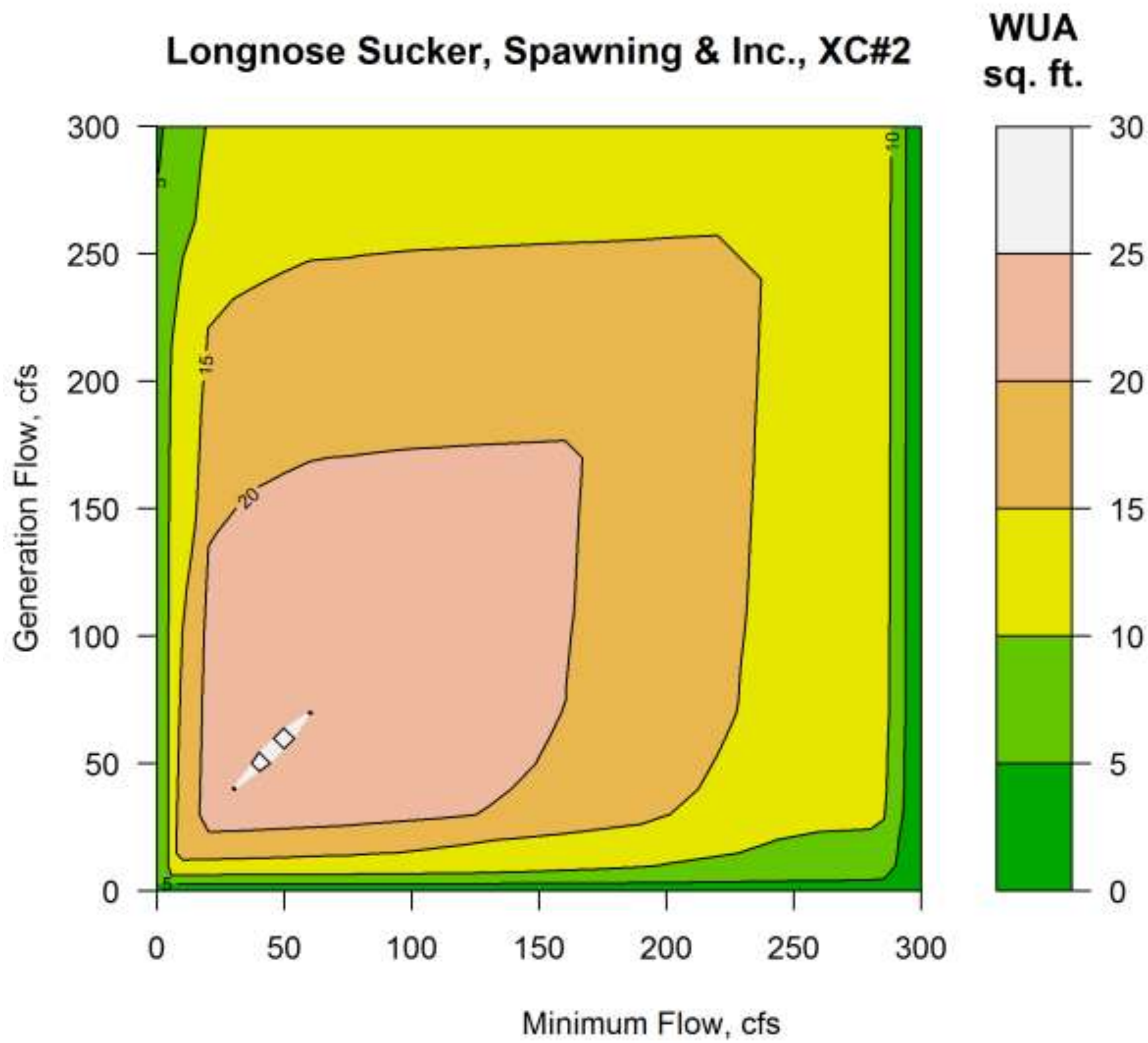
10
8
6
4
2


Longnose Sucker, Spawning & Inc., XC#1
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
10
12
14
16
18
16
14
12
10
8
6
4
2
0


Longnose Sucker, Spawning & Inc., XC#2
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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100
150
200
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300
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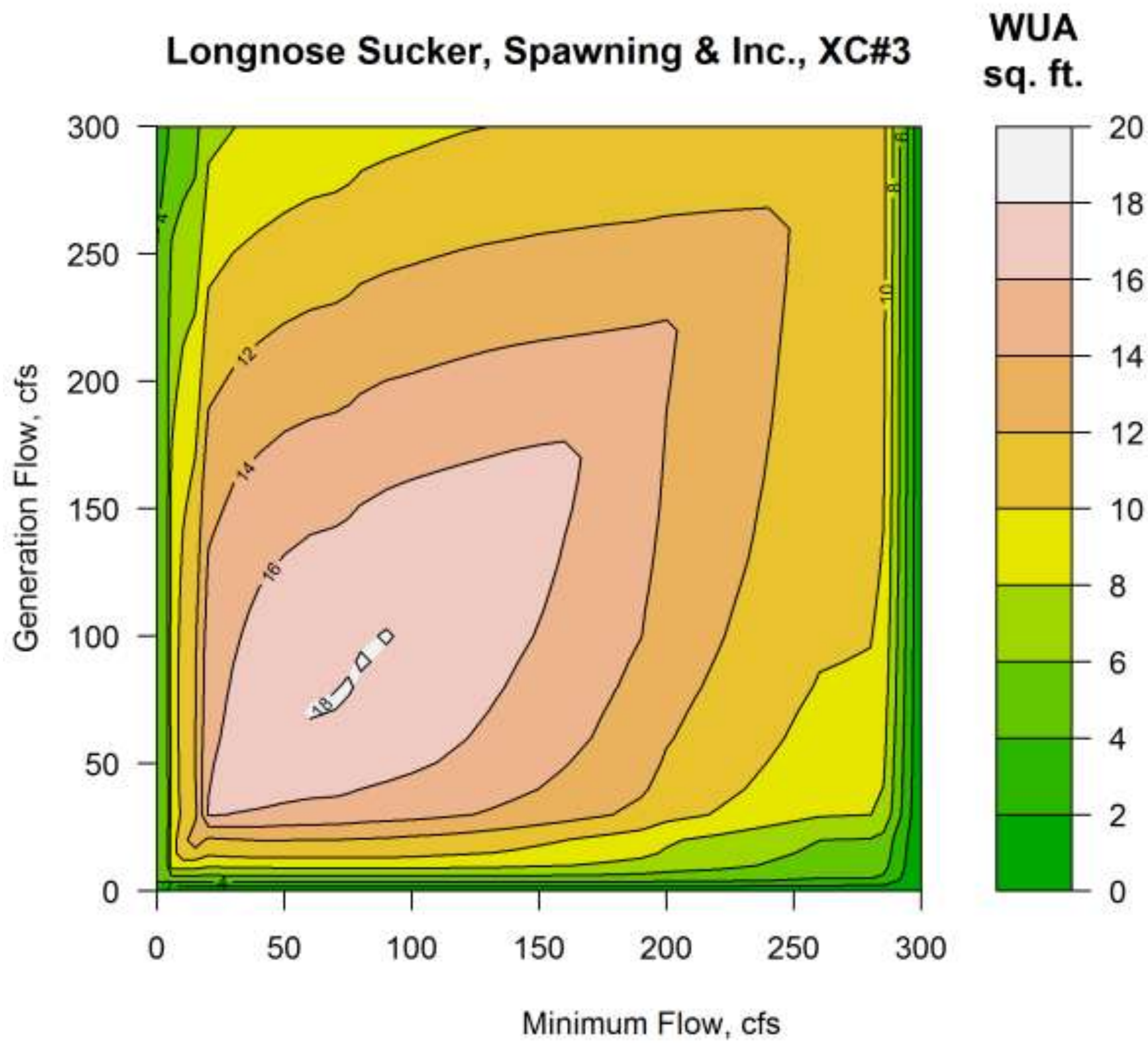
10
15
20
25
30


Longnose Sucker, Spawning & Inc., XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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150
200
250
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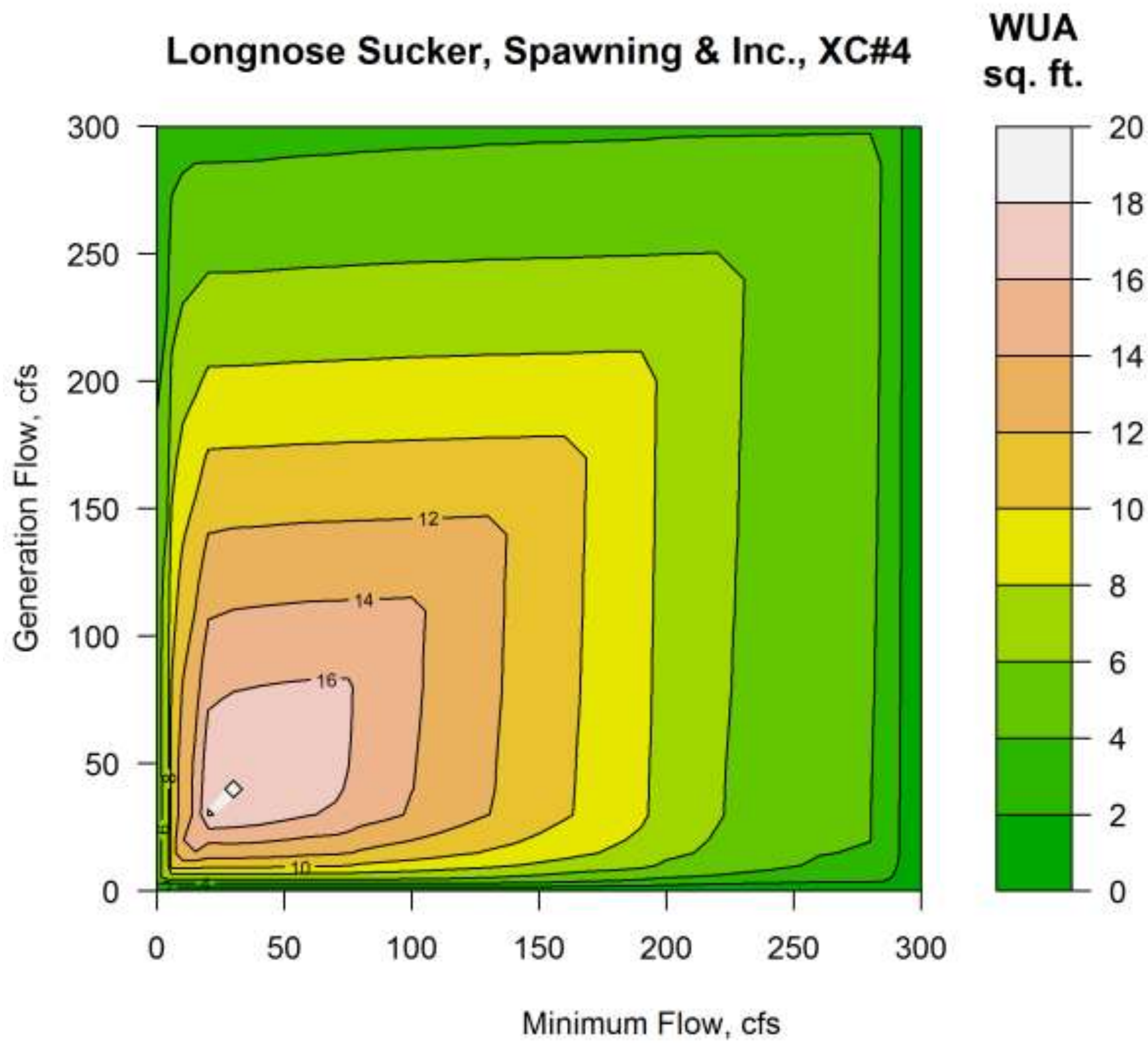
12
14
16
18
20



Longnose Sucker, Spawning & Inc., XC#4
WUA
sq. ft.
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200
150
100
50
0
Generation Flow, cfs
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50
100
150
200
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300
Minimum Flow, cfs
12
14
16
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6
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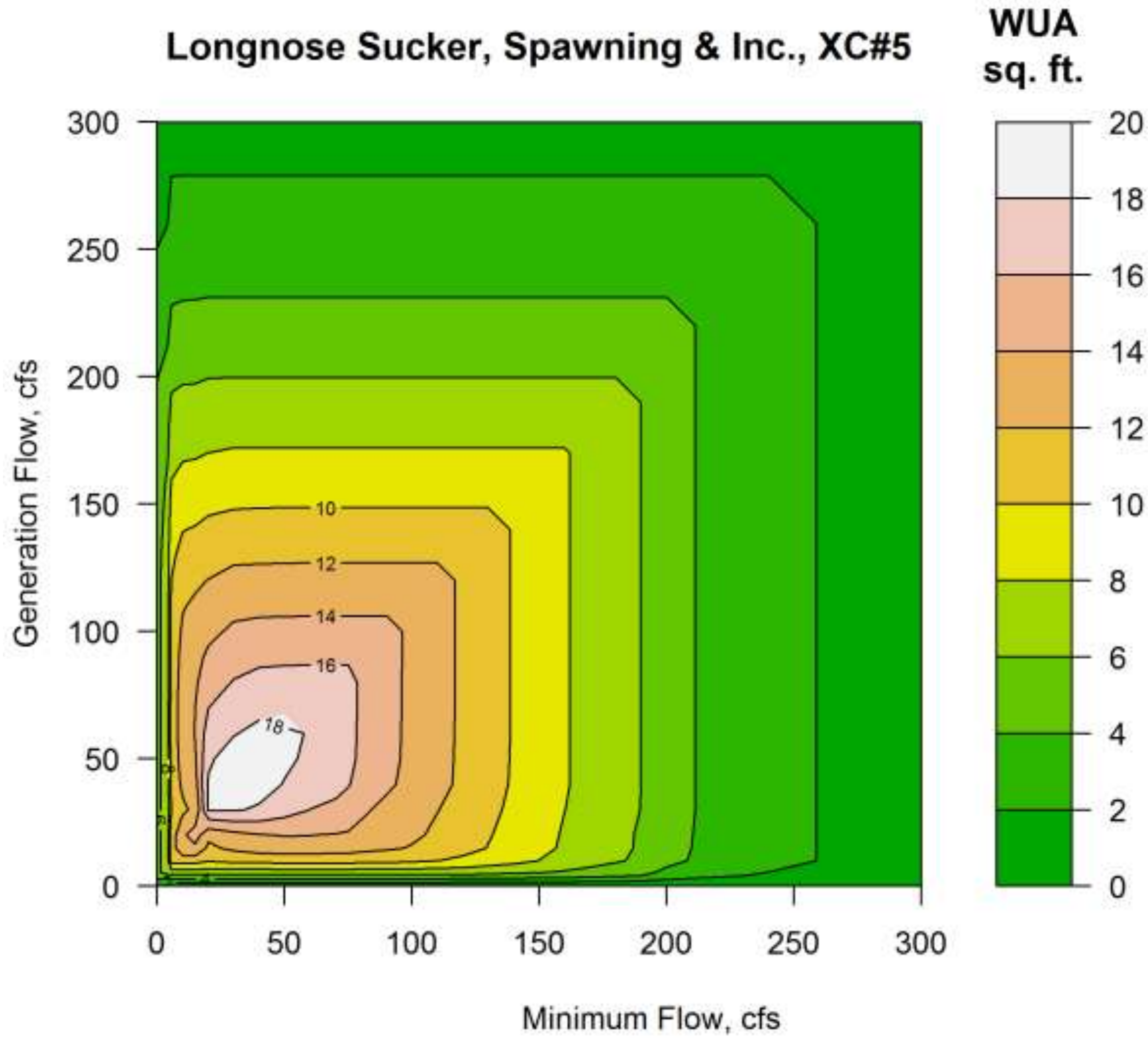
2
0


Longnose Sucker, Spawning & Inc., XC#5
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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250
200
150
100
50
0
0
50
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12
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2
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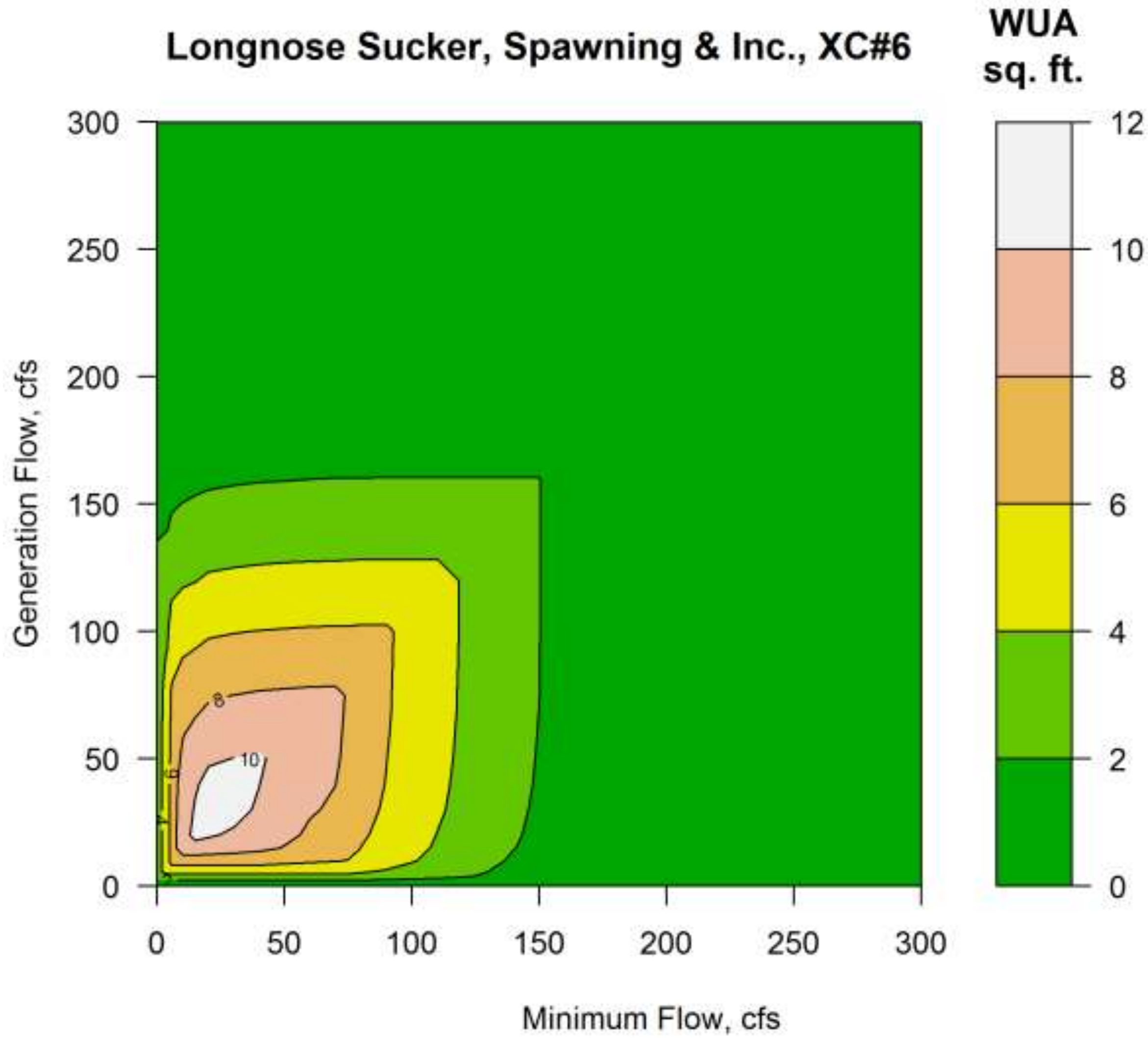
Longnose Sucker, Spawning & Inc., XC#6
WUA
sq. ft.
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Minimum Flow, cfs
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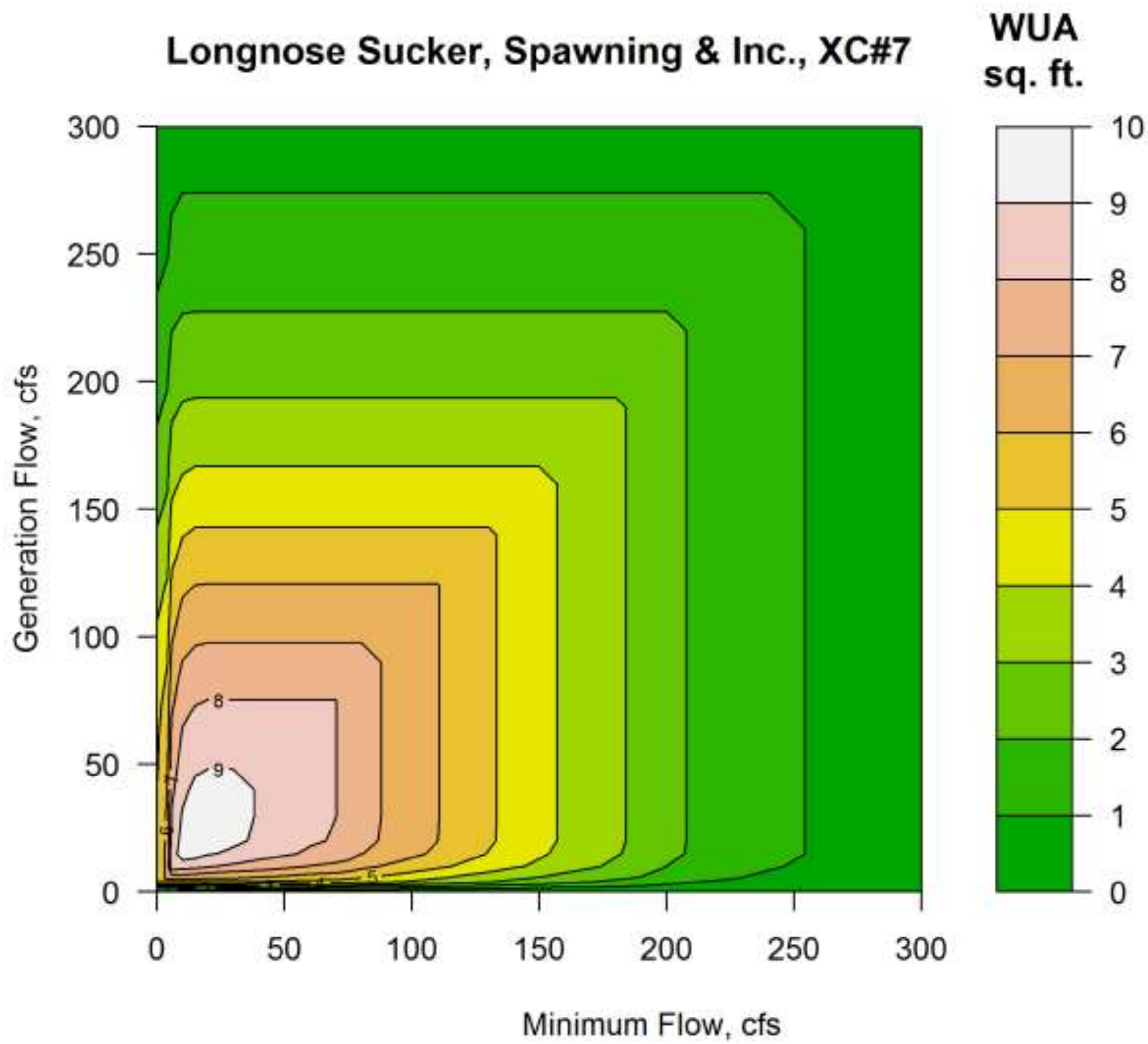
4
2


Longnose Sucker, Spawning & Inc., XC#7
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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7
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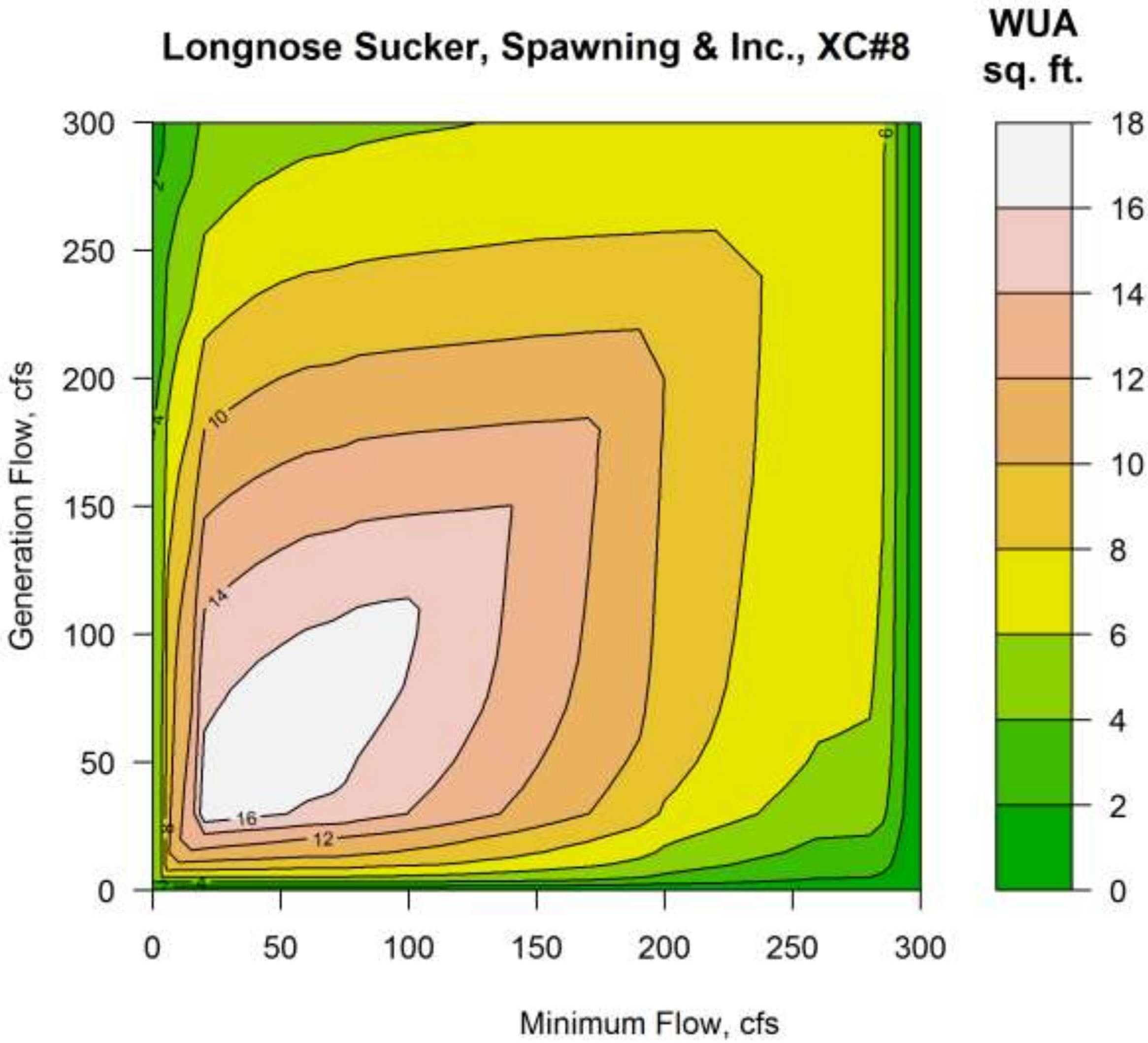
Longnose Sucker, Spawning & Inc., XC#8
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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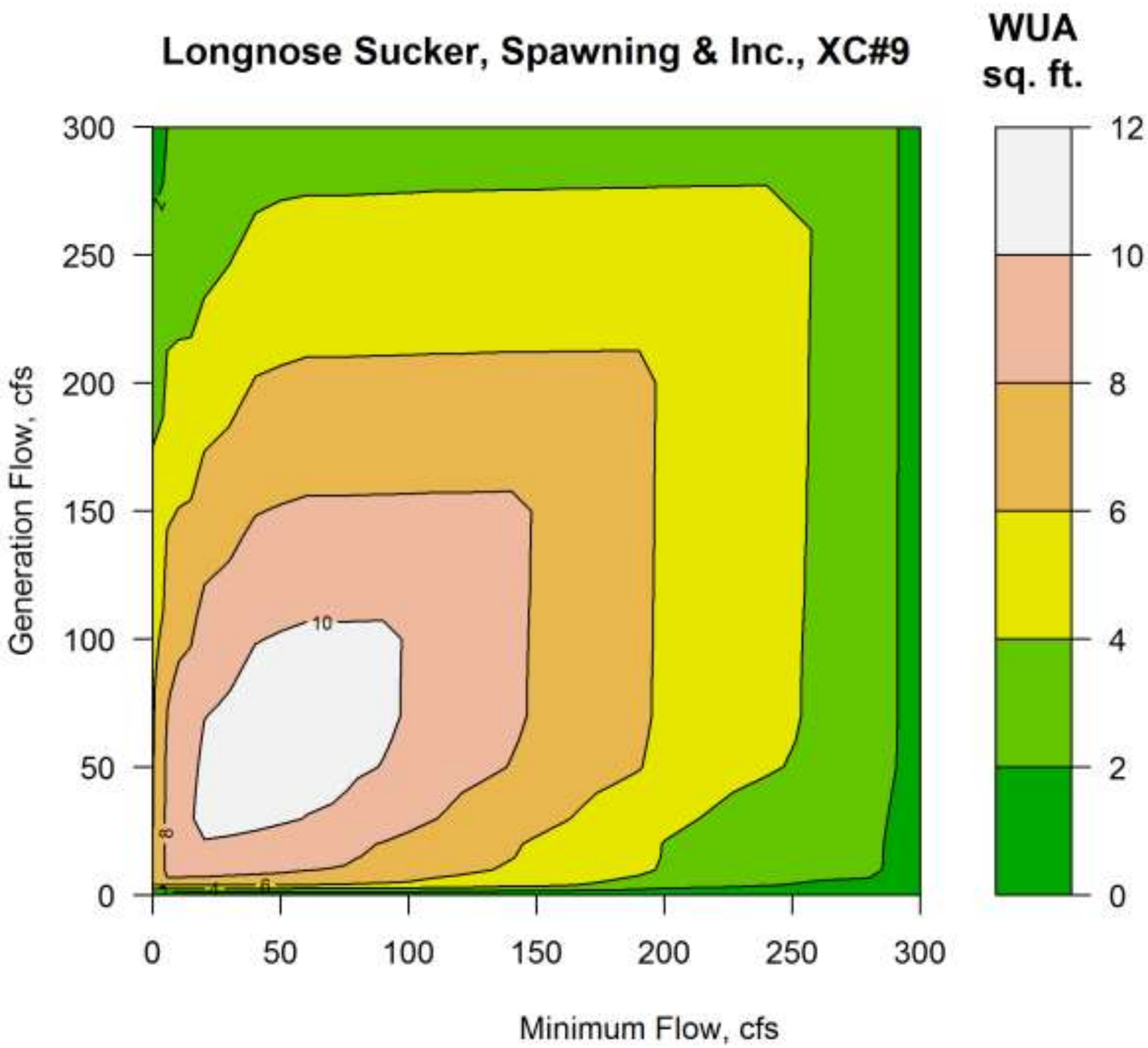
8
6
4
2


Longnose Sucker, Spawning & Inc., XC#9
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
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150
200
250
300
Minimum Flow, cfs
10
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6
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6
4
2
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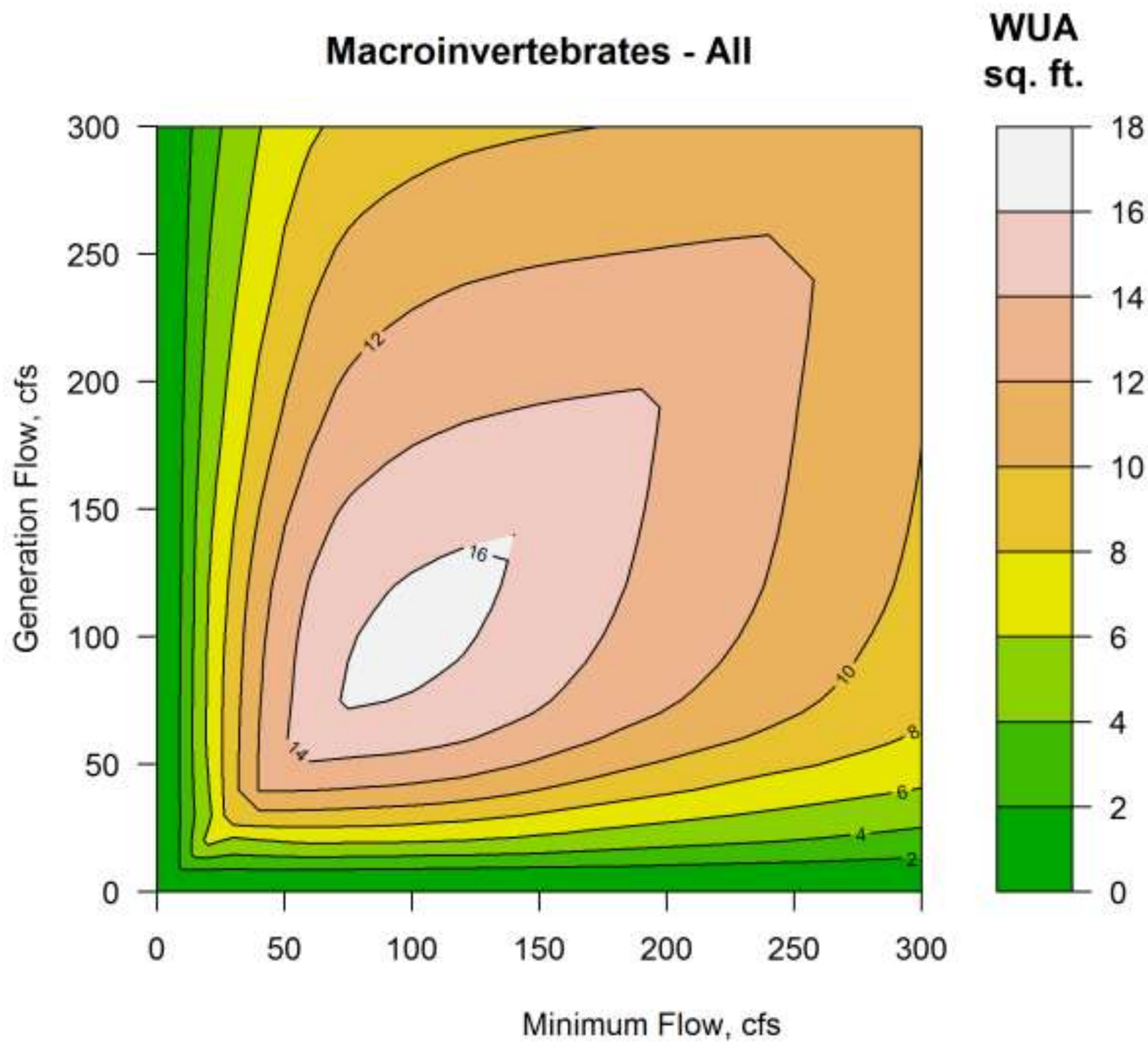
Macroinvertebrates - All
WUA
sq. ft.
300
250
200
150
100
50
0
Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
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12
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8
6
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2
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2
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10
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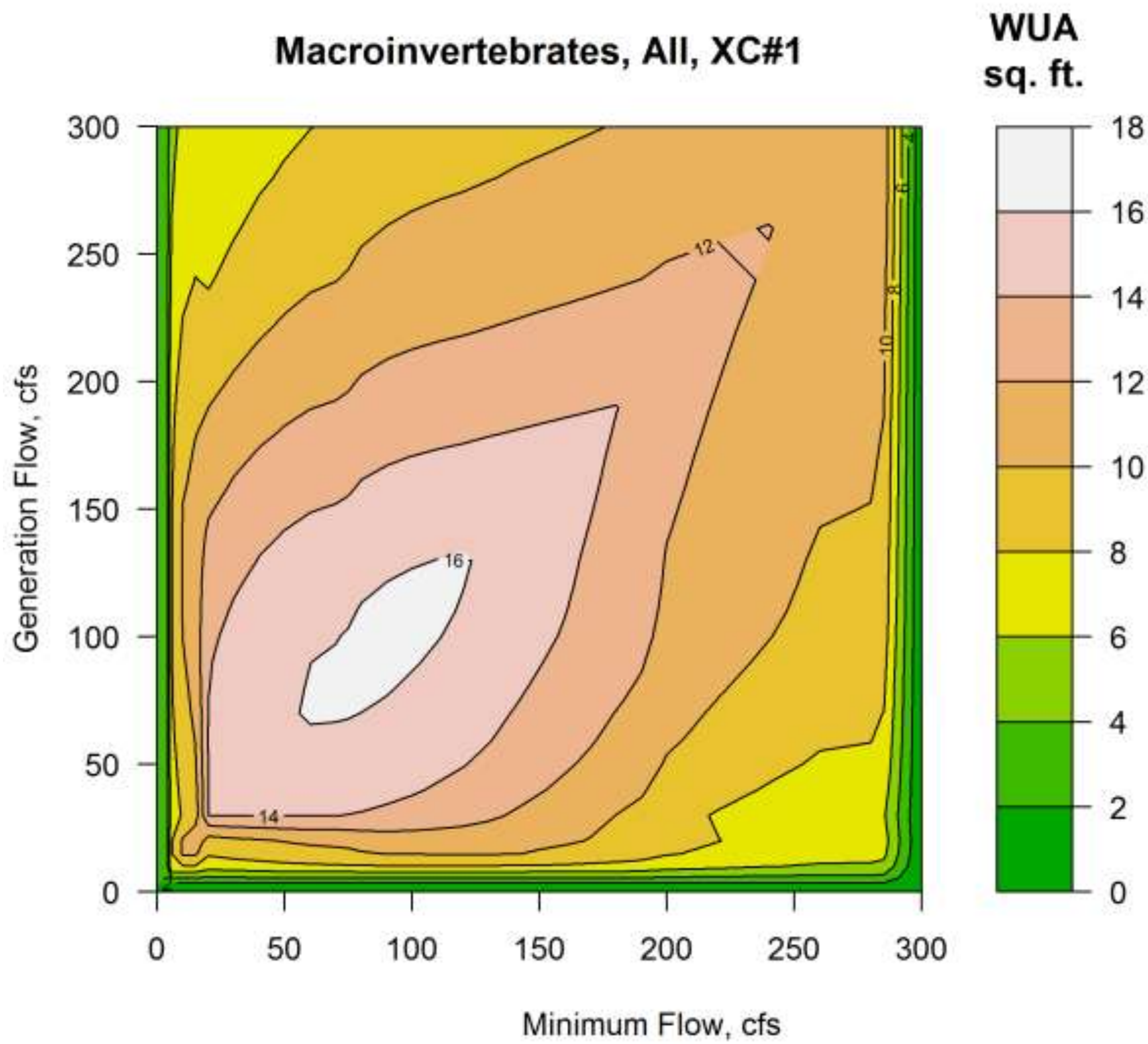
14
16


Macroinvertebrates, All, XC#1
WUA
sq. ft.
18
16
14
12
10
8
6
4
2
0
300
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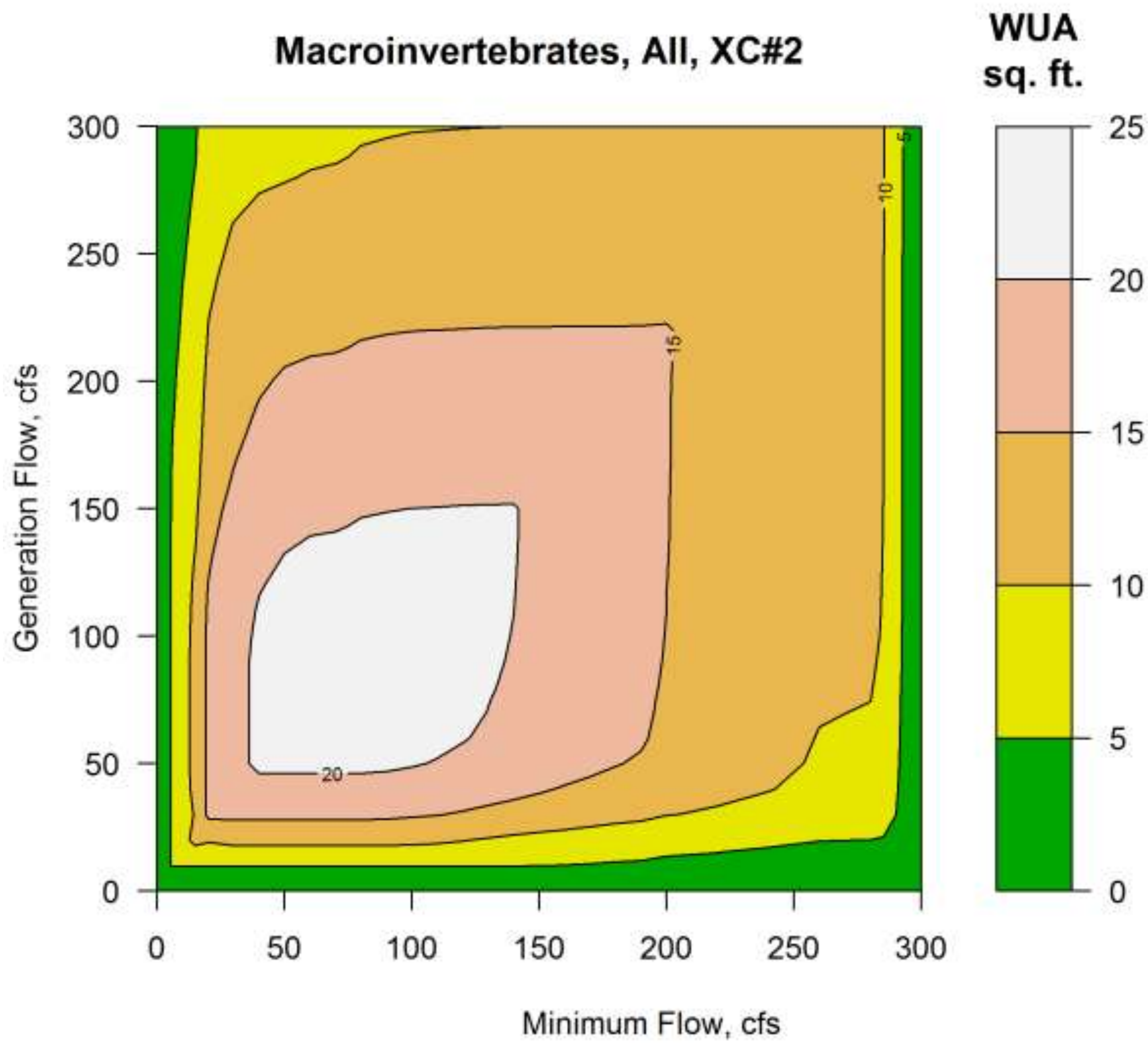
Macroinvertebrates, All, XC#2
WUA
sq. ft.
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Generation Flow, cfs
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Minimum Flow, cfs
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15
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5
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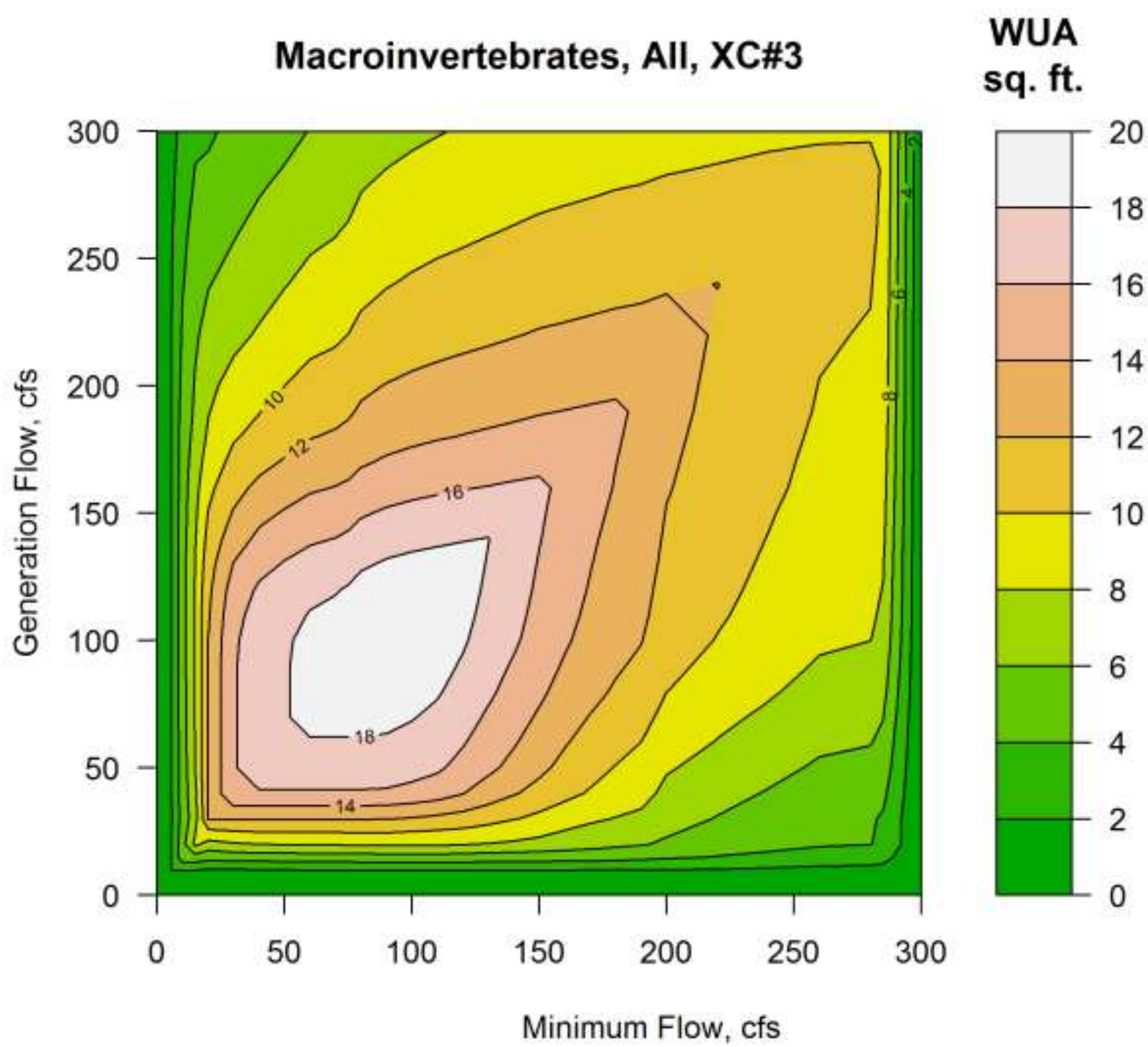
Macroinvertebrates, All, XC#3
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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4
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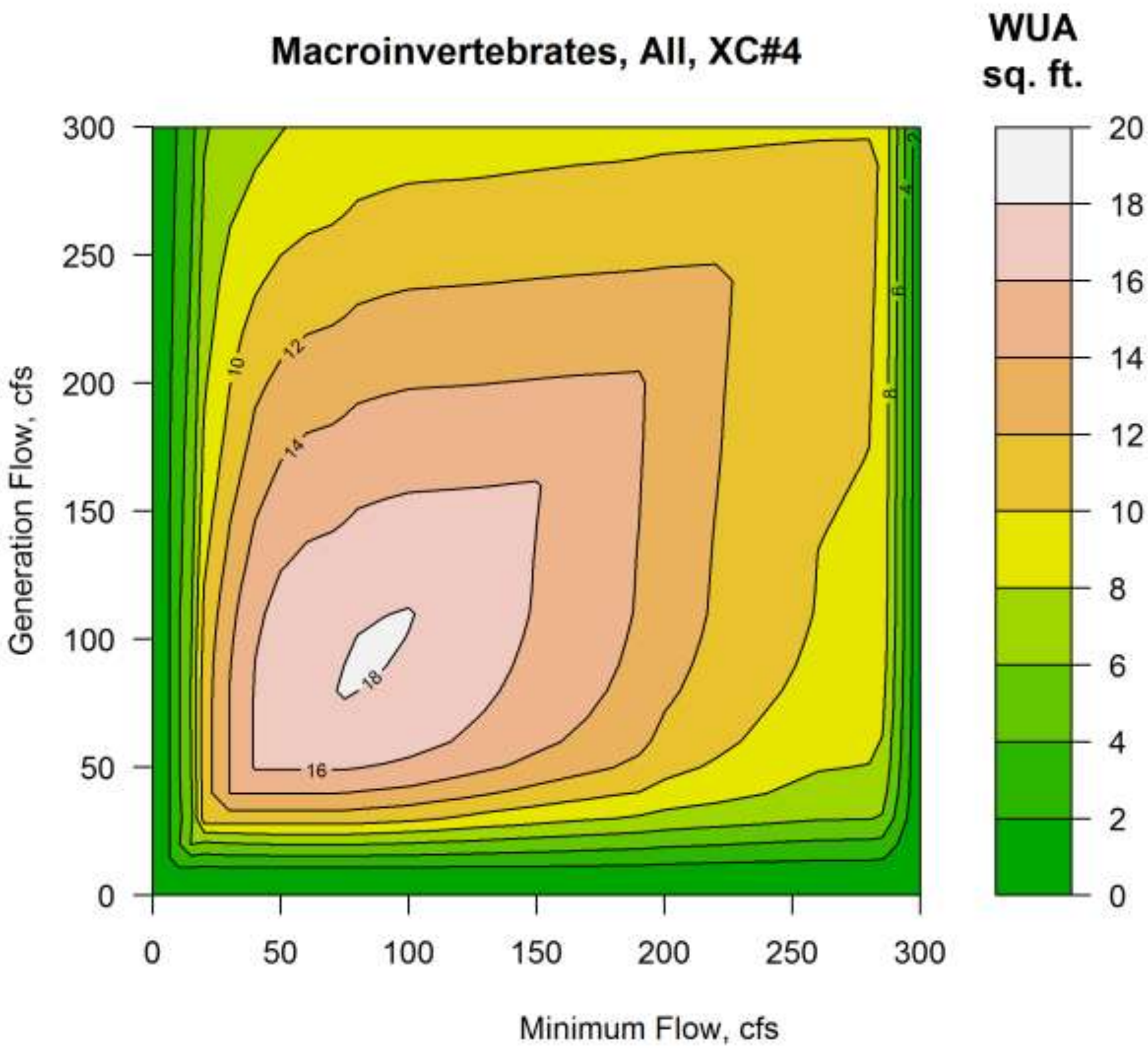
Macroinvertebrates, All, XC#4
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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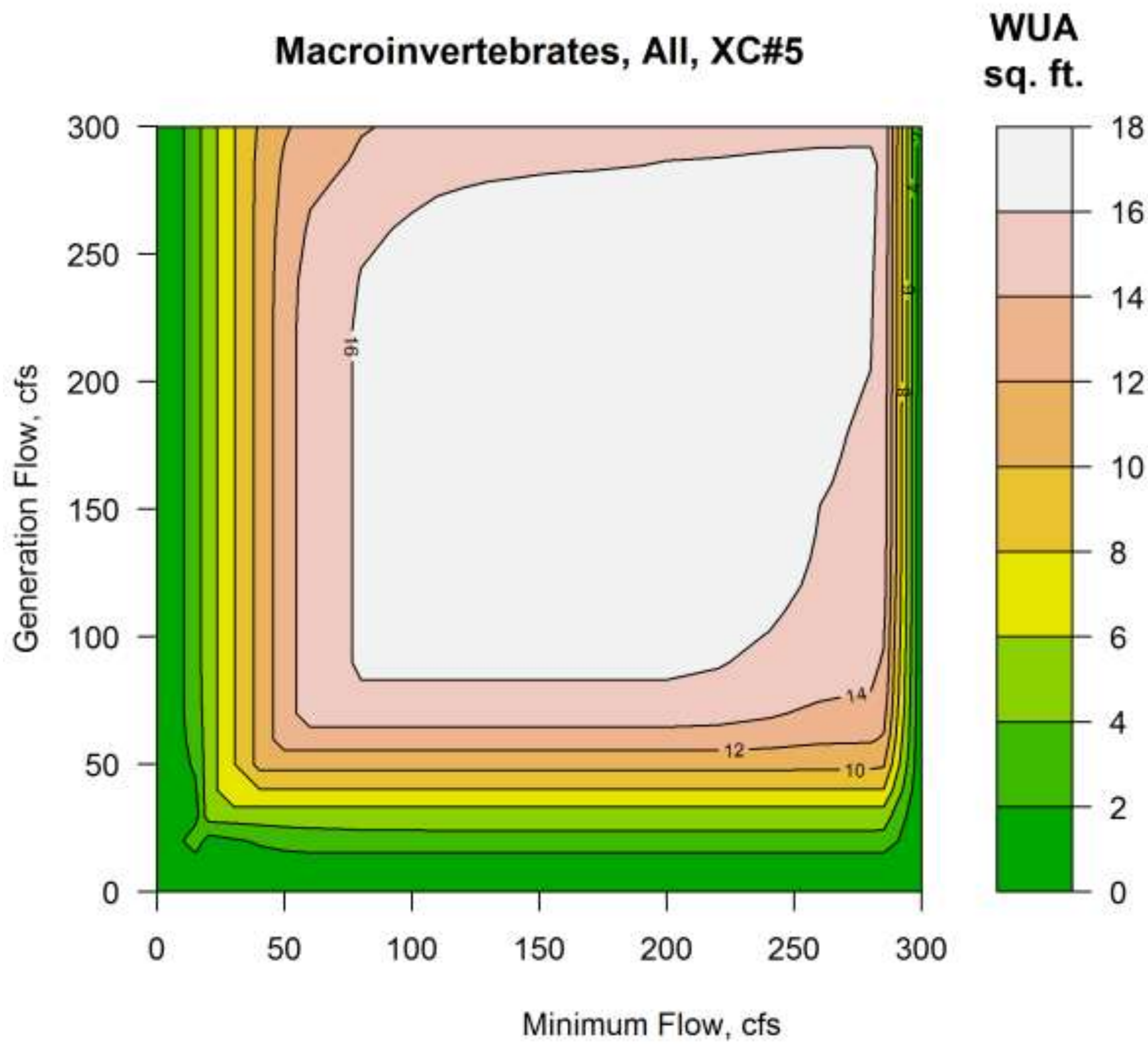
4
2


Macroinvertebrates, All, XC#5
WUA
sq. ft.
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200
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Generation Flow, cfs
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Minimum Flow, cfs
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2
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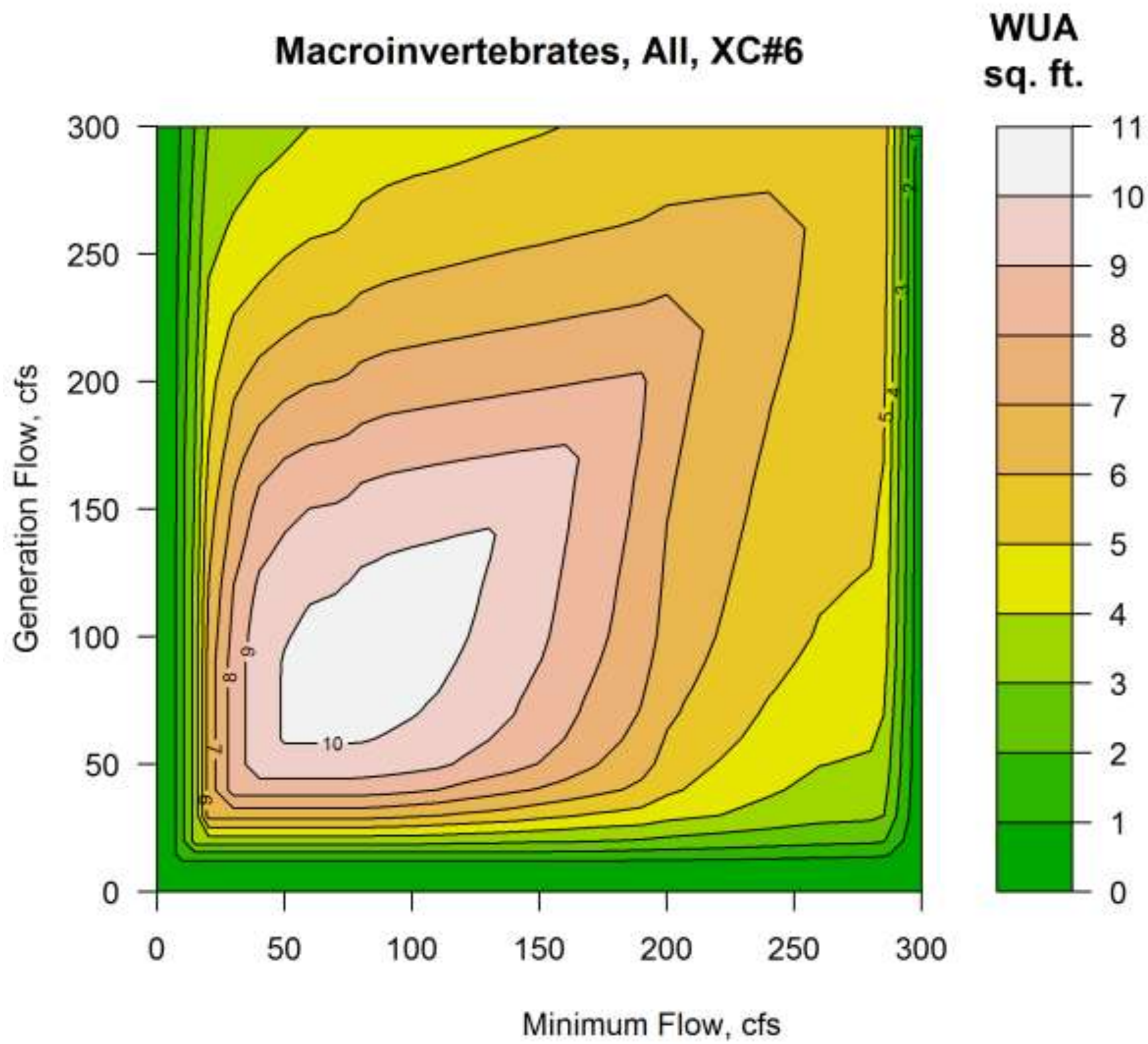
Macroinvertebrates, All, XC#6
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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10
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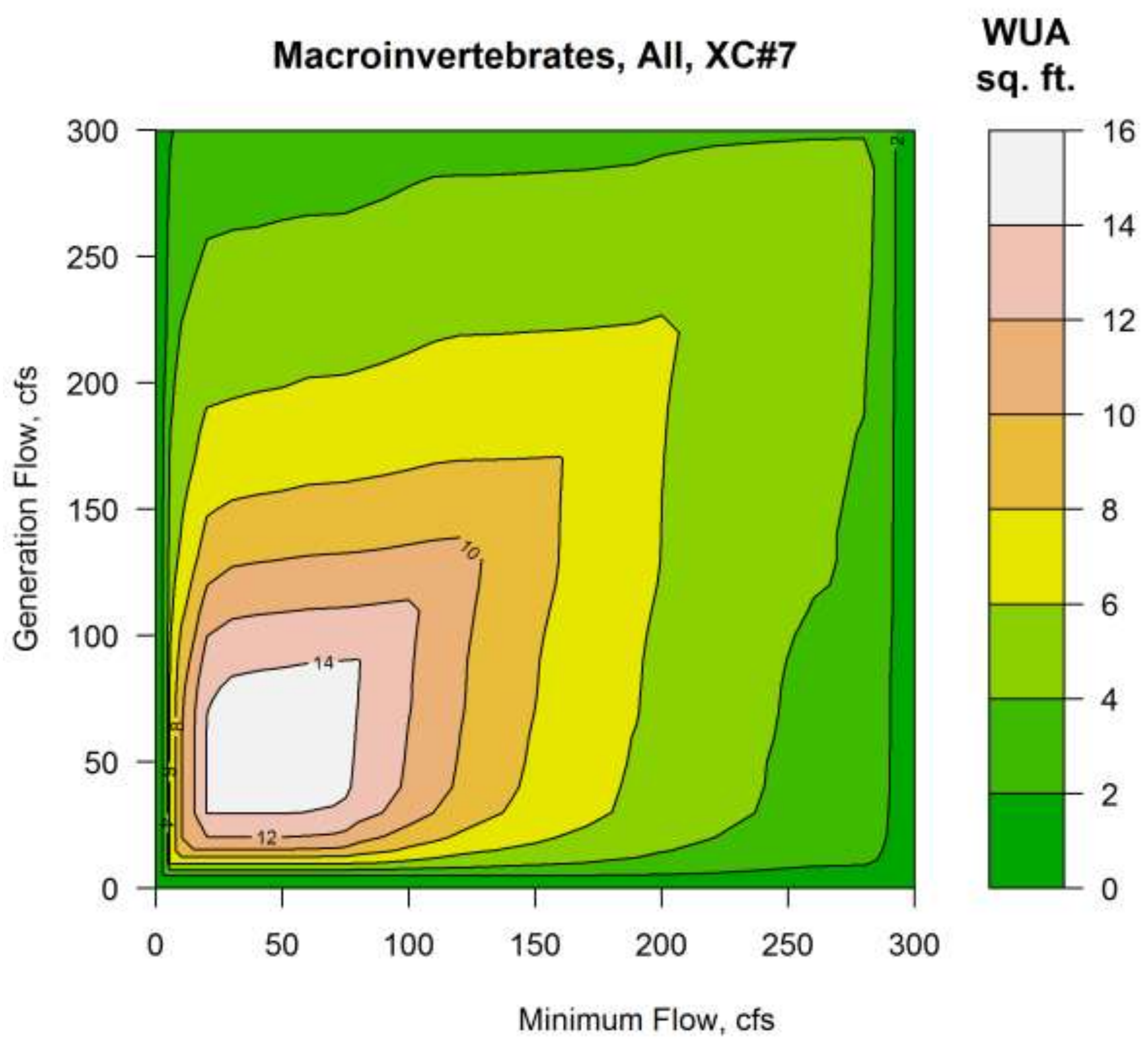
Macroinvertebrates, All, XC#7
WUA
sq. ft.
Generation Flow, cfs
Minimum Flow, cfs
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150
200
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4
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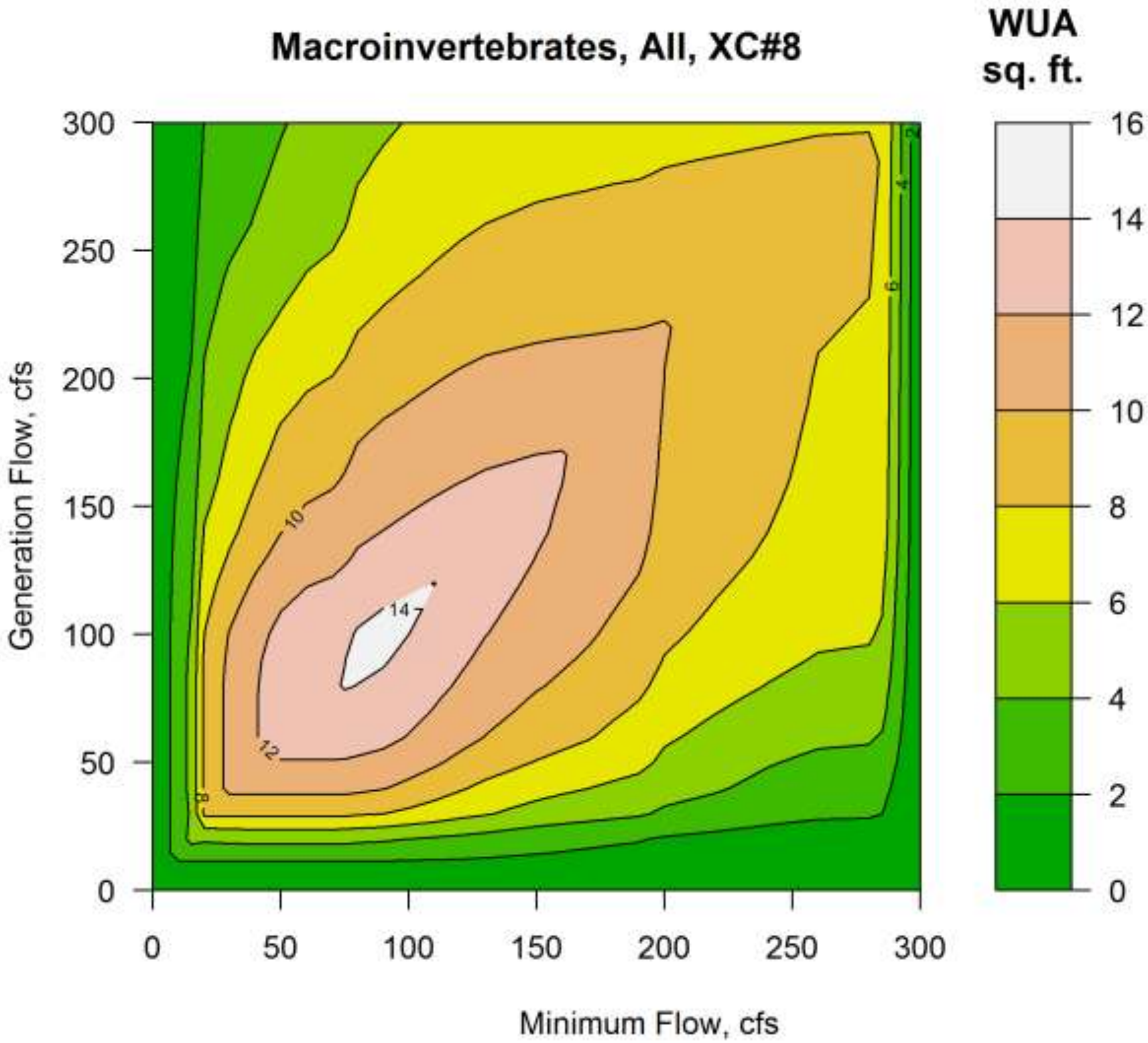
Macroinvertebrates, All, XC#8
WUA
sq. ft.
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200
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100
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Generation Flow, cfs
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2
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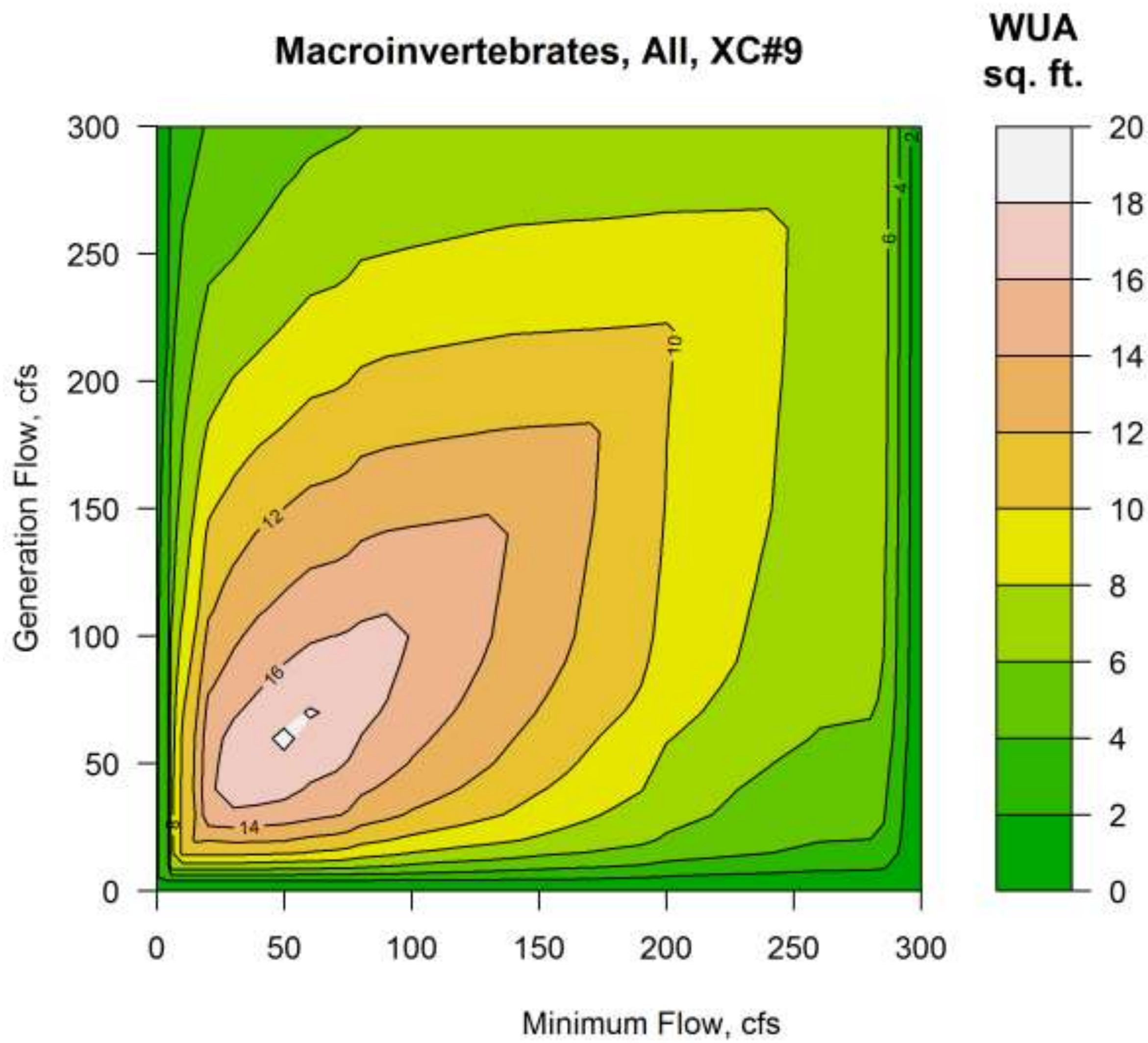
Macroinvertebrates, All, XC#9
WUA
sq. ft.
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250
200
150
100
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Generation Flow, cfs
0
50
100
150
200
250
300
Minimum Flow, cfs
20
18
16
14
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