Allocating Streamflows to Protect and Recover Threatened Salmon and Steelhead Populations

in the Russian River and other Northcoast Rivers of California

McBain and Trush
Trout Unlimited

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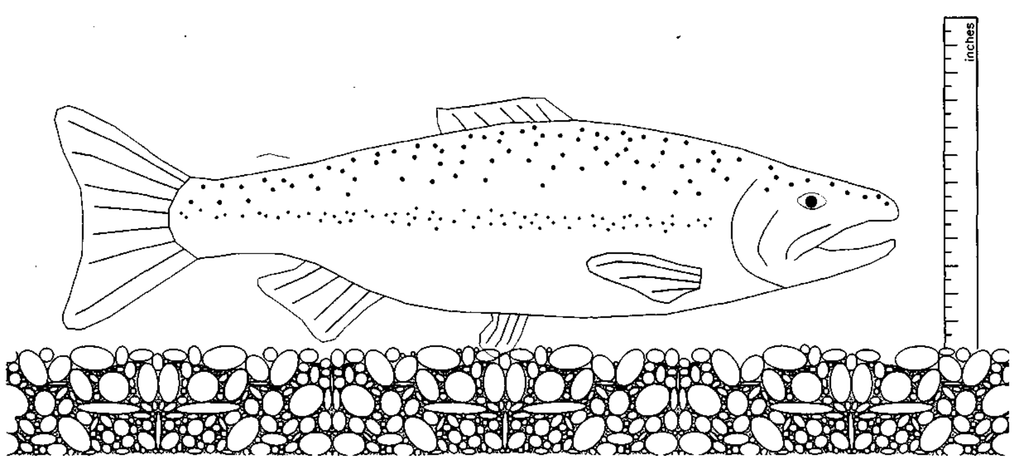

I do not know much about the Gods;
But I think the River is a strong, brown God-
Sullen, untamed, and intractable.

Keeping his seasons and rages,
Destroyer, reminder,
Of what men choose to forget.

T.S. Elliot

Allocating Streamflows to Protect and Recover Threatened Salmon and Steelhead Populations in the Russian River and Other Northcoastal Rivers of California

Commentary No. 3

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1. INTRODUCTION

The health of tributary watersheds is critical to maintaining threatened steelhead and salmon populations throughout Northcoast California river basins. Water diversions are being increasingly permitted for domestic and agricultural uses from these small tributary watersheds. The cumulative impact from many small diversions on salmon habitat is difficult to track, assess, and monitor. Trout Unlimited (TU) is concerned that protocols for allocating small diversions presently used by the State Water Resources Control Board (SWRCB) and proposed jointly by the National Marine Fisheries Service (NMFS) and California Department of Fish and Game (CDFG) do not protect salmon and steelhead habitat adequately and do not allow the recovery of threatened salmon and steelhead populations in Northern California.

In August 1997, the CA State Water Resources Control Board (SWRCB) staff published a report titled, *SWRCB Staff Report, Russian River Watershed, Proposed Actions to be taken by the Division of Water Rights on Pending Water Right Applications within the Russian River Watershed.* In this report SWRCB staff describe pending applications, discuss the methodology used to develop terms to protect fishery resources, evaluate water availability, and outline the proposed process for acting on these applications. An identical SWRCB allocation protocol was recommended for the Navarro River (1998). McBain and Trush wrote *A Commentary on the SWRCB Staff Report* in March 1998, then a second commentary in May 1999, *Commentary on the SWRCB Staff Protocol for Water Allocations in the Russian River and Other North Coastal Rivers,* in response to the SWRCB protocols. Both commentaries describe numerous flaws with SWRCB's water allocation protocol, including:

- the SWRCB Staff Report does not provide a ceiling, or methodology for determining a ceiling, that establishes a total acceptable withdrawal for a given watershed or basin. Without such a ceiling the SWRCB cannot assess cumulative watershed effects.
- the SWRCB Staff Report *does not address* the *volume and timing of water presently being diverted* (legally or illegally) within the basin.
- the SWRCB methodology *does not address differences in spatial scale between mainstem tributaries* (10 mi^2 and larger) *and smaller tributaries,* particularly in relation to salmonid life history and habitat requirements such as spawning ecology and fish passage;

SWRCB staff, after urging by TU, hosted a workshop in Sacramento on January 31, 2000. Dr.'s Peter Moyle, Matt Kondolf, and John Williams were invited to serve as peer reviewers of the various water allocation protocols proposed by SWRCB, NMFS, and Trout Unlimited (TU). During the workshop, several agencies requested a complete report of the TU field data and analyses. Steven Edmondson, from NMFS in Santa Rosa, sent a letter to Bill Trush dated March 31, 2000 (provided in Appendix 1) requesting clarification on several issues discussed in the workshop. Recently, CDFG and NMFS (May 2000) cooperatively drafted an alternative allocation protocol and had a different peer panel review their draft.

Although this commentary began as a response to Steven Edmondson's questions, it evolved into something larger. TU's goals for this third commentary primarily are two: (1) present an allocation protocol that provides the critical flow requirements necessary to protect salmonid habitat in small watersheds based on our field data and (2) demonstrate to the public and other agencies why the SWRCB and NMFS/CDFG allocation protocols do not protect anadromous salmonids and other fishery resources in small Northern California watersheds. Each allocation protocol evaluated in this commentary is judged, quantitatively, for its potential of significant take and its capability to recover threatened salmon and steelhead populations in small watersheds less than 10 mi^2. Although this commentary principally addresses small watersheds, this does not imply TU considers either the SWRCB or NMFS/CDFG allocation protocol adequate for watersheds greater than 10 mi^2 (see later comments).

TROUT UNLIMITED: RECOMMENDED ACTIONS

Trout Unlimited and McBain and Trush have been actively pursuing reform in SWRCB's water allocation protocol for several years, and recently advocating reform in the NMFS/CDFG allocation protocol. In the May 4, 1999 commentary TU presented a set of recommendations for allocating flows (reprinted in Appendix 1). Since then, and after many discussions, meetings, field data collection, and data analyses, we have revised our recommendations as follows:

A protocol for diverting streamflows must prevent a take on threatened salmon and steelhead populations and allow their recovery. No minimum bypass flow based on a specified exceedence probability from a daily average flow duration curve can protect salmon and steelhead in all watershed sizes. A consistent and defensible method based on the geomorphically identifiable active channel should be adopted by the SWRCB, such that no water can be diverted below the active channel stage height at any time during the water year. The SWRCB should designate all flows less than the active channel discharge as over-allocated throughout the water year in all stream channels, whether anadromous salmonids occupy or once occupied the stream channel, or whether streamflow is perennial or intermittent. In addition to minimum bypass flows, a specified fraction of higher flows exceeding the active channel stage height must be reserved for channel maintenance and habitat protection. To reserve a fraction of higher flows for critical biological junctions (e.g., salmonid migration and spawning), a specified maximum diversion rate for flows exceeding the active channel stage height shall cause no greater than one-half day alteration in the timing of the active channel flow.

Diversion structures on small salmonid bearing streams (size), or immediately upstream from a salmonid bearing stream, that are allowed to release (or bypass) only a minimum flow cannot protect salmon and steelhead habitat. Therefore, existing in-channel reservoirs on Class I and II stream channels designed to release only a minimum bypass flow, or release flows higher than the minimum bypass flow only when the reservoir fills and then spills, have a high potential for harming salmonids. These reservoirs must therefore be individually approved by CDFG following a quantitative procedure available to the public that accounts for (1) potential cumulative effects on downstream anadromous salmonid habitat, (2) use of upstream habitat (if applicable), (3) other fishery resources (as defined by the CDFG code), (4) off channel wetlands that are hydraulically connected to the channel surface flow, and (5) channel maintenance. Diversions from existing in-channel reservoirs on Class III channels have the same responsibility to protect downstream salmonid habitat, other fishery resources, and channel maintenance as any diversions from Class I and II stream channels. However, the potential for significant harm by many Class HI diversions may be less. Applications for new and existing in-channel reservoirs on Class III stream channels may be approved, provided quantitative demonstration that (I) the annual hydrograph for the watershed at the upper limit of potential anadromy has not been impaired using the above guidelines for the minimum bypass flow and maximum diversion rate and (2) downstream riparian vegetation and other fishery resources (particularly seasonal wetlands) are sustained. No approvals can be made until the lead agency has demonstrated that minimum bypass flow guidelines have been specifically designed to protect riparian vegetation and other fishery resources in Class II and III channels and swales. All downstream locations potentially impeding migratory access by adult and juvenile anadromous salmonids must be identified in the water right review process. Then, an explicit procedure must be followed to adequately assess potential cumulative adverse impacts from the existing *diversion structure (if applicable), all existing water rights upstream of potential barriers, and the proposed water right application. Operation of existing and new in-channel reservoirs that diminish the downstream supply of coarse bed material must have an approved operational plan for annually replacing an equivalent volume of coarse bed material into the downstream channel.*

We also recommend the following compliance and effectiveness monitoring provisions:

Guidelines for consistent compliance monitoring should be drafted and required by SWRCB as part of the water right application process. For commercial diversions, a licensed engineer must document how the elevation of a diversion intake was determined, sign-off on its installation, and provide annual compliance reports. Random selection and evaluation of these compliance reports should be conducted annually by the lead agency. Guidelines for this evaluation, as well as actions and/or penalties for non-compliance, also should be specified in the water right application. Without an accountable/ verifiable/ enforceable procedure for installing and operating an intake, TU will not support any allocation protocol based on a minimum bypass flow and maximum diversion rate, including our own.

Effectiveness monitoring is critical, but should not be the direct responsibility of the water users. The SWRCB (jointly with other agencies) should devise and implement an effectiveness monitoring program as part of an ongoing adaptive management plan. It should include development of regional relationships between watershed size and the active channel discharge, as well as develop basic hydraulic geometry relationships. Provisions in this plan must show a demonstrable feedback loop from future monitoring results to specified guideline changes. This program would immediately include setting maximum diversion rates for specific tributary watersheds, particularly those presently (or shortly) considered at or near over-allocation. SWRCB must provide a comprehensive inventory of all permitted, riparian, and other diversions. Otherwise, downstream cumulative adverse impacts cannot be assessed in pending water right applications. Although this policy may be administratively challenging, it can be administered, and is consistent with the need to protect the diminishing habitat of endangered salmonid species, as well as other fishery resources, and to allow recovery.

In the following chapters we evaluate the ecological implications of two fundamental components of water allocation protocols: minimum bypass flow and maximum diversion rate. We compare the biological performance of each proposed minimum bypass flow. To do this, we estimated the merits and shortcomings of each protocol if streamflows were allowed to naturally fluctuate up to the proposed minimum bypass flow but no higher. In the next several chapters, therefore, we ignore the ecological and geomorphological role of high flows. Later, the high flow hydrograph is combined with the minimum bypass flow to develop an overall allocation strategy using a maximum diversion rate. A final chapter addresses the annual yield and management implications for the three allocation protocols.

2. MINIMUM BYPASS FLOW EVALUATION

Protocols for diverting streamflow must clearly establish a minimum water surface elevation below which no diversions are allowed. The streamflow at this minimum water surface elevation is labeled the "minimum bypass flow." One criterion for establishing this water surface elevation must relate to the depths and velocities required by salmon and steelhead to meet habitat needs over the full range of water years encountered in Northern California river basins. This chapter presents the results of several analyses that quantify and evaluate flow depths needed for migration and spawning by salmon and steelhead. Their habitat needs are then compared to the flow depths provided by the minimum bypass flows of TU, NMFS/CDFG, and SWRCB in watersheds less than 10 mi^2.

2.1. Proposed Minimum Bypass Flows

The minimum bypass flow is the specified unregulated flow above which diversion is permitted. If diversion is via in-channel reservoir, then bypass flows will be controlled flows through reservoir release mechanisms, or by uncontrolled spills once the reservoir is full. Generally only a minimum bypass flow is released to retain as much reservoir storage as possible. If the in-channel reservoir does not have the capacity to store all runoff, the bypass flow can be the natural streamflow once storage has been overtopped. In-channel structures without release mechanisms are common, and cannot allow a bypass flow until the storage capacity of the reservoir overflows. If diversion is via pump or another extraction method to off-channel storage, then the bypass flow is the undiverted instream flow. Diversion from the stream channel, when the water stage height is above the minimum bypass flow only, occurs at a prescribed maximum diversion rate until the allocated volume has been met.

Three minimum bypass flows have been proposed:

SWRCB Minimum Bypass Flow

SWRCB recommends a minimum bypass flow equal to 60% of the unimpaired mean daily average annual discharge ($0.6Q_{ave}$) during the high flow runoff period December 15 through March 31 (Figure 1). The 1997 SWRCB report principally relies on four local PHABSIM studies to justify their bypass flow. Studies cited by SWRCB were performed on relatively large watersheds; Brush Creek at 16 mi^2 was the smallest. SWRCB selectively analyzed these studies, choosing one sample reach over another. We have reviewed their cited studies, but will not present our findings here. SWRCB concludes these studies identified the Q_{ave} flow as approximately the "optimum" flow, i.e., the flow providing the most spawning habitat. SWRCB then assumed that a bypass flow providing 80% of the spawning habitat at the "optimum" flow would not further impact the fishery resources during the high flow period. SWRCB also assumed that rearing habitat requires a lower bypass flow than spawning habitat. Using the habitat - flow relationships modeled in PHABSIM, SWRCB decided the $0.60Q_{ave}$ flow provided 80% of the "optimum" habitat. SWRCB staff therefore conclude (1997, pp. 19-20): "This level of flow [$0.60Q_{ave}$] should allow for the diversion of unappropriated water within the watershed without further impacting the fishery resources during the high flow period." SWRCB staffs use of "fishery resources" should include much more than fish (according to CDFG code), although their $0.60Q_{ave}$ minimum bypass flow is based only on modeled depth and velocity preferences of spawning adult salmonids in large watersheds. No requirements for riparian vegetation or other fishery resources were ever quantified, then related to the $0.60Q_{ave}$ bypass flow. SWRCB applies this minimum bypass flow to all watershed sizes.

NMFS/CDFG Minimum Bypass Flow

NMFS and CDFG recommend that the median daily average flow in February (Q_{feb}) serve as the minimum bypass flow for the same high flow runoff period adopted by SWRCB: December 15 through March 31. This bypass flow is determined from available streamflow gauging records from large tributary streams, but generally must rely on unit runoff calculations (cfs/mi^2) to extrapolate to smaller watersheds. They make no distinction in watershed size when recommending their bypass flow, nor address over-wintering habitat for juveniles. NMFS/CDFG assert that Q_{feb} approximates the maximum effective spawning habitat (NMFS/CDFG 2000), though no data (e.g., NMFS 2000) have been presented to substantiate this assertion.

TU Minimum Bypass Flow

TU recommends a bypass flow based on a readily identifiable geomorphic feature of alluvial channels, the "active channel", and the consequent biological functions it provides. In Northern California, the flow that just inundates the active channel (Q_{act}) has an exceedence probability of approximately 10% on a daily average flow duration curve. This was estimated by measuring the discharge just topping the active channel (described in the next section), then estimating its exceedence probability on a daily average flow duration curve. At a minimum, this bypass flow should be applied to watersheds less than 10 mi^2, the range in watershed size considered in this commentary.

To appreciate differences among the three minimum bypass flows, we plotted each on a few typical flood hydrographs from selected USGS gaging stations for comparison. None of the minimum bypass flows reserve a significant portion of a typical flood hydrograph for a small tributary in Dry Creek (Figure 2). On a larger watershed in the Russian River Basin, the minimum bypass flows are positioned roughly the same (Figure 3). Approximately, the Q_{feb} minimum bypass flow adopted by NMFS/CDFG is twice the SWRCB minimum bypass flow, and the TU minimum bypass flow is twice the NMFS/CDFG flow. The South Fork Eel River Basin has greater than double the discharge of the Russian River Basin, but relative differences in flow magnitude among the minimum bypass flows are approximately the same (Figure 4). The unit runoff, or cfs/mi^2, for the mean daily average flow in Elder Creek (Figure 4) is 4.15 cfs/mi^2; the unit runoff for the mean daily average flow in a similarly sized watershed in the Russian River Basin would be 1.85 cfs/mi^2. Although having less than half the average annual runoff, tributary channels in the Russian River Basin are greater than half the size of South Fork Eel River tributary channels with comparable drainage areas. This will have important consequences on regional spawning habitat impacts addressed later in this report. It also means that extrapolations of South Fork Eel River flow depths, for a particular exceedence probability, to Russian River or Navarro River flow depths will be conservative. The actual depths in the Russian River tributaries will be less than estimated in this commentary.

2.2. What Are Minimum Bypass Flows Supposed To Do?

SWRCB's original scenario for anadromous salmonid use of tributaries over-simplifies the ecological complexities of alluvial rivers and streams. No new diversions would occur in the new water year until December 15 (Figure 1). Early winter high flows would presumably provide the necessary flow depths and duration for migrating adult salmonids to reach natal tributaries. After December 15, a minimum bypass flow would presumably provide the necessary flow depths and velocities for the adults to spawn until March 31. During this spawning period, flows above the minimum baseflow would be available for diversion (Figure 1). Under this model, upstream access and adequate spawning provided by restrictions on the diversion period combined with a minimum bypass flow would "not cause further impacts to fishery resources during the high flow period." Unfortunately however, life history requirements of several species of salmonids (chinook, coho, and steelhead) overlap throughout the fall and through the spring. Adult migration, for example, occurs well past December 15, particularly for steelhead trout, and depends on the unpredictable frequency and timing of storm hydrographs. Steelhead can be spawning as late as mid-May, whereas chinook salmon could be spawning in early-October.

Therefore, minimum bypass flows should help provide sufficient magnitude, duration, and timing of instream flows to protect and ensure life history requirements throughout a water year and over all water year types, including upstream migration, spawning, inter-stream movements between flow peaks, incubation, rearing, and emigration. NMFS (2000) claims that targeting the "typical" natural flow condition is sufficient to prevent a take and allow recovery. There is no "typical" water year to which anadromous salmonids have evolved. TU believes streamflows within the active channel in all water year types must be reserved as a key first step towards maintaining and recovering threatened anadromous salmonid populations, especially those near the southern limits of their geographical range. As will be shown, TU also asserts that minimum bypass flows alone cannot satisfy all anadromous salmonid life history requirements.

2.3. The Active Channel Morphology

A distinct break in channel cross section occurs at a sub-bankfull stage height, forming a morphologically distinct inner channel within the bankfull channel. This inner channel, labeled the "active channel," generally coincides with the lowest limit of woody riparian vegetation, particularly white alder (Trush, Connor, and Knight 1988). The best field evidence of the active channel is often found along the edge of coarse point bars or lateral bars. A bench of coarse particles packed in a matrix of sand and small gravel originates at the active channel crest and extends upward to the bankfull stage height (Figure 5). In this oblique photo, the difference in elevation above and below the sharp active channel boundary is 0.8 ft. Osterkamp and Hupp (1984) call this bench the "channel shelf." In Northern California streams along straight channel reaches, white alders will root down to the active channel stage height, frequently forming this distinctive channel bench (Figure 6). The geomorphically distinct active channel prevents lower flows from spreading-out, keeping the active channelbed wetted throughout declining flows and minimizing changes in wetted channel width. This is a major factor for why very few redds are dewatered during extended periods of low winter baseflows typical in most water years.

A detailed investigation of the active channel was conducted on tributaries to the mainstem South Fork Eel River. Elder Creek, a 6.5 mi^2 watershed in the upper South Fork Eel River basin on the western flank of Cahto Peak, was the primary stream investigated. The U.S. Geological Survey has operated a hydrological benchmark gaging station near the mouth since WY1967. Elder Creek has a coarse grained channel with particle sizes ranging from 50 cm to 150 cm in steep riffles and 5 cm to 10 cm in point bar deposits. The low sinuosity channel, with an average gradient of 2.4 percent below a major waterfall (1.38 mi from the mouth), does exhibit depositional features typical of alluvial channels. Another stream studied, Rock Creek (3.0 mi^2), also originates on Cahto Peak. Upper Rock Creek is a bedrock-dominated channel similar to Elder Creek, whereas lower Rock Creek is an alluvial channel flowing through a South Fork Eel River terrace utilized by chinook, coho, steelhead, and Pacific lamprey.

The modifier "active" refers to the scoured appearance of the active channel. Generally, the most frequently scoured portion of the bankfull channel is the active channel (Figure 7). Because the active channel is a distinct morphological feature, there is a relationship between the active channel discharge and a sediment transport threshold. For Elder Creek, the USGS noted that sand transport did not begin until flows exceeded 60 cfs. The flow just reaching the crest of the active channel is approximately 67 cfs.

Active channel discharges for Elder Creek and Rock Creek have an exceedence probability on a daily average flow duration curve of approximately 10 percent, i.e., on average, the active channel discharge is equaled or exceeded 36.5 days per year (Figure 8). On smaller stream channels, such as Fox Creek (a 1.07 mi^2), the watershed adjacent to Elder Creek, the exceedence probability of the active channel discharge is closer to 8 percent. TU recommends that the 10% percent exceedence probability initially be assigned the active channel discharge for streams with watersheds less than 10 mi^2. However, the smaller channels (less than 1.5 mi^2 to 2 mi^2) probably have active channel discharges with slightly lower exceedence probabilities.

Sullivan Gulch is a 2.35 mi^2 tributary of the North Fork Mad River in Humboldt County. This tributary, also exhibiting a distinctive active channel morphology, is part of the NMFS Fish Passage Study contracted to Humboldt State University (Margaret Lang, principal investigator). Continuous streamflow monitoring was initiated in WY1999 at the Riverside Road culvert. Photos taken at specific streamflows (Figure 9) during the recession limb of a flood hydrograph in January 2000 show four stage-discharge relationships. Using the unit runoff from the Little River and North Fork Mad River USGS gages, the estimated 10% exceedence flow for Sullivan Gulch at Riverside Road is 21.6 cfs. Based on field evidence, the active channel discharge is 23 cfs (a 9% exceedence flow). The NMFS/CDFG proposed minimum bypass flow of Q_{feb} is 12 cfs and the SWRCB minimum bypass flow of $0.6Q_{ave}$ is 5 cfs.

The photo sequence (Figure 9) from Sullivan Gulch illustrates the proposed minimum bypass flows. At active channel stage (23 cfs) the inside lateral bar on the right bank (visible in photos C and D) would just be inundated. At 17 cfs (photo B), portions of the bar are still exposed. Although not as clear on the photograph, a distinct moss-covered, active channel bench on the left bank, immediately upstream of the culvert, is completely exposed at 17 cfs but already has its leading edge inundated at 39 cfs (photo C). Note also the water turbidity. Q_{act} begins to significantly mobilize fine sediment storage within the channel. Lower flows can still become turbid during surface runoff from roads.

The riffle in the photos' center is a classic oblique bar, where the bar's sharp downstream edge generally limits upstream passage as flows drop below Q_{act}. This sharp break is completely inundated above Q_{act}. Unfortunately we did not take a photo at 12 cfs. However, the increase in stage height over the 8.86 cfs flow (third photo in Figure 9) is less than 0.05 ft. Even at 17 cfs, the sharp downstream edge is still present and impedes upstream passage; by 39 cfs the edge has completely disappeared through inundation.

2.4. The Active Channel Hydraulic Geometry

Perhaps the most distinguishing feature of the active channel is its hydraulic geometry. Hydraulic geometry is the functional relationship between discharge (independent variable) and flow width, mean depth, and mean velocity measured at a cross section (Leopold and Maddock 1953). The hydraulic geometry relationship is a power function ($Y = cQ^b$) that plots as a straight line on log paper. A logarithmic presentation of hydraulic geometry masks subtle changes in the relationship between dependent and independent variables. Instead of plotting logarithmic Q (daily average discharge), thalweg depths were plotted linearly as the independent variable (Figure 10).

For the Spawner Riffle in Elder Creek (Figure 10), a sharp break in slope for average velocity occurs at a stage height corresponding to 65 cfs flow (the top of the active channel). We have many other examples of pool and riffle cross sections with similar breaks in hydraulic geometry from South Fork Eel River tributaries (e.g., Figures 19 and 20 in Trush (1989)), as well as for streams outside the South Fork Eel River Basin. The at-a-station hydraulic geometry shows that increasing discharge within the active channel is accommodated by major increases in average velocity, intermediate changes in average depth, and only minor changes in width. At $0.60Q_{ave}$ (16.2 cfs) on Elder Creek, the average velocity is 0.83 ft/sec. At Q_{ave} (27 cfs) velocity increases to 1.21 ft/sec, and at Q_{feb} (34 cfs) the average velocity is 1.28 ft/sec. At Q_{act} (67 cfs) the average velocity is 1.87 ft/see. This rapid increase in average velocity occurs over a total change in stage height of only 0.39 ft (4.7 inches, or 12 cm). Above Q_{act} average velocity increases at a much lower rate. For example, at bankfull discharge (550 cfs) average velocity rises to 3.3 ft/sec. What may seem as minor changes in discharge (due to diversions), and therefore small changes in stage height, will have significant influence on spawning habitat suitability and abundance (refer to cumulative spawning habitat section).

2.5. Spawning in the Active Channel

Steelhead trout spawn in a variety of habitat types (Figure 11). These variable spawning habitats rely on wide ranging winter flows (Trush 1989). In relatively wet years, the outer edges of pool tails and runs are sufficiently deep to provide spawning habitat during the declining limb of storm hydrographs. In dry years, the fish are forced to spawn near the thalweg of pool tails and in riffles because these are the only gravel patches with adequate depths and velocities. Unfortunately, gravel patches near the thalwegs of pool tails and in riffles are highly susceptible to scour by even modest flood events. The declining hydrograph limb essentially forces newly arriving adults to distribute their redds throughout the planform morphology as different portions of the channelbed become available for spawning. If high peak flows follow recent redd construction, only those redds closer to the channel margins, constructed during high flows and early in the declining limb, may survive. There is the implicit assumption of equally valuing the importance of each redd independent of the discharge at which a redd was created, and therefore where in the planform morphology the redd was constructed. Not all redds are created equally and have the same opportunity for success. In large part their opportunity depends on chance (e.g., the type of water year) and hydraulics (dependent on channel location).

Flow variation is therefore vital to creating diverse habitat. One subset of this total available habitat will favor egg survival during high flow years, while another subset will favor low flow years. As TU has stated in previous commentaries, the Russian River is at the extreme end of the steelhead and coho's range. Their perpetuation critically depends on the few wet years to survive the many average and dry water years. Minimum bypass flows that force median or average year flows onto these populations, as the SWRCB and NMFS/CDFG protocols intend, ignore this biological reality.

Steven Edmondson (March 31, 2000, p. l) asked: *Please explain why the upper boundaries of the active channel is a justifiable lower limit for water diversions, when natural flows generally do not wet the upper margins of the active channel during most of the time each winter. What data corroborate that spawning and incubation occur near the top margin of the active channel?* Almost all spawning does not occur close to the stage height of the active channel. Potential spawning habitat will be sensitive to small changes in stage height, and therefore small changes in flow, within the active channel. As stage height rises within the active channel, different portions of the channelbed are inundated at depths and velocities favored by spawning steelhead and salmon. During spawner surveys on the upper South Fork Eel River in the 1980's (Trush 1989), and subsequently in Humboldt County, only two redds were constructed outside the active channel (on a temporary road bulldozed across a stream channel). To generate sufficient depth outside the active channel, i.e., on top the active bench, would require very high flows with long duration. Therefore, successful spawning and incubation do not occur where the bed elevation approximates the Q_{act} stage height (i.e., "the top margin of the active channel"). The Q_{act} stage height produces sufficient depths and velocities to create spawning habitat well within the active channel boundaries. Similarly, you would not expect spawning at the Q_{feb} top margin (if this was the bypass flow): minimum water depth and velocity are necessary to create spawning habitat.

Water depths and velocities during redd construction in Elder Creek do not exhibit strong correlations with stream discharge (Figure 12). The only weak correlation appears as a lower limit in velocity with increasing discharge. The shallowest redds were approximately 0.6 ft (7.2 inches or 18.3 cm) in pool tails and 0.45 ft (5.4 inches or 13.7 cm) in glides and riffles. Only at flows exceeding 125 cfs was there a trend of increasing minimum depths with increasing discharge. This wide variability and poor correlation of depths and velocities to flow is expected. Each female steelhead is confronted with a wide range of spawnable habitats comprising different portions of the channelbed (refer to Trush 1989 for more detail). Which portion a given female selects for spawning will depend on the flows when she arrives. If she arrives one day following a peak discharge, the upper margin of pool tails provides the best high flow habitat with velocities of 1.5 ft/sec to 2.5 ft/sec and depths between 0.8 ft (9.6 inches or 24.4 cm) and 1.5 ft (18.0 inches or 46 cm) or greater. If she arrives five days following a peak discharge (and flows are already low again), small gravel patches in runs often provide the best habitat but again with similar velocities and depths as the high flow habitats.

If all steelhead spawning occurred on the thalweg, then the active channel in Elder Creek would contain all the cumulative habitat requiring flows less than Q_{act} to provide the full range of preferred depths and velocities. But steelhead usually spawn away from the thalweg, where most of the spawnable gravel has been deposited. Spawning gravels are found: (1) in depositional environments not located at the thalweg (and typically at a higher channelbed elevation), (2) near the thalweg in wide channel sections (e.g., in the tail of a long, wide, and straight run), and (3) just upstream of local hydraulic controls and channel widening (e.g., tails of pools). At pool and run tails, steelhead can spawn close to the thalweg during low flows (where depths and velocities are preferable). As flows increase, redd sites are selected higher in the tail and closer to the banks (where velocities and depths are now preferred). Collectively, these depositional environments are located in a variety of elevations above the thalweg (but within the active channel). As a rule-of-thumb, two thirds of the spawnable gravels in South Fork Eel River tributaries are at an elevation at least one third the change in elevation of active channel depth, e.g., if the active channel stage height is 30 cm above the thalweg, almost all redds were constructed 10 cm above the thalweg or higher. Occasionally, steelhead would spawn on the thalweg of the deep upstream edge of a pool tail.

Adult steelhead (and salmon) spawning is a very dynamic sequence of events. The magnitude and duration of peak flows are extremely important, allowing adult spawners to ascend high into small tributary watersheds to access spawning habitat. Extended peak duration equates to increased habitat availability. Once the storm hydrograph peaks and flow begins to recede, fish must either wait for the next storm or spawn. In small watersheds the spawning window may extend only one to four days (depending on several interrelated factors: antecedent conditions, peak magnitude, frequency of successive overlapping storms, watershed area, geographic location, etc.). On very small watersheds in the South Fork Eel River tributaries (Fox Creek at 1.07 mi^2), steelhead migrate, spawn, and emigrate within 48 hours following the peak discharge. Steelhead in Fox Creek need to spawn quickly, then emigrate to avoid stranding. On Elder Creek, most spawning by a wave of steelhead migrating up a flood peak would have ended 5 to 8 days later, with individual adults lingering several days more. The propensity to start spawning shortly following the peak must have significant life history consequences, rooted in adaptations to habitat available within the active channel.

2.6. How Deep is a Salmon? How Deep Does a Salmon Need?

How deep is an adult salmon or steelhead? From girth measurements of frozen and stuffed salmon and steelhead throughout the Arcata vicinity, we estimated a typical steelhead adult, not including the dorsal fin, is approximately 0.6 ft (7.2 inches or 18.3 cm) deep and a chinook salmon is approximately 0.8 ft (9.6 inches or 24.4 cm). We use a 7-inch depth in this commentary.

What minimal flow depth is needed for a salmon to migrate and spawn? Smith (1973) recommends a minimum spawning depth of 0.24 m (9.4 inches or 0.8 ft) for winter steelhead, 0.15 m (5.9 inches or 0.5 ft) for coho salmon, and 0.24 m (9.4 inches or 0.8 ft) for fall chinook salmon. Given our opportunistic data gathering in Arcata, these data indicate that a salmon's back should at least be covered. For minimum passage depths, generally 0.8 ft is considered the minimum for salmon, though some consider 1.0 ft the minimum. For very short barriers, such as a single road culvert, a minimum depth of 0.6 ft has been considered the acceptable minimum for steelhead. In this report we will consider the minimum acceptable depth for spawning and migration to be 0.8 ft for adult steelhead and salmon.

The use of minimum passage depth or minimum spawning depth criteria can be misleading. Flows just providing the minimum passage depth of 0.6 ft for steelhead (7.2 inches, or approximately 18 cm) and 0.8 ft for chinook salmon do not guarantee passage problems are avoided. A minimum spawning depth of 0.8 ft means an averaged sized steelhead must spawn (almost all spawning habitat is shallower) with at least its dorsal fin protruding from the water. While we have observed individual adults migrating and spawning under shallower conditions than these, a minimum of 0.8 ft does not guarantee minimum environmental conditions necessary for recovering and sustaining populations. Although we use minimum depth criteria in our analyses of passage and spawning, any minimum bypass flow that just meets these minima was considered inadequate for protection and recovery.

3. FISH PASSAGE EVALUATION OF PROPOSED MINIMUM BYPASS FLOWS

Minimum passage depth (MPD) is the minimum thalweg depth in a riffle. MPD's were collected over a wide range of drainage areas as part of a NMFS's study to assess road stream crossings. A linear regression predicts the mean MPD as a function of streamflow (Figure 13). Each point in Figure 13 is an average of at least 10 riffles. Drainage area was not a significant independent variable; a 5 cfs flow in a 2 mi^2 watershed had the same MPD as a 5 cfs flow in a 5 mi^2 watershed. We have assumed a similar morphology for the Russian River tributaries and Navarro River tributaries. This is a conservative assumption. The generally drier watersheds with flashier flows in the Russian River basin (as compared to the South Fork Eel River basin) will have shallower and wider cross sections (Luna Leopold pers. comm.). Therefore, our thalweg depth estimates for the Russian River will be conservatively high.

The negative 0.1 ft band bracketing the MPD regression largely accounts for lower MPDs encountered on the downstream leading edge of oblique point bars, though a small percentage of these bars will have even shallower MPDs. Alluvial channels (or partially alluvial) that flow from the hillside, then across the mainstem's terraces and floodplain (as many tributaries along the Russian River flow across terraces and the former floodplain), will have many oblique bars. Sullivan Gulch presents a similar setting: the oblique bar in the upper center of Figure 9C is just one of many throughout the lower channel. Field measured MPDs at the downstream edge of this oblique bar were in the lower 0.10 negative band (Figure 14).

Snider (1985), in an instream flow study for Brush Creek used by SWRCB in determining their minimum bypass flow, notes: "Eighteen potentially critical riffles were measured (i.e., width and depth at flows ranging from 13 to 15 cfs. The only riffle that appeared critical for upstream migration at flows greater than 15 cfs was at Scott's Crossing. This riffle was measured in early January, 1985, flowing at 15 cfs. The average water depth was 0.2 ft. The deep portion of the riffle was only 0.45 ft deep and only 1.0 ft wide. The overall length of the critical zone was over 40 ft. Adult steelhead were observed in a pool just below the riffle, but there was no evidence that any fish had moved upstream of the riffle during the recent past when flow was around 15 cfs." Using the MPD regression (Figure 13), a 15 cfs flow provides an average MPD of 0.69 ft for lower Brush Creek (16 mi^2), with most riffles between 0.79 and 0.59 ft.

To illustrate differences in MPDs generated by the three minimum bypass flows, we plotted MPD against a full-scale outline of an adult salmonid 0.6 ft (7 inches or 18 cm) broad (not including fins), and one inch off the stream bottom, for three watershed sizes in the Russian and South Fork Eel River basins. This visual approach provides a clearer image of what the various minimum bypass flows actually provide. The minimum safe passage depth of 0.8 ft (9.6 inches or 24.4 cm) was used as our minimum criteria, though 1.0 ft (12 inches or 30.5 cm) is frequently used for adult anadromous salmonids.

In the South Fork Eel River basin, the TU and NMFS/CDFG bypass flows provided MPDs above the minimum for Elder Creek (6.5 mi^2)(Figure 15A). The MPD equation is appropriate for flows 35 cfs and lower. The TU minimum bypass flow (67 cfs) was too high to estimate MPD. The NMFS/CDFG minimum bypass flow of 34 cfs gives an MPD of 1.17 ft (14.1 inches or 36 cm). The SWRCB minimum bypass flow (15.4 cfs) had a MPD of 0.70 ft (8.5 inches or 21.5 cm), approximately 0.1 ft below the minimum depth. On Rock Creek (3.0 mi^2), neither SWRCB nor NMFS/CDFG meet the 0.8 ft minimum depth (Figure 15B). On Fox Creek (1.07 mi^2), none of the minimum bypasses meet the minimum depth (Figure 15C).

In the Russian River basin, the minimum bypass flows do not fare as well as in the South Fork Eel River tributaries. For a 6.5 mi^2 watershed (Figure 16A), only the TU minimum bypass provides an MPD of 1.0 ft. The NMFS/CDFG minimum bypass barely provides 0.8 ft, whereas the SWRCB minimum bypass has the fish one third exposed. For a 3.0 mi^2 watershed (Figure 16B), the TU minimum bypass flow barely provides 0.6 ft. MPD for the SWRCB minimum bypass flow (0.40 ft) is only 0.08 ft lower than the MPD for NMFS/CDFG. The NMFS/CDFG and SWRCB minimum bypass flows leave the fish almost half exposed. For a 1.07 mi^2 watershed (Figure 16C), all minimum bypass flows fail; the best is TU with an MPD of only 0.43 ft.

The MPD curve can identify threshold watershed sizes that meet the minimum criteria of 0.8 ft and 1.0 ft for each proposed minimum bypass flow (Table 1). For example, unit runoff for Q_{act} in the middle Russian River tributaries is 4.1 cfs/mi^2. An MPD equal to 1.0 ft requires 27 cfs according to Figure 13. To estimate the minimum watershed that TU's minimum bypass flow will provide an MPD of 1.0 ft, divide 27 cfs by 4.1 cfs/mi^2 that equals 6.6 mi^2. Anadromous salmonids utilizing small tributaries must cope with depths less than 1.0 ft or 0.8 ft, especially for steelhead emigrating two to several days following a peak discharge. Table 1 also includes minimum watersheds for a 0.6 ft MPD.

This analysis demonstrates minimum bypass flows alone cannot provide adequate passage in small watersheds. In very small watersheds, brief periods of high discharges are necessary to provide adequate flow depths for upstream migration and oftentimes spawning. Therefore, in-channel reservoirs on watersheds less than 10 mi^2 that do not pass peak flows (within or outside the December 15 to March 30 winter period) are preventing anadromous salmonid migration regardless of the bypass flow applied. In larger watersheds, such as Elder Creek, male steelhead frequently travel up and down the tributaries many days following the peak discharge that originally brought them upstream. Migration, therefore, is not confined to simply migrating upstream during a flood event. Even a minimum passage depth of 0.6 ft, that is highly conservative against salmon and steelhead, cannot be attained by any proposed minimum bypass flows on all anadromous salmonid-bearing streams (Table 1). The MPD is an averaged minimum depth. Many riffles, particularly in alluvial channel reaches, will have at least 5 to 10 percent of the riffles considerably less than the average MPD (unpubl. data for NMFS passage study by Humboldt State University).

3.1. Maximum Spawning Depths for Minimum Bypass Flows

Thalweg depth is a function of drainage area (Figure 17). We targeted spawning reaches, rather than the deepest most confined riffles, to estimate thalweg depths over a range of small watershed sizes and flows. The data for Figure 17 were compiled from extensive field surveys in Mendocino County and Humboldt County as part of Trush's dissertation and NMFS's fish passage research being conducted by Humboldt State University. We could use Figure 17 to estimate the greatest depth a fish could spawn (i.e., spawning on the thalweg), but most spawning habitat is not on the thalweg. A range of channelbed elevations can be identified that provide potential spawning habitat for any given flow. Almost all spawning habitat surveyed on South Fork Eel River tributaries was at least 0.3 ft higher than the thalweg (but generally even higher). To estimate the maximum depth of spawning habitat provided by a given minimum bypass flow, we used Figure 17 with the deepest spawning gravels positioned 10 cm (0.33 ft) above the thalweg. In large streams such as Elder Creek, most spawning gravel areas will be closer to 20 cm (0.66 ft) than 10 cm above the thalweg.

Maximum spawning depths for each minimum bypass flow were plotted on our salmon diagrams to provide a more visual appreciation of this analysis's significance. If the bypass flow cannot cover the back of a salmon while spawning in the deepest gravel habitat (0.8 ft), we feel safe to conclude the minimum bypass flow could not provide sufficient spawning habitat. Beginning with the South Fork Eel River, the maximum spawning depths for Elder Creek (6.5 mi^2) are provided by the TU and NMFS/CDFG minimum bypass flows, but not the SWRCB minimum bypass flow (Figure 18A). For Rock Creek (3.0 mi^2), neither the SWRCB nor NMFS/CDFG minimum bypass flows is adequate for the deepest spawning habitat (Figure 18B). For Fox Creek (1.07 mi^2), none of the minimum bypass flows are adequate (Figure 18C). On the Russian River, the bypass flows perform considerably worse. For a 6.5 mi^2 watershed, only TU's minimum bypass flow exceeds the 0.8 ft minimum (Figure 19A). For a 3.0 mi^2 watershed, the TU bypass flow almost provides 0.6 ft, but only for the deepest habitat (Figure 19B). For a 1.07 mi^2 watershed, the minimum bypass flows are clearly inadequate (Figure 19C). How much deeper should the flow be in order to provide most of the spawning habitat? This will be addressed for Elder Creek and Rock Creek in another section (cumulative spawning habitat) of this report.

If the reader does not consider South Fork Eel River data relevant to the Russian River or Navarro River tributaries, a short exercise asking the following question may help demonstrate the relevancy. How deep would a Q_{ave} flow (essentially a Q_{feb} flow), or SWRCB bypass flow, be in a small watershed? We selected a hypothetical channel with a 2.5 mi^2 watershed (e.g., Mill Creek has a 2.5 mi^2 watershed that supports steelhead). To estimate flow depth, we needed an estimate for Q_{ave}, a water velocity, and a channel width. Q_{ave} equals width (w_{ave}) * average depth (d_{ave}) * average velocity (u_{ave}). We rearranged this equation to solve for d_{ave} ($d_{ave} = Q_{ave}/(w_{ave} * u_{ave})$) by estimating conservative values for the other variables. Unit runoff (cfs per mi^2) at Q_{ave} for Maacama Creek at the USGS gaging station (43.4 mi^2) is 1.87 cfs/mi^2. Using this unit runoff, Mill Creek has a Q_{ave} of 2.5 mi^2 * 1.87 cfs/mi^2 equal to 4.68 cfs. A channel width of 10 ft at a pool tail or straight low gradient run providing spawnable gravels is a low width estimate. We also were conservative by assuming the average velocity in our pool tail or run was only 1.0 ft/sec (definitely a slow velocity for spawning). Our estimate of average depth (d_{ave}) equals 4.68 cfs/(10 ft * 1 ft/sec) or 0.47 ft (5.6 inches). The SWRCB bypass flow for providing 80% of the "optimum" habitat would be 0.6 * 4.68 cfs or 2.81 cfs. Assuming an 8 ft channel width and a 1 ft/sec velocity, average depth for the SWRCB bypass flow would equal 0.35 ft (4.2 inches). These estimates are actually optimistic compared to more realistic computations. If we assign a 1.5% slope to our hypothetical spawning habitat (e.g., a uniform run), the average velocity would be 1.4 ft/sec (using Mannings equation with n = 0.060) producing an average depth of 0.30 ft (3.6 inches) flowing at 3.36 cfs. Q_{feb} or $0.60Q_{ave}$ simply do not flow deep enough to support spawning activities as SWRCB and CDFG/NMFS claim. A similar calculation is presented in our first commentary (McBain and Trush 1998).

A few photos may help the reader appreciate maximum spawning depth and the MPD. In Figure 20A, an adult chinook salmon is actively migrating upstream (note: a portion of the back is sticking out of the water). A downstream culvert delays salmon migration by approximately 2 days. Looking downstream, the left bank (top of photo) active channel bench was recently overtopped as evidence by the orientation of swept vegetation. The flow in the photo is 9 cfs. Q_{act} for Sullivan Gulch (2.35 mi^2) is 22 cfs, Q_{feb} is 12 cfs, Q_{ave} is 8 cfs, and $0.60Q_{ave}$ is 5 cfs. At 20 cfs, streamflow laps at the top streamside edge of this left bank active bench. Predicted MPD at 9 cfs is 0.54 ft (calculated from Figure 13), i.e., the MPD equation predicts this chinook salmon would be exposed during migration. However, the adult chinook is not at the minimum depth location; the minimum depth location for this run is another 6 ft downstream.

In Figure 20B, a chinook female is positioned downstream of an oblique bar immediately upstream of the previous photo (Figure 20A). She is located on the thalweg, with all her dorsal fin and a small portion of her back sticking out of the water. Using Figure 17 we predict the thalweg depth for typical riffles to be approximately 0.75 ft, and would not be surprised that a chinook with a 8.3-inch deep flank (measured 2 days later after she died) would be exposed. There are still locations where she can hide fully submerged, but the stream's broad alluvial riffles are too shallow. The MPD for this oblique riffle, 0.40 ft, is less than the predicted MPD of 0.54 ft. We have video footage of this female's repeated attempts to negotiate this riffle. She finally succeeded by turning completely on her side and arching over the center of the oblique riffle.

In Figure 20C, three adult chinook salmon are spawning at the head of a pool's tail deposit. This is one of the few locations at 9 cfs that is sufficiently deep and marginally fast enough as a redd site. Their backs are barely inundated. Note the extensive gravel in this pool tail. Flows exceeding 18 cfs are needed to provide minimally acceptable depths for spawning in approximately two thirds of the tail. The position of this redd in the center of the channel will make it highly prone to scour.

In all three photos (Figures 20A to 20C), the reader might ask how depth conditions might differ at 12 cfs (Q_{feb}) or at 22 cfs (Q_{act})? Detailed MPD data are available for this riffle (and others) through the NMFS fish passage study contracted to Humboldt State University. At 12 cfs the predicted MPD is 0.62 ft and at 22 cfs it is 0.87 ft; the measured MPDs were 0.11 ft less. The difference in elevation between 9 cfs and 12 cfs using the MPD equation is only 0.08 ft (0.97 inches). For small watersheds, such as Sullivan Gulch, the Q_{feb} flow provides very similar hydraulic conditions to Q_{ave}. The MPD at $0.06Q_{ave}$ is 0.44 ft, though the measured MPD was 0.32 ft. Adult movement between riffles would be eliminated by the SWRCB's minimum bypass flow and greatly restrained by the NMFS/CDFG minimum bypass flow. Only a few of the deepest spawning habitats could be spawned with the adults' backs just covered by the flow.

3.2. Rantz's Study: Eureka, I Found Spatial Scale

An obvious task is to contrast cumulative spawning area provided by flows up to the Q_{act} minimum bypass flow compared to flows up to the Q_{feb} minimum bypass flow or a $0.60Q_{ave}$ minimum bypass flow. This can be accomplished empirically or can be modeled. "Cumulative area" should be considered because different portions of the channelbed provide habitat up through the Q_{act} stage height, and higher. Graphically, the X-axis should be daily flow and the Y-axis cumulative spawning area. Flows on the X-axis ideally should extend to approximately the 5 percent exceedence flow (i.e., $p = 0.05$) on a daily average flow duration curve, flows encountered 1 to 2 days following a significant flood peak. This higher flow is especially critical for watersheds less than 2.5 mi^2 where steelhead often must enter a tributary, select a redd site, spawn, then leave in less than 36 to 48 hrs following peak discharge.

Unfortunately these data are difficult to find. SWRCB staff graphically portrays a spawning habitat relationship with flow in Figure 4.1-2 of their Russian River Report (SWRCB 1997) duplicated here as Figure 21. The Y-axis is not cumulative spawning area, but spawning area (weighted usable area, or WUA) estimated at given discharges. The "optimum flow" is not optimal for spawning (e.g., providing the highest egg survival), only the flow that purportedly provides the most spawning habitat. This flow would be of interest in a highly regulated river where a single flow might be released for long periods. For the Russian and Navarro streams, the "optimum flow" simply serves as an administrative cap on naturally varying flows: flows exceeding the "optimum" can be diverted. The "optimum flow" as a bypass flow eliminates an unknown percentage of the total available habitat (generated by naturally variable intra- and inter-annual annual hydrographs). If the SWRCB justification was adopted (a $0.60Q_{ave}$ bypass flow provides 80% of the "optimum habitat"), what percentage of the total available habitat, not "optimum habitat" would be lost with a bypass flow? More than 20% would be lost, but how much more?

S.E. Rantz published (1964) *Stream Hydrology Related to the Optimum Discharge for King Salmon Spawning in the Northern California Coast Ranges* in USGS Profession Paper No. 1779-AA. He uses the same definition for "optimum discharge" as the SWRCB staff, "the minimum discharge that will give the maximum spawning area", but documents and graphs (in his Table 2 and Figure 3) the Y-axis as "the ratio of favorable spawning area to potentially usable area" for a given discharge (on the X-axis). The Y-axis is not cumulative spawning area. Rantz therefore estimates the relationship between optimum discharge, as defined, and total spawning habitat available under naturally varying flows, In Figure 3, the *Van Duzen River near Carlotta* site has sufficient points to define an "optimum" discharge, as opposed to *the Middle Fork Eel River near Covelo* site that might achieve an "optimum discharge" between 600 cfs and 800 cfs. The "optimum" discharge for the Van Duzen site, with a discharge of approximately 1000 cfs provided roughly 80% of the total available habitat. A 1000 cfs daily average flow had an exceedence probability of 19%, probably close to the Q_{feb} discharge (we did not do the analysis). The South Fork Eel River near Leggett site had an optimum discharge of 400 cfs providing 100% of the available spawning habitat and an exceedence probability of 34%, probably close to the $0.6Q_{ave}$ flow. These two sites support the NMFS/CDFG and SWRCB bypass flows, respectively.

Rantz attempted to quantify his findings by computing a regression equation using mean channel width (wave in ft) in spawning reaches at Q_{ave} and drainage area (DA, in mi^2) as the independent variables. The following equation predicts the optimum discharge (Q_{opt}):

$$Q_{opt} = 0.89(Q_{ave})^{1.09} * (w_{ave}/DA)^{1.44}\ .$$

A channel's w_{ave}/DA ratio would equal 1 at a drainage area of 35 mi^2 to 40 mi^2. When the ratio equals 1, the term in Rantz's equation, $0.89Q_{ave}{}^{1.09}$, predicts a Q_{opt} slightly greater than Q_{ave} (e.g., if Q_{ave} equals 50 cfs, Q_{opt} equals 63 cfs). Bigger channels have smaller w_{ave}/DA ratios. Channels from watersheds greater than 40 mi^2 have ratios <1 (as documented in Rantz) predicting Q_{opt} can occur at flows less than Q_{ave} using the Rantz equation. Conversely, Rantz predicts Q_{opt} for stream channels from decreasing drainage areas (watersheds below 40 mi^2) require increasingly higher flows exceeding Q_{ave}. Rantz's equation recognizes a spatial scale effect of drainage area on the relationship between spawning habitat and flow frequency.

3.3. Is the Optimum Flow Optimal?

Rantz defines the optimum discharge for spawning as the single flow that provides the most spawning area. Although defined simply, the interpretation and significance of the "optimum" discharge are not straightforward. Rantz's Canon Creek habitat curve (Figure 22) can be presented using the SWRCB format (the standard WUA curve). The Y-axis must be reconstructed such that the percentage of habitat produced by a given flow (relative to total available habitat) is expressed as a percentage of the habitat produced by the "optimum" flow. Therefore the optimum flow, which accounts for 75% of the total available habitat on Canon Creek, would comprise 100% of the "optimal" habitat in the SWRCB format (Figure 22). The Q_{feb} flow, which accounts for 60% of the total available habitat, would comprise 80% of the "optimal" habitat in the SWRCB format (Figure 22). Unfortunately, we cannot reverse this calculation: a standard WUA curve cannot be transformed into Rantz's X-Y axes. There is no way of ascertaining from the typical weighted usable habitat area curve (e.g., Figure 4.1-1 in SWRCB 1997, reproduced in this report as Figure 21) the amount of new channelbed surface area that becomes spawning habitat at flows exceeding the "optimal" discharge.

We will use an example to clarify. On the Little Sulphur Study Site (approximate drainage area of 40 mi^2 at this site), the "optimum" flow is identified as 85 cfs (Figure 23). A classic interpretation of this curve is that flows greater than 85 cfs produce less habitat. If any single discharge is contrasted with another, this interpretation is appropriate: by drawing a horizontal line at 5,000 WUA in Figure 23, a 46 cfs discharge produces the same amount of spawnable channelbed as a 165 cfs discharge. But the 165 cfs discharge creates a very different hydraulic environment from the much smaller 46 cfs discharge. Although both flows may create the same amount of spawning habitat, different portions of the channelbed are spawnable at low versus high flows. As habitat near the thalweg becomes too deep and/or fast with increasing flows, new habitat is created farther from the thalweg. If flows only fluctuated up to the "optimal" flow of 85 cfs, how much of the channelbed would have contributed spawning habitat? If flows fluctuated up to 120 cfs, how much more of the channelbed would have contributed spawning habitat?

A cumulative spawning habitat curve can be constructed to quantify this accumulation of channelbed surface area serving as habitat (i.e., an accumulation of unique habitats) with increasing discharge. This curve can only be constructed by keeping track (mapping in the field) of when (at what flow) each portion of the channelbed becomes spawnable, as Rantz did with his limited sample size (one reach per stream). However, the flatness of the Little Sulphur Creek Site's WUA curve strongly indicates considerably more channelbed surface area is becoming spawning habitat. Other WUA curves are similarly shaped. The extended wide hump of the Brush Creek WUA curve. The prudent strategy would be to preserve naturally fluctuating habitat past the peak until WUA abundance drops off very rapidly. On Figure 23, this occurs at approximately 165 cfs for spawning. The Q_{act} flow for this site is approximately 160 cfs to 170 cfs. On smaller watersheds (especially less than 10 mi^2), we hypothesize that: (1) the optimum flow as defined by SWRCB will require a lower exceedence flow (i.e., a higher and less frequent discharge) and (2) the optimum flow will provide less and less of the total available spawning habitat. What evidence exists?

Rantz sampled only one relatively small stream, an alluvially meandering reach of Canon Creek near Korbel (on the Mad River). Lower Canon Creek is spawned by chinook, coho, Pacific lamprey, and steelhead. Its drainage area is comparatively large (16.2 mi^2) to what we consider small in this report (an upper drainage area of 10 mi^2). Estimated "optimum" spawning discharge was 165 cfs having an estimated exceedence probability of 4% that provides approximately 70% of the total available habitat. Rantz cautions: "the regression equation may give more reliable estimates if the stream width used in the equation is the average width of the stream, observed at many long potential spawning reaches when the discharge is at or near its mean value." Using a W_{ave}/DA ratio of 1.91, his regression predicts 116 cfs for Q_{opt}, whereas his field data for the one sample site indicate 165 cfs. Recently, we had the opportunity to assist mapping planform morphology in lower Canon Creek. The w_{ave} was between 25 ft and 30 ft; a better estimate of Q_{ave} (i.e., an updated daily average flow duration curve) would be 55 cfs rather than 37 cfs as reported in Rantz. Using these updated data, the Rantz equation predicts a Q_{opt} of 131 cfs. By plotting Rantz's data for Canon Creek (Figure 22), NMFS's Q_{feb} bypass flow (80 cfs, using unit runoff from the nearby N.F. Mad River USGS gaging station with slight modification by the Little River

USGS gaging data) would provide 55% to 60% of available spawning habitat. SWRCB's bypass flow provides even less (approximately 40% to 45%). Q_{act} is approximately 145 cfs and to the right of the optimum flow (Figure 22); Q_{act} would therefore supply greater than 75% of the total available habitat because flows would fluctuate below the Q_{act} bypass (including occasionally flowing at Q_{opt}). We cannot determine from the graph how much more than 75% of the total available spawning habitat would be provided, i.e., how much new channelbed surface that is spawnable above Q_{opt} that was not spawnable below Q_{opt}.

Rearing habitat has been ignored by NMFS while SWRCB considers rearing less demanding of flows than spawning (SWRCB 1997). But is it? The WUA curve for juvenile rearing habitat in Little Sulphur Creek Study Site exhibits an even more pronounced plateau than the spawning habitat WUA curve (Figure 23). Clearly different parts of the channel are providing unique rearing habitat at different flows. For example, a 20 cfs flow provides 15,000 WUA of rearing habitat as does 120 cfs (Figure 23). These two flows are radically different hydraulically. By SWRCB adopting the "optimum" rearing flow of 40 cfs (approximately 17,500 WUA), their biologists (and CDFG's) are asserting that additional habitat created between 40 cfs and 150 cfs is not significant even though overwintering habitat is generally considered the limiting factor. Because off-channel habitat typically comprises a very small fraction of the total channelbed surface, the WUA curve does not distinguish it from other habitats. Based on our field experience in alluvial and bedrock-dominated streams less than 10 mi^2, a separate WUA curve developed only for off-channel habitat would exhibit an "optimum" flow much higher than 40 cfs. Q_{feb} would be approximately 83 cfs. Note that the WUA rearing curve drops off rapidly at 140 cfs (Figure 23), with Q_{act} at 160 cfs to 170 cfs.

3.4. Summary

This section's title was a trick question. No optimal spawning habitat exists on unregulated streams, consequently there can be no optimum flow. The disparity between the habitat provided by the "optimum flow" and the total available habitat should increase with decreasing drainage area. Rantz's study does not provide the definitive analysis documenting a drainage area effect in all watershed sizes, but it validates the commonsense expectation that drainage area is important. The backside of the WUA curve, rather than the front, better identifies the range of flows required to support naturally complex spawning and rearing habitat.

4. TOTAL CUMULATIVE SPAWNING HABITAT FOR STEELHEAD

4.1. Cumulative Spawning Habitat Curves

Cumulative spawning habitat data were inventoried for channel reaches, though never analyzed, during Trush's field research on Elder Creek and other tributaries to the South Fork Eel River. The surface area of channelbed providing spawning habitat was quantified over a range of discharges. Only a general summary was included in the dissertation. However, the data were collected and recorded such that cumulative spawning area could be plotted as a function of flow. In the original fieldbooks, each distinct patch of spawning habitat was assigned to one of seven flow classes (instead of the three generalized flow categories reported in Trush's dissertation) for 2.4 km of Elder Creek and 1.6 km of Rock Creek, then plotted cumulatively as a function of the assigned flow classes (Figures 24 and 25). The data were collected over several years by drafting detailed planmaps of the channel and repeatedly visiting each potential spawning site over a range of discharges (flow classes). Larger sites, such as broad pool tails, provided spawning habitat over several flow classes (reported collectively as "All" flows in the dissertation). These sites were subdivided, assigning only a portion of the total spawning habitat area to each appropriate flow class.

Lower Elder Creek is steep (averaging 2.4 percent), characterized by a coarse channelbed substrate and confined morphology spawned exclusively by steelhead and Pacific lamprey (one pair of coho salmon adults was observed near the mouth). Flows less than Q_{act} (67.0 cfs) cumulatively provide 85% to 80% of the total available steelhead spawning habitat (Figure 24). Flows less than Q_{feb} (34.5 cfs) cumulatively provide 30% to 35% of total available habitat, whereas flows less than $0.60Q_{ave}$ (15.4 cfs) cumulatively provide 5% of the total available spawning habitat.

Lower Rock Creek, in contrast to Elder Creek, is an alluvially meandering channel with a 1% gradient spawned by steelhead, chinook salmon, coho salmon, and Pacific lamprey. Rock Creek (3.00 mi^2) has roughly half the watershed area as Elder Creek (6.50 mi^2). Cumulative spawning habitat was skewed even more toward the higher flows (Figure 25) than Elder Creek's cumulative habitat: flows equal to and less than Q_{feb} (16.2 cfs) cumulatively provide 18% of total available habitat (707.1 m^2), whereas flows less than $0.60Q_{ave}$ (7.25 cfs) cumulatively provide < 5% of total available spawning habitat. Flows less than Q_{act}, cumulatively provide approximately 82% of the total available spawning habitat (Figure 25). Upper Rock Creek has a morphology similar to Elder Creek: steep and rocky. The percentage of total cumulative spawning habitat as a function of flow, however, was similar to lower Rock Creek's cumulative habitat curve (Figure 25).

If daily average flows were kept equal at or below $0.60Q_{ave,}$ approximately 90% of the potential spawning habitat in Elder Creek from the Falls to the South Fork Eel River confluence would be eliminated. The Falls is impassable at $0.60Q_{ave}$ and Q_{feb}; all spawning habitat upstream also would be eliminated. Conservatively (probably more), half the spawning habitat is above the Falls. A baseflow of $0.60Q_{ave}$ or less for Elder Creek would therefore eliminate approximately 95% of the potential spawning habitat. A baseflow of Q_{feb} or less would eliminate 80% of the potential spawning habitat. Because the Falls is unique to Elder Creek, we will only consider downstream habitat to generalize the findings. However, this highlights another serious concern: passage barriers (partial or otherwise) can be created or worsened by upstream diversions. We've read no discussion/provisions in the CDFG/NMFS May 2000 draft that addresses how barriers (especially existing partial barriers) would be factored into a recommended minimum bypass flow. Neither does SWRCB address this clear cumulative effect.

For Sullivan Gulch (2.35 mi^2) spawnable channelbed at each flow is outlined on the photos (Figure 9). In very low flows, the only marginal habitat is centered on the downstream leading edge of the pool, where the main body of the pool transitions into the pool tail. At higher flows, spawning habitat initially is created close to the thalweg of the pool tail, then farther toward the right bank (looking downstream) and slightly downstream. The total cumulative spawnable area can be constructed, for this single pool tail, by overlapping the spawnable areas over the full range of daily flows, i.e., total spawnable area accumulates with increasing discharge until flows are too deep and/or fast for any of the pool tail to be spawnable.

4.2. Summary

Cumulative spawning habitat curves from two small anadromous salmonid streams in Northern California, extracted from Trush's fieldwork, evaluated the effectiveness of minimum bypass flows for providing spawning habitat relative to the total spawning habitat that would have been available without flow regulation. The NMFS/CDFG and SWRCB bypass flows cannot provide adequate spawning habitat in stream channels with drainage areas less than 10 mi^2 for anadromous salmonids. When considered independent of maximum diversion rates, the NMFS minimum bypass flow of Q_{feb} provides 35% of the total cumulative spawning habitat in a 6.5 mi^2 tributary of the South Fork Eel River. In a nearby 3.0 mi^2 tributary, the Q_{feb} minimum bypass only provides 18%. The SWRCB minimum bypass flow fared considerably worse than the NMFS bypass. On the same two South Fork Eel River tributaries, SWRCB's $0.6Q_{ave}$ minimum bypass flow provided only 5% and 3% of the total cumulative spawning habitat. In contrast, the TU minimum bypass flow provides 85% and 82% of the total cumulative spawning habitat on the same South Fork Eel River tributaries. Runoff in the central Russian River basin is roughly half that of the upper South Fork Eel River basin. The loss of habitat in small Russian River watersheds should be substantially greater if the NMFS minimum bypass flow is applied, though it has not been quantified. If the TU minimum bypass flow was applied to similarly sized tributaries in the Russian River basin, habitat inventories would undoubtedly show higher habitat losses than on the South Fork Eel River tributaries.

The scale effect on spawning habitat availability is apparent: flow frequency does not create spawning habitat, only adequate flow depths and velocities do. As watershed size decreases, relatively larger and therefore less frequent flows are required to generate adequate spawning depths with appropriate velocities. Rantz recorded this commonsense phenomenon, and these South Fork Eel River habitat inventories support the same outcome. Could a common quantitative relationship between increasing habitat abundance at decreasing flow frequencies span a wider range of watershed areas than Rantz originally sampled and modeled? Although Rantz's smallest watershed was 16.2 mi^2, we applied his equation to Elder Creek (6.5 mi^2) for predicting the "optimum" flow. Channel width at Q_{ave} is 15 ft to 16 ft, making the w_{ave}/DA ratio approximately 2.5. Predicted Q_{opt} is 121 cfs: definitely too high given the cumulative habitat curve (Figure 24). Small streams function differently. Although the flow magnitude at $p = 0.10$ completely inundates the active channel in small watersheds, we are investigating the likelihood that the active channel in large channels is inundated by more frequent flows.

The watershed scale effect is related to the confining influence of the active channel, and therefore related to channel dimensions, hydrograph characteristics, and ultimately drainage area. If the active channel cannot confine flows to a depth preferred by spawning salmonids, then a favorable depth within the active channel only can be attained by larger flows that spill onto the active bench. At what watershed size is a threshold realized when Q_{act} cannot generate sufficient depths and velocities to create all, or mostly all, the cumulative spawning habitat within the active channel? For Elder Creek (6.5 mi^2), Q_{act} created approximately 85% of the total cumulative habitat within the active channel. Q_{act} on Rock Creek (3.00 mi^2) created approximately the same percentage. For the South Fork Eel River basin this threshold may occur on 1 mi^2 watersheds or less; our analysis of Fox Creek showed the active channel flow was marginal in providing adequate spawning habitat depth. In the Russian River basin, with half the runoff of the South Fork Eel Basin, the minimum watershed size flowing at Q_{act} would be close to 2.5 mi^2 or 3.0 mi^2.

5. MAXIMUM DIVERSION RATES AND THE ANNUAL HYDROGRAPH

High flows are needed for a variety of biological and physical functions. A maximum diversion rate allows a set flow rate to be diverted whenever the natural streamflow exceeds the minimum bypass flow. Methodologies for determining the maximum diversion rate vary among the proposed allocation protocols. TU's maximum diversion rate requires the declining limb of a 1.1-yr to 1.5-yr flood hydrograph to reach the active channel stage height 0.5 days earlier than it would if flows were unregulated. For example, on Rock Creek a maximum diversion rate of 9 cfs/day will force the active channel stage height to occur 0.5 days sooner than it would if unregulated (Figure 26). Empirical data were plotted for several different drainage areas for the Russian River basin, then used to develop a preliminary regression equation that predicts the maximum diversion rate as a function of drainage area (Figure 27). NMFS now proposes a maximum diversion rate that is 15% of the 20% exceedence flow for the winter period (previously their proposed rate was 20% of the 20% exceedence flow for the winter period). For example, on Rock Creek the 20% exceedence flow for the winter period (December 15 through March 31) is 40.2 cfs. NMFS's maximum diversion rate for Rock Creek (3.00 mi^2) would be 15% of 40.2 cfs, or 6.03 cfs. SWRCB has not, to our knowledge, specified an overall watershed diversion rate, and therefore offers no way to assess downstream cumulative effects. For the SWRCB protocol, TU diverted high flows (above their bypass of $0.6Q_{ave}$) at a rate equal to 20% and/or 40% (where noted) of the 20% winter exceedence flow. The 20% rate is the same as NMFS's originally proposed rate in the January 31, 2000 meeting.

Diversions above the minimum bypass flow will alter the annual hydrograph, thus affecting minimum passage depth, maximum spawning depth, and available spawning/rearing habitat. The first impact evaluated was cumulative spawning habitat.

5.1. Cumulative Spawning Habitat Effects

A single flood hydrograph on Rock Creek (Figure 28) was modeled for cumulative spawning habitat effects created by each allocation protocol. Table 2 summarizes the effects of each allocation protocol on a single high flow event for Rock Creek. The first set of columns provide the mean daily discharges resulting from each maximum diversion rate and minimum bypass flow. The second set of columns provides the minimum fish passage depths for the unregulated and altered hydrographs. The third set of columns, documenting habitat loss attributable to each diversion protocol, requires an explanation and example. If a female steelhead arrived in Rock Creek on February 10th, approximately 86% of the total spawning habitat (707.1 m^2) would be available (as defined earlier and presented in Figure 25) over the next several days. The other 14% of the total spawning habitat was available on February 8th and 9th at higher flows before this particular female arrived. If Rock Creek diversions were fully allocated using the TU proposal, this female steelhead would experience a mean daily flow of 31.0 cfs rather than 32.8 cfs (if there had been no diversions) on February 10th. Using the cumulative spawning habitat curve for lower Rock Creek (0.95 km long channel segment) in Figure 25, the difference in cumulative habitat between the two flows is 86% (608 m^2) and 84% (594 m^2), respectively at 32.8 cfs and 31.0 cfs. Therefore, a female steelhead arriving February 10th, 48 hrs following the hydrographs peak discharge, would have 594 m^2 of habitat to choose from over the next several days (as flows gradually decrease and provide a wide range of habitats) rather than 608 m^2. This would equal a habitat loss attributable to the TU protocol of 2.3% ((608 m^2 - 594 m^2)/608 m^2) * 100)). The NMFS protocol imposes a 10% habitat loss for females arriving February 10th ((608 m^2 - 544 m^2)/608 m^2) * 100)) and a 45% loss for females arriving February 11th ((438 m^2 - 240 m^2)/438 m^2)* 100)). The SWRCB protocol (using a 20% maximum diversion rate) would create habitat losses for fish arriving on February 10th and 11th of 75% and 85% respectively.

On February 12^{th}, 96 hours after the peak flow, a female would have all habitat naturally available for spawning under the TU proposal because no flow would be diverted. Under the NMFS proposal, approximately 50% of the potentially spawnable habitat would not have been available to this female. Under the SWRCB proposal, approximately 90% would not have been available. The MPD for February 12^{th} allowing upstream migration (and movement between redds for the males) would have been favorable under the TU protocol (0.90 ft), marginal using the NMFS/CDFG protocol (0.75 ft), and poor under the SWRCB protocol (0.50 ft) with barriers likely.

With most spawning initiated 1 to 4 days following the peak discharge (complicating factors have been addressed, also refer to Trush 1989), the NMFS/CDFG and SWRCB protocols significantly impact habitat availability (Figure 29). The consequences of losing 50% or more of the potentially spawnable habitat would not be easy to quantify. More redds would be constructed closer to the thalweg, where scour during high flows and sand infiltration during low flows are especially high. We are calculating the increase in redd scour at these locations, but have not finished our analyses. Females would be more likely to excavate other redds (constructed the previous high flow event by a different female) because of the reduced site selection. Reduced flow depths expose adults to greater predation (including out-migrating adults) and force greater energy expenditure to pass shallow riffles. Fewer redds would be successfully completed. As discussed, redds constructed nearer the margins of the active channel and farther from the thalweg (i.e., only spawnable at relatively high flows) have a minor chance of being de-watered compared to the high chance for redds constructed closer to the thalweg of being scoured and/or infilled by sands moving at low discharges. Collectively these factors lower the chance of an egg inside the female successfully emerging as a fry.

Although stage heights above the thalweg can only differ by 5 cm to 8 cm between Q_{feb} and Q_{act}, there are major differences in the habitat provided in Elder Creek. As already shown, Q_{act} on Elder Creek provides 85% of the cumulative total habitat, whereas Q_{feb} provides only 30%. This steep increase can be explained by hydraulic geometry relationships. At flow stages less than the active channel stage height, most hydraulic adjustment occurs by sharp velocity increases, intermediate depth increases, and almost no width increases (e.g., Figure 10). Small increases in flow depth above the tops of the channelbed's cobbles significantly decrease hydraulic roughness, thus increasing average velocities. Potential spawning habitat requires more than adequate depths, but sufficient velocities as well. On Elder Creek, surface velocities at active redds were not closely correlated to discharge; females sought different channel locations with common velocities and depths spanning a wide range of flows (Figure 12). Most spawning occurred at 1.5 ft/sec to 2.5 ft/sec velocities. As velocities rise rapidly up to the active channel stage height, the diversity of velocities throughout the channel also increases, creating diverse (different channel locations) and more abundant spawning habitat.

How important is eliminating 50% or more (Figure 29) of the cumulative spawning habitat? At one level this is a nonsensical question. If the annual flow regime is a wet water year, then eliminating 50% of the habitat best suited for high flows would be significant. "Best-suited" means those channelbed locations where a deposited egg will have the best chance of successfully producing an emergent fry. At any given channelbed location, this chance will largely depend on the flow regime immediately following egg deposition. If the annual flow regime is a dry water year, then eliminating 50% of the habitat best suited for low flows would be significant. Unfortunately (or perhaps not), we do not have the flexibility to selectively eliminate the least suitable habitat each water year. Our best, most practical strategy for recovery is to maintain the full range of naturally variable spawning locations. An unacceptable strategy is managing for the "typical" year.

5.2. MPD and Maximum Spawning Depth Effects

The maximum diversion rate also impacts minimum passage depth. For each stream, predicted MPD is plotted for each daily flow throughout the receding limb of a selected high flow event using 5 diversion scenarios: unregulated, TU protocol, NMFS/CDFG protocol, SWRCB protocol with a 20% maximum diversion rate, and SWRCB protocol with a 40% maximum diversion rate. More than a 10% loss in the migration window, defined by a minimum MPD of 0.8 ft, was considered significant. Maximum spawning depths follow a similar pattern as MPD changes, though slightly shallower, e.g., the MPD at active channel flow for Rock Creek is 1.08 ft (33 cm) whereas the maximum spawning depth at active channel flow is 0.89 ft (27 cm) (from Figure 13).

Daily average discharge was modeled under the three protocols for each day in a selected flood hydrograph following peak discharge (i.e., analyzing the descending limb of the flood hydrograph). MPD was estimated from Figure 13 for each daily average discharge reported as hours since the peak discharge. Likewise, maximum spawning depths were calculated from Figure 17. By plotting these daily data on the same salmonid diagrams used to evaluate bypass flows (e.g., Figure 15A), the reader can evaluate daily changes in MPD and maximum spawning depths, attributable to each diversion protocol, during the descending hydrograph limb when adult salmonids migrate up small tributaries and spawn.

In Rock Creek (Figure 30A through 30E), anadromous salmonids had approximately 115 hours following peak discharge to migrate while the MPD was 0.8 ft or greater. The TU protocol provided the same migration window of 115 hours. The NMFS/CDFG protocol reduced this migration window approximately 40% by sustaining only 72 hours of flows with an MPD greater than 0.8 ft. The two SWRCB protocols reduced the migration window by 45% and 60% (63 hours and 45 hours). In smaller Fox Creek (Figures 31A through 31E), anadromous salmonids had approximately 24 hours following peak discharge to migrate while the MPD was 0.8 ft or greater. The TU protocol provided a migration window of 18 hours (a 25% reduction). The NMFS/CDFG protocol had a migration window of approximately 20 hours (a 17% reduction). The two SWRCB protocols reduced the migration window by 25% and 42% (18 hours and 14 hours). The reader can evaluate the same flood hydrograph on Elder Creek (Figures 32). These results show that the TU protocol performed significantly better than the NMFS/CDFG and SWRCB protocols on a larger stream where the active channel flow surpasses minimum depth criteria for migration, while (2) the NMFS/CDFG protocol performed slightly better on a very small stream where the active channel flow cannot meet the minimum passage depth (refer to earlier comments in the minimum bypass flow evaluation).

A similar analysis for the same tributary drainage areas (i.e., 6.5 mi^2, 3.0 mi^2, and 1.07 mi^2) has been analyzed for the Russian River Basin, but the figures have not been drafted (Figures 33A-E, 34A-E, and 35A-E). Modeled flood hydrographs (January 14 through February 5 in WY1964) were adjusted (for unit runoff) from the Franz Creek U.S.G.S Gaging Station No. 11463940. Results are pending.

Also in the Russian River basin, a 1.29 mi^2 tributary of Dry Creek (Figure 36A through 36E), the MPD for the unregulated flood hydrograph dropped to 0.8 ft approximately 30 hours after the peak discharge. The TU protocol would shorten the passage window to 26 hours (a 13% reduction), while the NMFS/CDFG protocol would shorten it to 28 hours (a 7% reduction). The two SWRCB protocols reduced the migration window by 13% and 20% (26 hours and 24 hours). Another MPD analysis for a tributary to Soda Creek in the Navarro River basin produced similar results (Figures 37A to 37E) for a flashier flood event.

There will be a watershed size that has an active channel that simply cannot provide a minimum passage depth of 0.8 ft when flowing full. It seems that Fox Creek at 1.07 mi^2, and supporting a vigorous steelhead population, is slightly below this minimum threshold size. As noted earlier, the exceedence probability for the active channel flow in very small watersheds may be lower than 10%. An 8% exceedence flow of 13.2 cfs for Fox Creek would still not generate an MPD of 0.8 ft or greater however. The minimum bypass flow necessary to provide a 0.8 ft MPD requires 19 cfs (based on the MPD regression), representing a 5% exceedence probability on the Fox Creek daily average flow duration curve. This would be a very high minimum "baseflow."

We estimated that a 0.5 day alteration (for determining the maximum diversion rate) of the active channel flow (i.e., earlier than it should have occurred on the receding flood limb due to diversions) was the maximum allowed. In very small watersheds where the active channel flow cannot provide a minimum MPD of 0.8 ft, a 0.25 day alteration may be necessary instead. This would allocate more of the upper recession limb for upstream migration and spawning. If a diversion rate of 0.25 days was applied to the Fox Creek for the same February WY1985 flood event, the passage window would be extended to 21 hours (a 9% reduction).

Other consequences with respect to passage must be considered. A steelhead migrating up to a small tributary must migrate through a larger tributary first. The 40% reduction of the MPD window by the NMFS/CDFG protocol for a small third order channel such as Rock Creek will greatly affect the chance of steelhead successfully reaching and then migrating into a smaller second order channel. The NMFS/CDFG and SWRCB protocols probably would eliminate use of smaller tributaries except in water years when there are major temporal overlaps of flood hydrographs.

Once steelhead spawn, they emigrate quickly to avoid stranding in small watersheds (refer to Trush 1989). Using 0.6 ft as a minimum outmigration passage depth on Fox Creek, the unregulated hydrograph provides 50 hours from the peak discharge until the MPD drops to 0.6 ft. For the TU protocol the window would be 48 hours (a 4% reduction). For the NMFS/CDFG protocol the window would be 40 hours (a 20% reduction). The lower the minimum bypass flow, the less chance of successful outmigration for steelhead.

Similar analyses for MPD in the Russian River Basin and for maximum spawning depths in both river basins is available on request. Maximum spawning depths are generally 2 to 5 cm shallower than the MPD.

5.3. Summary

When a maximum diversion rate and minimum bypass flow were applied to individual high flow events, we expected the NMFS/CDFG protocol to perform better (impact less habitat) than when their minimum bypass flow was applied alone. However on Rock Creek their daily diversion rate of 15% of the 20% winter exceedence flow, extracting down to the Q_{feb} minimum bypass flow, still reduced available spawning habitat up to approximately 50% (Table 2) when steelhead were most prone to initiate spawning. For the NMFS/CDFG diversion protocol, the maximum diversion rate, though determined arbitrarily, is not the problem at a maximum diversion rate of 15%.

Their minimum bypass flow is too low. NMFS/CDFG wants to continue diverting during the middle, and lower third, of the flood hydrograph's receding limb when rapid drops in velocity are associated with small decreases in discharge. These rapid hydraulic changes are responsible for the steepest portion of the cumulative spawning curves (Figures 24 and 25), i.e., small changes in discharge produce major changes in habitat availability. In contrast the TU diversions (though greater than the staying above the sharp changes in velocity and avoiding the steep portion of the cumulative spawning habitat curves.

We have shown that a higher maximum diversion rate than the NMFS/CDFG rate, but confined to the upper half of the flood recession limb, is a sound recommendation. With one catch. In very small streams, where the active channel flow does not meet minimum depth criteria, a lower maximum diversion rate (equivalent to a 0.25 day alteration rather than 0.5 days) may be necessary.

6. CHANNEL MAINTENANCE AND THE ANNUAL HYDROGRAPH

The channel maintenance issue was addressed in earlier commentaries (McBain and Trush 1998, 1999). Our revised position does not affect channel maintenance flows. S. Edmondson (2000, p.4) writes, *Flushing flows equivalent to $Q_{1.5}$ or Q_2 (unimpaired flows with a recurrence interval of 1.5 to 2 years) would be protected because maximum cumulative withdrawal rates of 15% of the "winter 20% exceedence flow " is an insignificant and very small fraction of $Q_{1.5}$ and Q_2. Do you agree that limiting the maximum cumulative rate of withdrawal to 15% of the "winter 20% exceedence flow " would be sufficiently protective of flushing flows in tributaries of coastal watersheds?*

A necessary objective for maintaining a healthy stream ecosystem is to maintain the magnitude and duration of a wide range of channel forming events; flushing flows do not maintain stream ecosystems, only limited aspects of channel morphology. Maintenance requires naturally occurring flood events with flow magnitudes considerably greater than $Q_{1.5\text{-yr}}$ or $Q_{2\text{-yr}}$. We only mention this because TU cannot support a project that provided $Q_{1.5\text{-yr}}$ or $Q_{2\text{-yr}}$ releases but prevented (through diversion) higher events. Permitted fill-and-spill reservoirs are already eliminating high flow events within the SWRCB's winter diversion period. Channel maintenance would be critical for all streams supporting aquatic life, i.e., all Class I and Class II streams designated in the California Forest Practice Rules, and intermittent streams with riparian vegetation, i.e., most Class III streams.

The NMFS/CDFG and TU allocation protocols preserve geomorphically significant flood events on larger watersheds. On small watersheds (< 5 mi^2), alteration of the flood recession limbs by a maximum diversion rate may affect duration of flows transporting finer bedload. We have not evaluated potential consequences of altering the recession limb on channel morphology, but both proposed maximum diversion rates should prevent significant impacts. However, the importance of a diversion structure eliminating bed material to the channel (captured in the reservoir and not returned to the downstream channel) is significant locally and cumulatively. Channel maintenance is recognized as a necessary objective for maintaining the health of aquatic systems and recovery/maintenance of anadromous salmonid populations. Therefore sediment supply reduction/elimination by onstream reservoirs must be mitigated. SWRCB and NMFS/CDFG have not proposed mitigative measures.

7. ANNUAL DIVERSION YIELDS AND MANAGEMENT ISSUES

The TU allocation protocol was designed to: (1) minimize impacts to anadromous salmonid populations by diverting when the hydraulic geometry was not producing major changes in depths and velocities and (2) avoid affecting geomorphic thresholds. The TU protocol can be used anytime during high runoff and need not be restricted to the Dec 15 to March 31 diversion window. With the SWRCB and NMFS/CDFG protocols this would not be the case. Because habitat impacts will occur with their protocols, diversions into April could be particularly damaging for late-migrating steelhead, while diversions in November and early-December would interfere with upstream passage for all salmonid species.

To estimate annual diversion volumes from the three allocation protocols, TU modeled: (1) water years 1980 through 1989 in Elder Creek (6.5 mi^2) and Fox Creek (1.07 mi^2) from the South Fork Eel River basin (Table 3), (2) 6.5 mi^2 and 1.07 mi^2 watersheds from the Russian River Basin scaled from the Franz Creek USGS gaging record for WY1964 through WY1968 (Table 4), and (3) WY1968 and WY1969 from a Dry Creek Tributary in the Russian River Basin (Table 4). Although our primary concern is salmon habitat protection and recovery, a more exhaustive analysis of annual water yields is warranted. TU feels this analysis is the responsibility of the permitting agencies. A 2 cfs diversion needs 10 complete days to divert 40 ac-ft. Reliability of annual diversion volumes can be as, or more, important than the actual annual yield in determining the viability of a project such as a vineyard. Therefore, the number of annual diversion days among a wide range of water year types is important to the water permit applicants. The more predictable the number of days, the more reliable the water source. The more predictable the number of days, the more users able to sustain their projects from the same total diversion volume. This aspect of water diversion also warrants more modeling of diverted annual hydrographs by the permitting agencies.

Generally, the SWRCB protocol (using a 20% maximum diversion rate) diverted the most, followed by TU, and then NMFS/CDFG. If storm runoff was low before December 15, the NMFS/CDFG protocol diverted more ac-ft than the TU protocol (e.g., in WY1981 in Elder Creek). For Dry Creek we used a Q_{act} with an exceedence probability of 8% rather than 10%. In Appendix 2, we also provide the unregulated annual hydrographs with their counterpart diverted hydrographs diverted using the three allocation protocols. You must squint to distinguish the differences between unregulated and diverted hydrographs. Using this scale of presentation only, one could easily conclude that none of the protocols are significantly affecting the unregulated hydrograph, and therefore are not harming salmon. But what seems like small changes in flow within the active channel actually create significant changes in average velocity and cumulative spawning habitat. Figure 38A illustrates a section of the WY1966 hydrograph at a closer scale. Diversions that appeared minor at the larger scale, now appear more significant. There is sufficient detail in Figure 38A and others (Figures 38B and 38C) for the reader to do her/his analysis, e.g., apply the MPD equation to assess migratory access (Figure 13) or apply the thalweg-drainage area regression (Figure 17). Diversions from the lower half of the recession limb and extended baseflows will have significant effects on anadromous salmonid habitat.

We are not proposing how much flow should be allocated for present and future use in given watersheds. This is missing from the SWRCB cumulative effects analysis, particularly because they provide no upper limit to diversions, as NMFS/CDFG and TU do. NMFS has criticized the original TU protocol (diverting only within the "Window") as not providing enough flow to water users. We were surprised that NMFS should be the agency determining this volume; we are unaware of how NMFS made this determination. Nevertheless, our protocol for small streams generally diverts more ac-ft annually than the NMFS/CDFG allocation protocol, while not jeopardizing salmon and steelhead spawning habitat.

7.1. Passive Enforcement

The TU protocol lends itself to passive enforcement better than the other protocols. Passive enforcement using the NMFS/CDFG or SWRCB protocol must somehow prevent diversions outside the Dec 15 to March 31 window. This will be extremely difficult to do, especially given the extent of past enforcement by SWRCB in the past. Perhaps a data logger on the pump could be installed to document which days the pump was turned on. These records would be part of an annual report. The TU protocol would not require annual reporting from a data logger.

If we haven't yet dispelled the misconception that Q_{act} is a much larger flow than the other bypasses, examination of any USGS rating curve is recommended. For Rock Creek, the difference in stage height between $0.6Q_{ave}$ and Q_{act} water surfaces was less than 0.5 ft. On smaller streams, this difference in stage height will be much less. Installation of an immobile pump intake/sump constructed anywhere within this elevational range would cost the same. TU feels strongly that licensed engineers should be required to document how the diversion elevation was determined and sign-off on their installation; in the case of Rock Creek, 0.5 ft does not leave much room for error. Documentation should require field measurements at a flow similar to the recommended bypass flow in order to back-calculate channel roughness. Engineers tend to under-estimate roughness in the Mannings Equation, thus usually overestimating discharge at a given stage height. This, in turn, will result in the inlet being installed at too low an elevation. Annual inspections documenting that the same elevation is still appropriate also should be required. A simple cross section at the intake, and at the downstream hydraulic control, would indicate if the local bed topography and/or local hydraulics have changed. Without an accountable procedure for estimating stage height for installing the intake (none of the agencies have specified one), TU could not support any allocation protocol based on a minimum bypass flow and maximum diversion rate. Including our own protocol.

Fill-and-spill reservoirs in the headwaters have a tremendous potential for causing cumulative downstream effects. SWRCB overlooks this problem, or claims the problem has been solved by requiring a very low minimum bypass flow that somehow is capable of protecting all fishery and riparian resources. In the May 2000 NMFS/CDFG DRAFT, the 10% maximum diversion (10% of the annual flow can be diverted) is not defensible or enforceable. We agree that many of the very small headwater diversions should not be subject to the same level of enforcement monitoring and documentation. However, these diversions must be accounted for in assessing overall cumulative watershed effects AND immediate downstream effects. TU will be commenting on this problem in the near future.

7.2. Hypotheses for Monitoring

A single bypass flow, based on an exceedence probability or median discharge for a specific month, cannot be applied to all watershed sizes. That is why TU limited its recommended minimum bypass flow to small watersheds 10 mi^2 or less. Even within this size range, we suspect the exceedence probability of the active channel flow changes with drainage area. An average exceedence probability of 10% was measured in small watersheds, but a positive correlation between exceedence probability of the active channel flow and drainage area exists. For Fox Creek with a drainage area of 1.07 mi^2, the active channel exceedence probability is likely closer to 8% than 10%. This would increase the active channel flow from 11 cfs to 13 cfs. Our analyses of MPD and spawning gravel depths showed the active channel would not be an adequate bypass flow for lower Fox Creek. Obviously, watersheds will become so small that unregulated active channel flow could not accommodate anadromous salmonids. Fortunately, we do not find anadromous salmonids in ALL watershed sizes. There must be a threshold watershed size where the hydrograph, combined with the hydraulic geometry, cannot accommodate these fish. In the South Fork Eel River drainage this threshold size must be near 0.5 mi^2. On the middle Russian River the threshold must be larger, probably closer to 1.0 mi^2 or 1.5 mi^2. Anadromous salmonids may use these very small watersheds only in the "good" years with overlapping flood hydrographs.

A necessary tool for our proposed methodology is a quantitative relationship between active channel discharge, exceedence probability, and all drainage areas for specific geographic regions. This should take no longer than one winter season to complete. We did not have sufficient analyses, in time for this commentary, to present a preliminary version of this regression model for active channel exceedence and drainage area for all watershed sizes, but could estimate it if pressed for the Russian River, Navarro River, and South Fork Eel River basins. In big watersheds, greater than 100 mi^2, the active channel is still present (though not as conspicuous as in small channels) but may be overtopped by flows more frequent than $p = 0.10$. This may help explain why Rantz and the PHABSM studies referenced by SWRCB (1997) predict that "optimum flows" in big watersheds occur at higher exceedence probabilities (i.e., near or less than Q_{ave} flows (approximately $p = 0.25$).

Cumulative spawning habitat must be mapped over its full range of spawning flows to estimate how much of the total habitat will be available up to a given flow. No "optimal" flow would be identified because no "optimal" flow exists in nature. TU will not support monitoring and analyses of spawning habitat based on the traditional approach of PHABSIM modeling. One water year with its unique flow regime may favor redds constructed near the thalweg early in the spawning season, while another water year may favor redds constructed far from the thalweg and late in the spawning season. Annual numbers of eggs successfully hatched will likely have nothing to do with the flow providing the most square feet of spawnable channelbed (i.e., the "optimal" flow). We expect the following trends in spawning habitat availability and abundance as watershed area decreases: (1) larger, less frequent flows (i.e., have a lower exceedence probability) will become increasingly important producers of spawnable habitat and (2) any single flow, including the "optimum" flow used by SWRCB, will account for less and less of the total available spawning habitat. There also is the implicit assumption of equally valuing the importance of each redd independent of the discharge at which a redd was created, and therefore where in the planform morphology the redd was constructed. The reality however is that not all redds are created equally and have the same opportunity for success. In large part their opportunity depends on chance and hydraulics, both highly dictated by a naturally variable hydrograph. Again, the flow producing the most square feet of spawnable channelbed probably rarely produces the most redds.

A call for broad-based monitoring is not the near-term solution (e.g., more streamflow gaging). Developing regional curves for the active channel discharge and maximum diversion rate can be done simply and expediently. Given the concept of "optimum flow" does not adequately identify variable flow requirements for diverse spawning habitat, TU will not consider a PHABSIM study acceptable. Monitoring often is an excuse to continue the status quo. We don't need further monitoring to tell us that minimum bypass flows unable to cover the backs of adult salmonids are adequate and capable of recovering populations. Do we need more data? Certainly, but not at the expense of allowing the SWRCB protocol or NMFS/CDFG protocol to continue unmodified. A workshop should be convened to outline an hypothesis-driven monitoring program founded on quantifiable objectives. TU is prepared to propose such a set of hypotheses and quantifiable objectives.

7.3. Unit Runoff Approach Is Flawed

As we presented at the January 31 meeting, the SWRCB runoff model does not account for a well known drainage area effect. Unit runoff (cfs/mi^2) typically is higher in smaller watersheds. The isohyetal contours for mean annual precipitation used by SWRCB (1997; 1998) are insensitive to local orographic effects (e.g., Figure 3 in Attachment A of SWRCB 1997 or Figure 4 in SWRCB 1998), thus under-predicting rainfall in the headwaters. The results of the basin modeling (SWRCB 1997) reflect this by predicting very similar unit runoff irrespective of drainage area. In Table 5 of Attachment A (SWRCB 1997), simple division of the predicted mean annual discharge (at the bottom of columns) by the drainage area (at the top of columns) provides only small changes in unit runoff among the watersheds analyzed, e.g., Mark West Creek (51.5 mi^2) was given the same unit runoff of 1.78 cfs/mi^2 as Mill Creek (2.5 mi^2).

Two consequences arise from this bias by SWRCB, and by NMFS/CDFG adopting this model in their May 2000 draft. First, recommendations for headwater streams based on an exceedence probability derived from the model (e.g., as by SWRCB) or from relatively large gaging stations (e.g., as by NMFS) will under-allocate bypass flows. This is particularly crucial in headwater streams where small projects can divert all winter runoff and only release a designated bypass flow. The water permit applicant is rewarded for this hydrological error: the additional unpredicted runoff goes to the applicant. This also means that any proposed guideline allowing "swale" diversions on Class III streams to be completely diverted, as the 10% diversion proposed by NMFS/CDFG does, will sanction more than 10% total annual flow diversion.

How significant is this error? We do not have sufficient synoptic data for the Russian River or Navarro River, but do have hydrologic data for the upper South Fork Eel River in Mendocino County (a county also included by NMFS/CDFG in their May Draft 2000). Synoptic discharges (flows measured at the same time over a range of drainage areas) during 3 baseflows were measured in watersheds ranging from 0.11 mi^2 (or 70 acres) up to 40 mi^2 (Figure 39). If the South Fork Eel River estimate (40 mi^2) for unit runoff was used to estimate discharge in the 0.11 mi^2 watershed, there would be a 15% to 20% underestimate of the small watershed's discharge. Elder Creek, at 6.5 mi^2, was sufficiently small to estimate discharges in the smaller watersheds, such as Fox Creek.

Limited gaging data in very small streams from the Russian and Navarro rivers actually show a reversed trend. Gaging stations on Soda Creek tributary (USGS Gaging Station No. 11467850 (DA = 1.53 mi^2) and Dry Creek tributary nr Hopland (USGS Gaging Station No. 11464050 (DA = 1.29 mi^2)) have lower unit runoff than nearby larger stations for the few years these stations' gaging records overlap. For example, Soda Creek tributary had a Q_{ave} for WY1967 of 2.55 cfs (1.67 cfs/mi^2) whereas nearby Rancheria Creek (USGS Station No. 11467800) with a drainage area of 65.6 mi^2 had a WY1967 Q_{ave} unit runoff of 3.13 cfs/mi^2). There may be several plausible explanations for this phenomenon.

Because basic uncertainties in hydrology have been overlooked, neither SWRCB nor NMFS/CDFG has adequately analyzed and validated their proposed flow allocation methodologies. The changing shape of the daily average flow duration, becoming more concave with smaller drainage area, will greatly affect flow estimates for given exceedence probabilities. For example (as discussed in the January 31st 2000 meeting), Q_{feb} can be a zero flow in very small watersheds (probably in 0.15 mi^2 and smaller, or approximately 100 acres and smaller) and on larger watersheds be essentially equivalent to Q_{ave}.

The refinement of daily average flow duration curves is minor relative to over-riding deficiencies of the SWRCB and NMFS/CDFG minimum bypass flows for protecting salmon spawning habitat. A more accurate forecast of the flow rate at Q_{feb} or $0.6Q_{ave}$ will not provide better protection to salmon and steelhead.

7.4. A Contemporary Example of TU's Concerns: Gird Creek

SWRCB (1997) lists Gird Creek as a 3.27 mi^2 watershed with a Q_{ave} of 5.56 cfs (1.70 cfs/mi^2) that supports 2 miles of steelhead habitat (US Army Corps 1978: *Evaluation of Fish Habitat and Barriers to Fish Migration: Russian River Mainstem and Lower Dry Creek).* In the application (30259) requesting 42 ac-ft of annual storage from an Unnamed Stream tributary to Gird Creek, 185 acres would be impounded above the point of diversion (POD). On a page titled *Flow Calculation and Comparison for A30259 (Galef),* the table provides watershed areas at several key locations: Above the POD (185 acres), the Unnamed Tributary (312 acres), the Critical Reach (1098 acres), and for entire Gird Creek (11607 acres). However, the acreage reported for the entire watershed is for an 18.12 mi^2 watershed, not 3.27 mi^2 as reported in SWRCB (1997). Is this a typographic error? It isn't a misplaced decimal point. The flow estimates for the entire watershed also are incorrect. At 1.70 cfs/mi^2 (using the SWRCB model)(Why does SWRCB use the Maacama Creek gage rather than their model?), 0.60Q_{ave} is 3.34 cfs (not 18.03 cfs). We will assume the other acreage estimates are correct; the flow estimates are consistent.

Annual average runoff from 185 acres (1.92 ac-ft per acre) would be approximately 355 ac-ft. For entire Gird Creek, the annual average runoff (unregulated) is 4018 ac-ft. Therefore, the percentage of unregulated runoff affected (diverted and delayed) is 355 ac-ft/4018 ac-ft * 100 = 8.8% relative to the entire watershed. But is the entire watershed's annual average runoff the appropriate denominator? Should annual average runoff from the watershed area of the Unnamed Tributary of 312 acres be the denominator, i.e., 355 ac-ft/599 ac-ft, or 59%. Or should we only be considering the onset of steelhead habitat, presumably at the top of the critical reach (1098 acres), i.e., 355 ac-ft/2108 ac-ft, or 16.8%. Where did SWRCB select to evaluate cumulative effects? Where did CDFG/NMFS select to evaluate cumulative effects? If this diversion is approved, how close is this watershed (or where within) to being over-allocated? How did the agencies factor the storage capacity of the reservoir into their cumulative effects analyses? With fill-and-spill reservoirs one never is sure how (duration, timing, frequency, and magnitude) daily flows pass through when salmon are primed to migrate and spawn. For salmonids, the volume is not as important as the effect of the diversion on the flood hydrograph particularly for these small flashy streams. This is why we, at the first stage of analysis, considered total runoff from the impounded acreage rather than the ac-ft to be diverted, in our cumulative effects analysis, i.e., we use 355 ac-ft rather than 42 ac-ft in the numerator of our ratio.

A key location, given the focus on salmonids, is at the top of the critical reach. If an early season flood occurs, can steelhead migrate and spawn in the mainstem without the contributing influence of 185 acres upstream? Using the NMFS/CDFG protocol the maximum diversion rate would be approximately 2 cfs. Would the impounded 185 acre watershed have contributed more than 2 cfs during the flood event? During the middle portion (and well above the minimum bypass Q_{feb}) of a flood event, 15 cfs per mi^2 is typical (refer to annual hydrographs for Dry Creek Tributary (1.27 mi^2)), or 0.023 cfs/acre (15 cfs/640 acres). For a 185 acre watershed this equates to 4.26 cfs. Therefore, according to the NMFS/CDFG protocol this application would likely exceed the maximum diversion rate early in the season (before their diversion window of December 15) and occasionally later. Did NMFS and/or CDFG voice a concern on the field inspection? This impounded acreage represents 16.8% of the watershed area above the critical reach. Using the proposed NMFS/CDFG guideline of 10% diversion (109.8 acres)(NMFS/CDFG May 3, 2000 DRAFT provision #7), the lost cfs during the same event would be 3.40 cfs, again higher than their maximum diversion rate. Therefore, if NMFS/CDFG applied their 10% diversion guideline, they would be contradicting other requirements of their allocation protocol.

How can 0.03 cfs protect fishery resources in the Class II channel below the POD? Clearly, the minimum bypass flows for this Class II channel below the POD must maintain riparian values. How can SWRCB justify 0.02 cfs or 0.03 cfs bypass flows, when these flow estimates are based only on fish requirements? Would 0.03 cfs flowing down this Class II channel qualify as "not dewatered" using the May 2000 NMFS/CDFG Draft guidelines? For a minimum bypass flow of 0.6Q_{ave} at the critical reach (using their estimate of 1.86 cfs), the typical riffle depth will be 0.36 ft (4.4 inches, 11 cm). For a minimum bypass flow of Q_{feb} at the critical reach (using SWRCB's estimate of 3.61 cfs), the typical riffle depth will be 0.41 ft (4.9 inches, 12.4 cm). Neither of these is remotely adequate for maintaining anadromous salmonid habitat. Given the small size of this watershed and its location in the Russian River, no minimum bypass flow would be adequate. The fish need portions of the flood hydrograph in order to migrate, spawn, and possibly emigrate. This makes the cumulative effects analysis, we just crudely went through, all that more critical.

8. SUMMARY

This commentary addresses only small watersheds; but this does not infer that TU supports either the SWRCB or NMFS/CDFG allocation protocol being applied to larger watersheds. Because larger watersheds are comprised of many smaller watersheds, our size limitation of 10 mi^2 probably encompasses most of the stream channels supporting steelhead and coho. Rantz found a strong drainage area effect in his smallest sampled watershed of 16.2 mi^2. We suspect the active channel flow is not met by the SWRCB or NMFS/CDFG minimum bypass flow for watersheds up to 20 mi^2 and probably larger. Without an analysis, instead relying on basic field instinct and experience, a significant portion (greater than 50%) of the total available habitat to anadromous salmonids is found upstream of 20 mi^2 drainage areas. Neither the SWRCB nor the NMFS/CDFG minimum bypass flow is appropriate for most steelhead and coho habitat in the Russian, Navarro, and South Fork Eel rivers.

The same frequency of flow in different sized watersheds does not provide the same flow depths or velocities, and therefore cannot supply the same relative portion of the total spawning habitat available in unregulated channels. A spatial scale must be factored into any minimum bypass flow recommendation that is predicated on an exceedence probability picked off a daily average flow duration curve. As we have shown, all three proposed bypass flows suffer from this scale problem to varying degrees: the SWRCB minimum bypass suffers the worst and the TU minimum bypass suffers the least. The administrative desire to keep any allocation procedure simple is tempting. Unfortunately, the "one size fits all" bypass flows recommended by SWRCB and NMFS/CDFG ignore spatial scale. Both will result in significant loss of anadromous salmonid spawning habitat and seriously impede migration in small streams whenever either is implemented.

NMFS (2000) states (p.11) that: *A suitable bypass flow standard should allow fishes to move upstream through riffle habitats during the spawning and incubation period, if winter baseflows historically facilitated such movements.* But the NMFS/CDFG minimum bypass flow for small watersheds does not sustain favorable migratory or spawning conditions for anadromous salmonids in watersheds less than 10 mi^2, and probably larger, anywhere throughout Northern California. If the maximum diversion rate and minimum bypass flow are applied jointly, the NMFS/CDFG protocol still does not sustain favorable spawning conditions for anadromous salmonids in watersheds less than 10 mi^2. NMFS (2000) also states (p.19) that: *Comparisons of February median flow and 60% mean annual flow on historic winter hydrographs suggest that a February median flow provides appreciably more protection to sensitive salmonid spawning habitats than the 60% mean annual standard.* We have shown this is not the reality for small watersheds: the February median flow (Q_{feb}) is often only marginally deeper than the SWRCB minimum bypass flow ($0.60Q_{ave}$), and both are well below an acceptable minimum depth. TU believes that preventing flows in the active channel from being diverted is a key first step toward maintaining and recovering anadromous salmonid populations. However, the TU minimum bypass flow will not sustain favorable spawning conditions for very small watersheds, probably less than 1.5 mi^2 for the South Fork

Eel River tributaries and less than 3.5 mi^2 for Russian River tributaries. If the maximum diversion rate and minimum bypass flow are applied jointly, the TU protocol still could not sustain favorable spawning conditions for anadromous salmonids in very small watersheds less than 1.0 mi^2 for South Fork Eel River tributaries and less than 2.5 mi^2 for Russian River tributaries. Both watershed areas (for the Russian and South Fork Eel river basins) are probably near the lower watershed size threshold for supporting anadromous salmonid populations.

No minimum bypass flow can protect salmonid habitat on the smallest watersheds supporting anadromous fish. Anadromous salmonids need the flood hydrograph in order for these populations to persist. The "one-size-fits-all" bypass flow adopted by SWRCB and NMFS/CDFG defies geomorphic and ecological commonsense. TU effectively dodges this criticism by limiting this report to watersheds less than 10 mi^2. A 10% exceedence probability for the active channel should be appropriate up to at a 20 mi^2 watershed until more field studies are available. Larger watersheds may have a more frequent exceedence probability (i.e., a higher exceedence probability). However on very small watersheds, the size dependent on annual precipitation and geomorphology, the exceedence will be less frequent than TU recommends, e.g., a 7% exceedence probability for a 1 mi^2 watershed in the South Fork Eel River basin. Therefore, TU recommends that a quantitative relationship between active channel flow and drainage area be developed, this coming water year, for specific regions. Also on very small watersheds supporting salmonids and Pacific lamprey (or immediately upstream of salmonid habitat), the maximum diversion rate may need to be reduced to a 0.25 day alteration of the active channel flow rather than 0.5 days.

The NMFS/CDFG proposed allocation strategy, a better allocation strategy than the SWRCB protocol, still seriously jeopardizes anadromous salmonids in watersheds less than 10 mi^2. With no methodology, NMFS was no way to account for spatial scale. NMFS needs to quantitatively justify how a 50% loss of spawning habitat (and greater) and significantly reduced minimum passage depths can sustain, let alone recover, anadromous salmonid populations in small watersheds. Up till now (including their May 2000 NMFS/CDFG DRAFT), NMFS has provided no data justifying any quantitative recommendation (e.g., the Q_{feb} minimum bypass). We have shown that an "analysis" cannot be comprised of visually comparing hydrographs modeled after different diversion protocols. Biological significance cannot be inferred from flow duration analyses without supporting hydraulic data and objective thresholds (as attempted in NMFS 2000).

For the water years modeled, the TU protocol usually allocated more ac-ft than the NMFS protocol, and occasionally more than the SWRCB protocol (using a 20% diversion rate). TU "broke" the rules by rejecting the December 15 to March 31 diversion window adopted by SWRCB. We did so because the original concept was: (1) too flawed to work: accommodate migration before December 15, then accommodate spawning thereafter, (2) widespread use of fill-and-spill reservoirs, and the ongoing approval of these diversion structures by SWRCB, makes this diversion window illusionary, and (3) adequate enforcement of a diversion window is highly unlikely given SWRCB's lack of past enforcement. NMFS/CDFG could also reject the December 15 to March 31 diversion window. A similar change in their protocol would provide more diversion than TU's protocol. But it would also extend the habitat damage and call into question NMFS/CDFG's primary motive behind their proposed protocol. If NMFS felt that their protocol provides sufficient flow to the diverters (and we have been told by them that they do), why not adopt a protocol adapted to Northern California's small streams that (1) uses a minimum bypass flow that can be seen and measured as the active channel, (2) affords considerably greater habitat protection, (3) incorporates spatial scale effects, (4) is easier to implement (no diversion period needed), (5) is derived in part from their own data (the MPD curve) and recommended thresholds (passage depth minimums), (6) generally allocates more annual diversion, and (7) is founded on real field data?

How hard would it be to implement the TU protocol? A key component is identification of the active channel. There is no great body of scientific literature documenting what is obvious in the field. We spent one day in the field showing Simpson Timber fisheries biologists how to identify the active channel in their stream monitoring program. They had no problem identifying it. However, we DO NOT propose each water permit application have its own determination of where the active channel stage height is, or what discharge and exceedence probability it might be. A regional relationship must be developed between drainage area and Q_{act}. This would require one winter season of cooperative stream channel measurements among the agencies and public. TU could offer a preliminary relationship before this winter season begins. A water user could then simply determine the drainage area at the point of diversion and use the regional curve to estimate the minimum bypass flow. A water user could contest the estimate by quantitatively demonstrating a more protective minimum bypass flow or overall allocation protocol. With a regional curve, the TU protocol would require no hydrological analyses by the water user or the permitting agency. A similar regional curve can easily be developed for estimating our maximum diversion rate as a function of drainage area.

Claims that NMFS/CDFG or SWRCB protocols are more reproducible than TU's protocol are false. An hydrologist can show that the median February flow is LESS THAN the SWRCB's $0.6Q_{ave}$ flow in very small streams. "Reproducible" is not consistently picking the same exceedence off a daily average flow duration curve. Any arbitrary exceedence probability using this criterion, such as for NMFS's diversion rate and minimum bypass flow, would be considered "reproducible." A protocol that is consistent must provide consistent protection for salmon and steelhead among all watershed sizes. We have shown that for the South Fork Eel River an exceedence probability of 10% does provide consistent protection for small watersheds less than 10 mi^2 down to approximately 1.5 mi^2. A regional curve for active channel flows and their estimated exceedence probabilities will provide the consistent protection other protocols lack.

If one does not trust our active channel approach, then a minimum bypass flow can be recommended for streams with watersheds less than 10 mi^2 that simply provides a specified minimum depth, e.g., 1.0 ft or 0.8 ft as discussed in our report. This approach, though considerably weaker than TU's, doesn't require adopting the active channel concept. No agency has answered this straightforward question: How deep are the $0.60Q_{ave}$ and Q_{feb} minimum bypass flows in a 3 mi^2 watershed? Yet each reassures the public their protocol protects salmon and steelhead. TU wants a scientific approach to developing and demonstrating an allocation protocol that can protect and recover salmon and steelhead in Northern California. SWRCB science has offered a flawed, overly simplistic analysis of a few PHABSIM studies from relatively large watersheds. SWRCB has offered no objective protocol for assessing cumulative downstream impacts. NMFS and CDFG have offered no quantitative analyses of flow depths for the minimum bypass flow. TU has proposed an allocation protocol, specific to small watersheds based on field data and quantitative analyses, for preventing a take on threatened salmon and steelhead populations and allowing recovery.

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Table 2. Cumulative spawning habitat loss (%) attributable to each proposed diversion protocol for a Rock Creek flood hydrograph, South Fork Eel River Basin.

		Diverted Hydrograph			Minimum Passage Depths (ft)				Percent of Total Habitat Made Unavailable		
Date	Unregulated Discharge	SWRCB	NMFS	TU	Unregulated	SWRCB	NMFS	TU	SWRCB	NMFS	TU
8-Feb-85	93	86	88	84	>1.5	>1.5	>1.5	>1.5	0	0	0
9-Feb-85	52	45	47	43	>1.5	1.24	1.49	1.42	5	1	2
10-Feb-85	33	25	27	31	1.14	0.74	0.99	1.1	75	10	2.3
11-Feb-85	25	17	19	25	0.94	0.54	0.79	0.94	85	45	0
12-Feb-85	23	15	17	23	0.9	0.5	0.75	0.9	90	56	0
13-Feb-85	20	12	16	20	0.82	0.5	0.72	0.82	86	43	0
14-Feb-85	18	10	16	18	0.77	0.5	0.72	0.77	83	33	0
15-Feb-85	16	8	16	16	0.72	0.5	0.72	0.72	75	1	0
16-Feb-85	15	7	15	15	0.69	0.5	0.69	0.69	73	0	0
17-Feb-85	13	7	13	13	0.65	0.5	0.65	0.65	60	0	0
18-Feb-85	12	7	12	12	0.62	0.5	0.62	0.62	57	0	0
19-Feb-85	11	7	11	11	0.6	0.5	0.6	0.6	51	0	0
20-Feb-85	10	7	10	10	0.57	0.5	0.57	0.57	47	0	0
21-Feb-85	10	7	10	10	0.56	0.5	0.56	0.56	0	0	0
22-Feb-85	9	7	9	9	0.55	0.5	0.55	0.55	0	0	0

Table 3. Modeled annual diversion volumes (ac-ft) from Elder Creek (6.5 mi^2) and Fox Creek (1.07 mi^2), both South Fork Eel River tributaries, in WY1980 through WY1989 for each proposed allocation protocol.

Elder Creek nr Branscomb (USGS Station 11-475560); DA= 6.5 mi^2

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Average	Min	Max
SWRCB Annual Allocation (af)	2,753	2,014	2,503	3,309	2,240	811	2,461	2,347	1,352	2,081	2,187	811	3,309
NMFS/CDFG Annual Allocation (af)	1,434	937	1,340	2,304	1,184	313	1,505	1,123	574	941	1,166	313	2,304
TU Annual Allocation (af)	1,093	355	2,471	3,447	1,515	565	1,438	530	978	904	1,330	355	3,447

Fox Creek (modeled from Elder Creek); DA= 1.07 mi^2

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1984.5	1980	1989
SWRCB Annual Allocation (af)	452	331	411	544	368	133	404	368	222	342	358	133	544
NMFS/CDFG Annual Allocation (af)	235	154	220	377	194	51	247	184	94	154	191	51	377
TU Annual Allocation (af)	181	59	408	568	250	94	237	87	161	150	220	59	568

1.0 ft Minimum Passage Depth		
Minimum Bypass Flow	***SF Eel River Basin***	***Russian River Basin***
TU	2.5 mi^2	6.6 mi^2
NMFS/CDFG	5.1 mi^2	13.1 mi^2
SWRCB	11.4 mi^2	23.9 mi^2

0.8 ft Minimum Passage Depth		
Minimum Bypass Flow	***SF Eel River Basin***	***Russian River Basin***
TU	1.8 mi^2	4.7 mi^2
NMFS/CDFG	3.7 mi^2	9.4 mi^2
SWRCB	8.2 mi^2	17.2 mi^2

0.6 ft Minimum Passage Depth		
Minimum Bypass Flow	***SF Eel River Basin***	***Russian River Basin***
TU	1.0 mi^2	2.8 mi^2
NMFS/CDFG	2.1 mi^2	5.5 mi^2
SWRCB	4.8 mi^2	10.0 mi^2

Table 1. Threshold watershed size (mi^2) for each proposed minimum bypass flow based on 1.0 ft, 0.8 ft, and 0.6 ft minimum criteria for the South Fork Eel River Basin and Russian River Basin.

Table 4. Modeled annual diversion volumes (ac-ft) from Franz Creek sub-watersheds (6.5 mi^2 and 1.07 mi^2) in WY1964 through WY1968 and from an unnamed Dry Creek Tributary (1.27 mi^2) in WY1968 and WY1969 for each proposed allocation protocol.

Franz Creek Tributary (modelled) 6.5 mi^2

	1964	1965	1966	1967	1968	Average	Min	Max
SWRCB *Annual Allocation (af)*	123	484	651	490	621	474	123	651
NMFS/CDFG Annual Allocation (af)	85	334	449	353	425	329	85	449
TU Annual Allocation (af)	184	566	565	1130	570	603	184	1,130

Franz Creek Tributary (modelled) 1.07 mi^2

	1964	1965	1966	1967	1968	Average	Min	Max
SWRCB *Annual Allocation (af)*	20	80	108	81	103	78	20	108
NMFS/CDFG Annual Allocation (af)	14	55	74	58	71	54	14	74
TU Annual Allocation (af)	26	82	81	163	82	87	26	163

Dry Creek Tributary 1.27 mi^2

	1968	1969				Average	Min	Max
SWRCB Annual Allocation (af)	203	304				254	203	304
NMFS/CDFG Annual Allocation (af)	56	126				91	56	126
TU Annual Allocation (af)	50	121				86	50	121

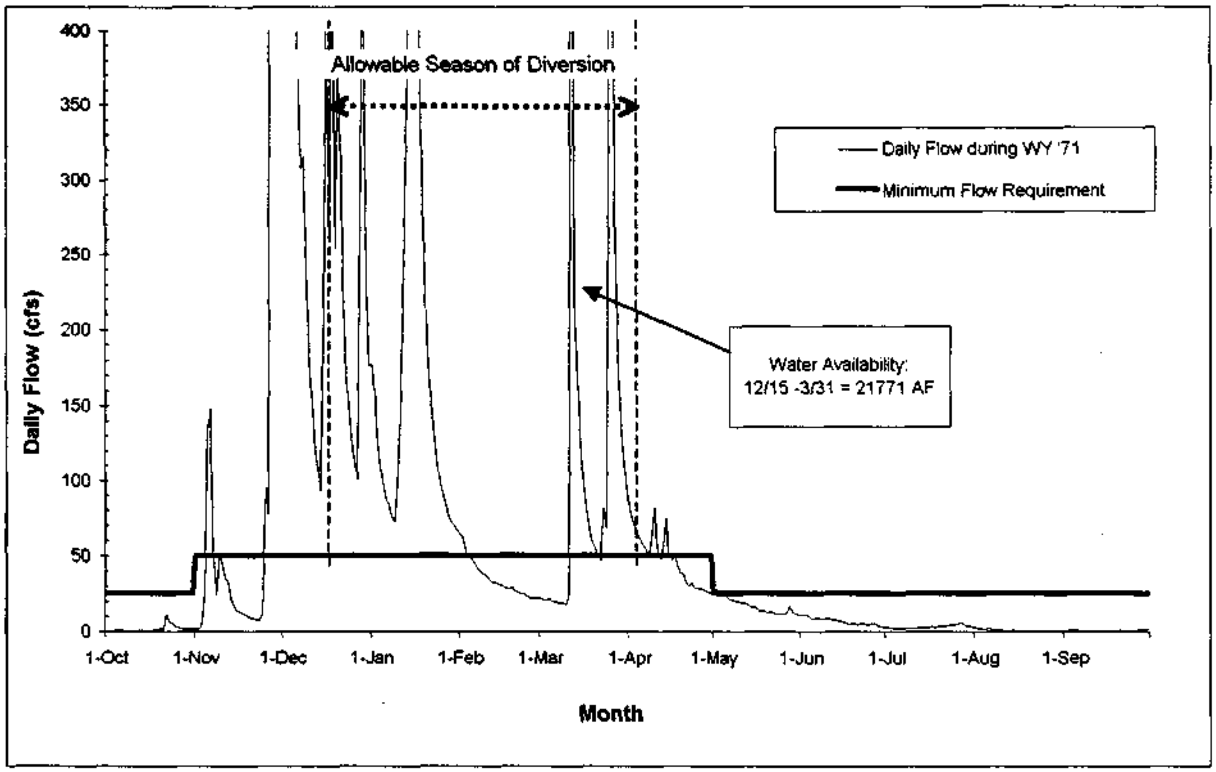


Figure 1. Reprint of Figure 10b (p. 34) of the *SWRCB Staff Report* (SWRCB 1997): "Water availability and fish flow requirements in Maacama Creek near Kellogg, for average water year conditions." The "Allowable Season of Diversion" is shown from December 15 to March 31 and the "Minimum Flow Requirement" represents the SWRCB 0.6Q_{ave} minimum bypass flow.

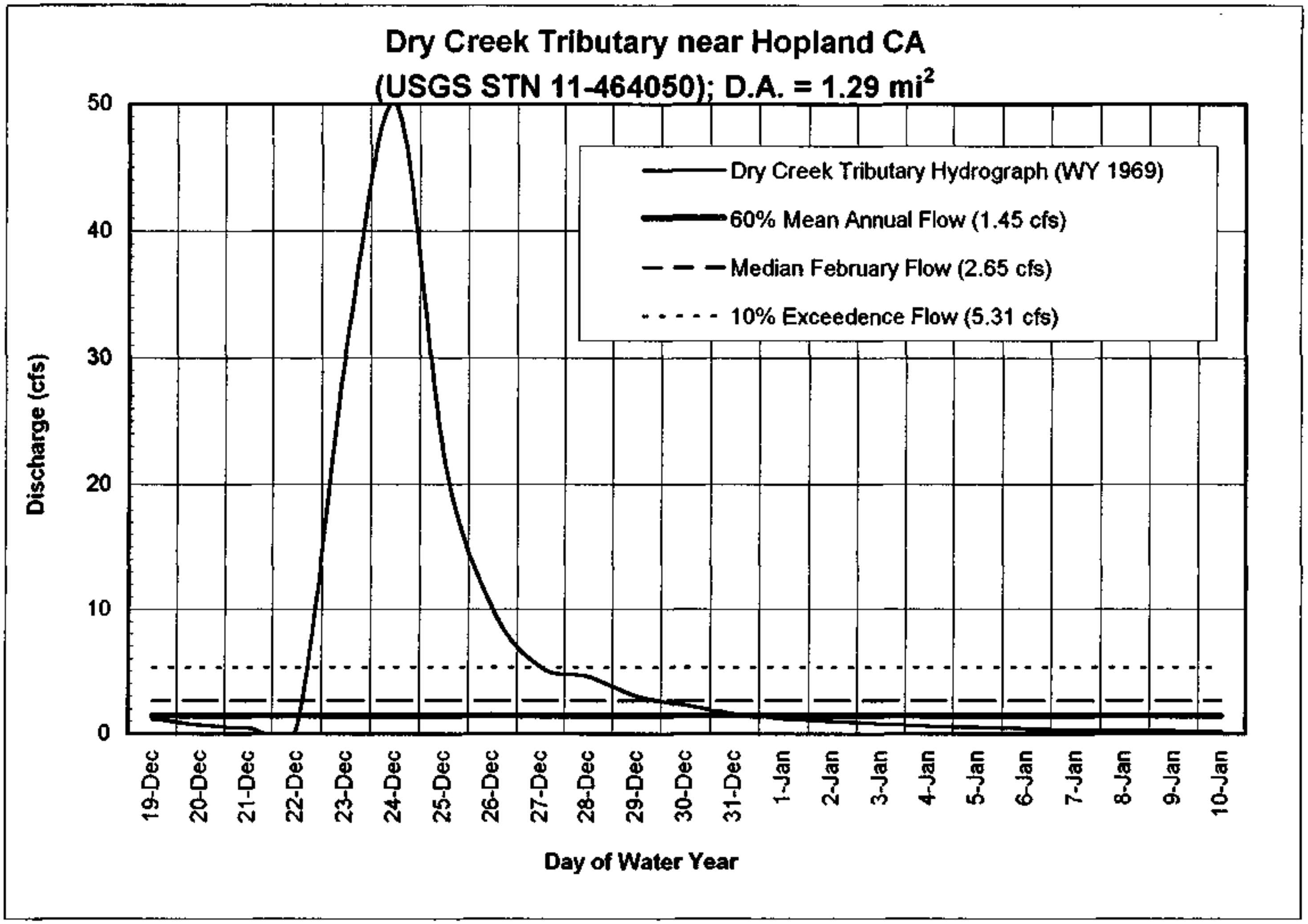


Figure 2. Flood hydrograph for an unnamed tributary to Dry Creek nr Hopland (U.S.G.S. Gaging Station No. 11464050) in the Russian River Basin with proposed SWRCB, NMFS/CDFG, and TU minimum bypass flows.

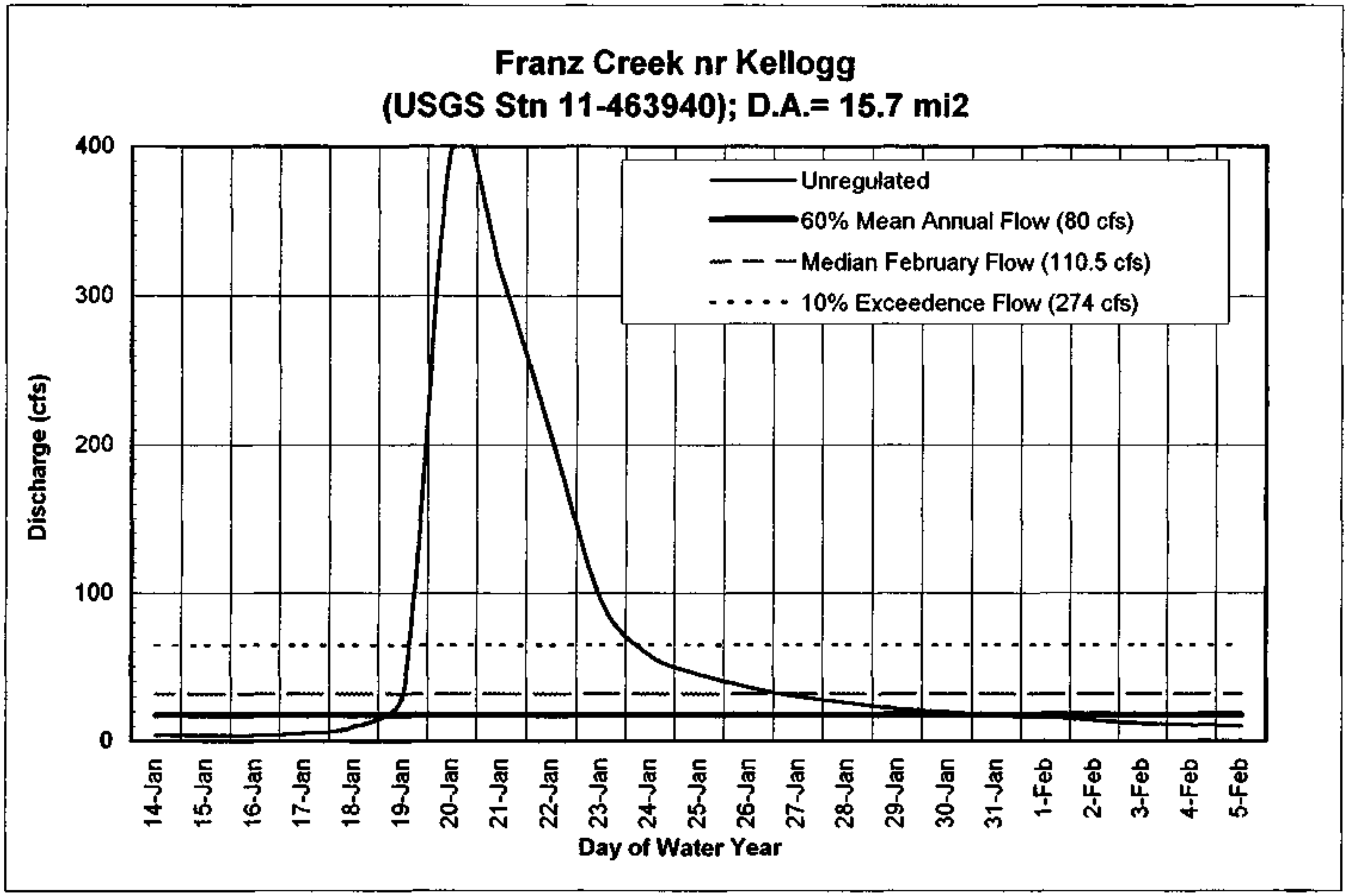


Figure 3. Flood hydrograph for Franz Creek (U.S.G.S. Gaging Station No. 11463940 Franz Creek nr Kellogg) in the Russian River Basin with proposed SWRCB, NMFS/CDFG, and TU minimum bypass flows.

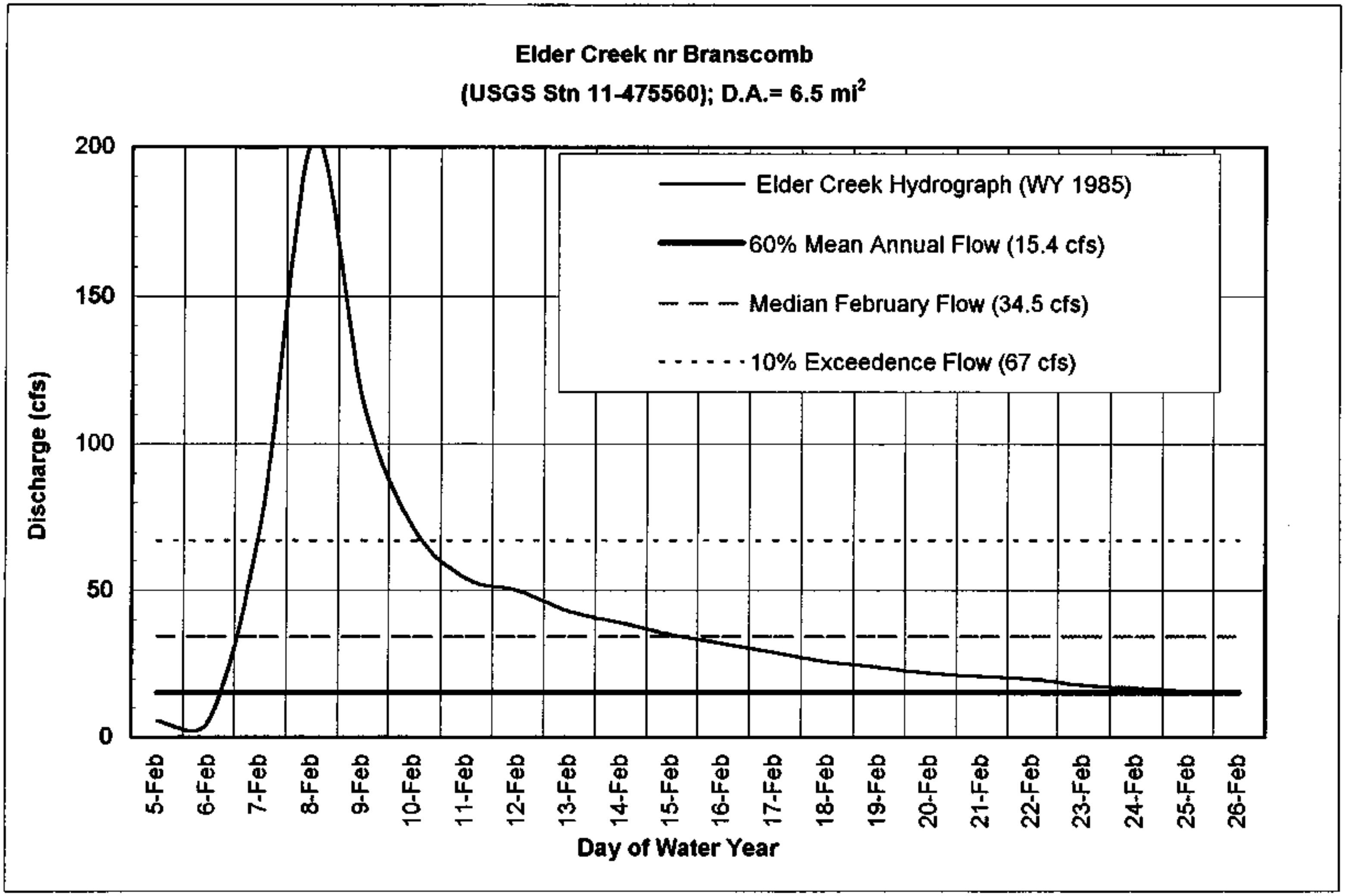


Figure 4. Flood hydrograph for Elder Creek (U.S.G.S. Gaging Station No. 11475560 Elder Creek nr Branscomb) in the South Fork Eel River Basin with proposed SWRCB, NMFS/CDFG, and TU minimum bypass flows.

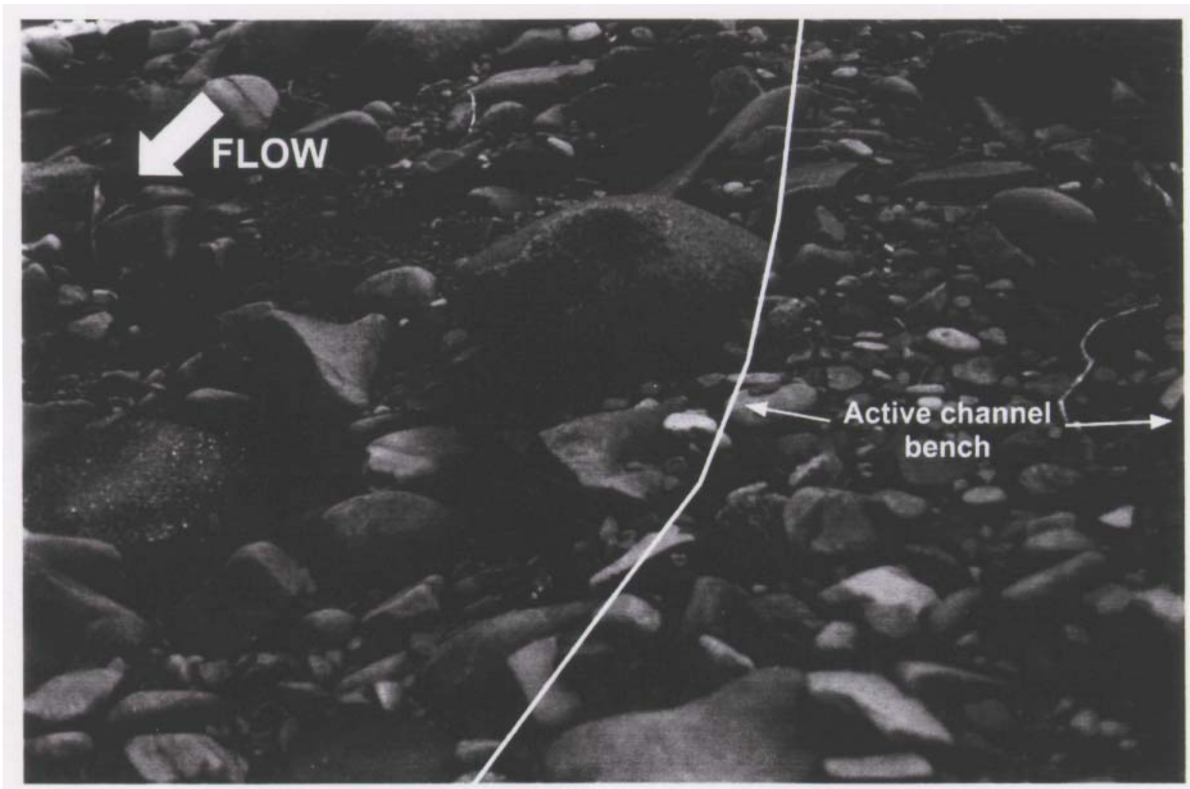


Figure 5. An active channel bench on Elder Creek, South Fork Eel River Basin. The large boulder in the center is 1.5 feet across.

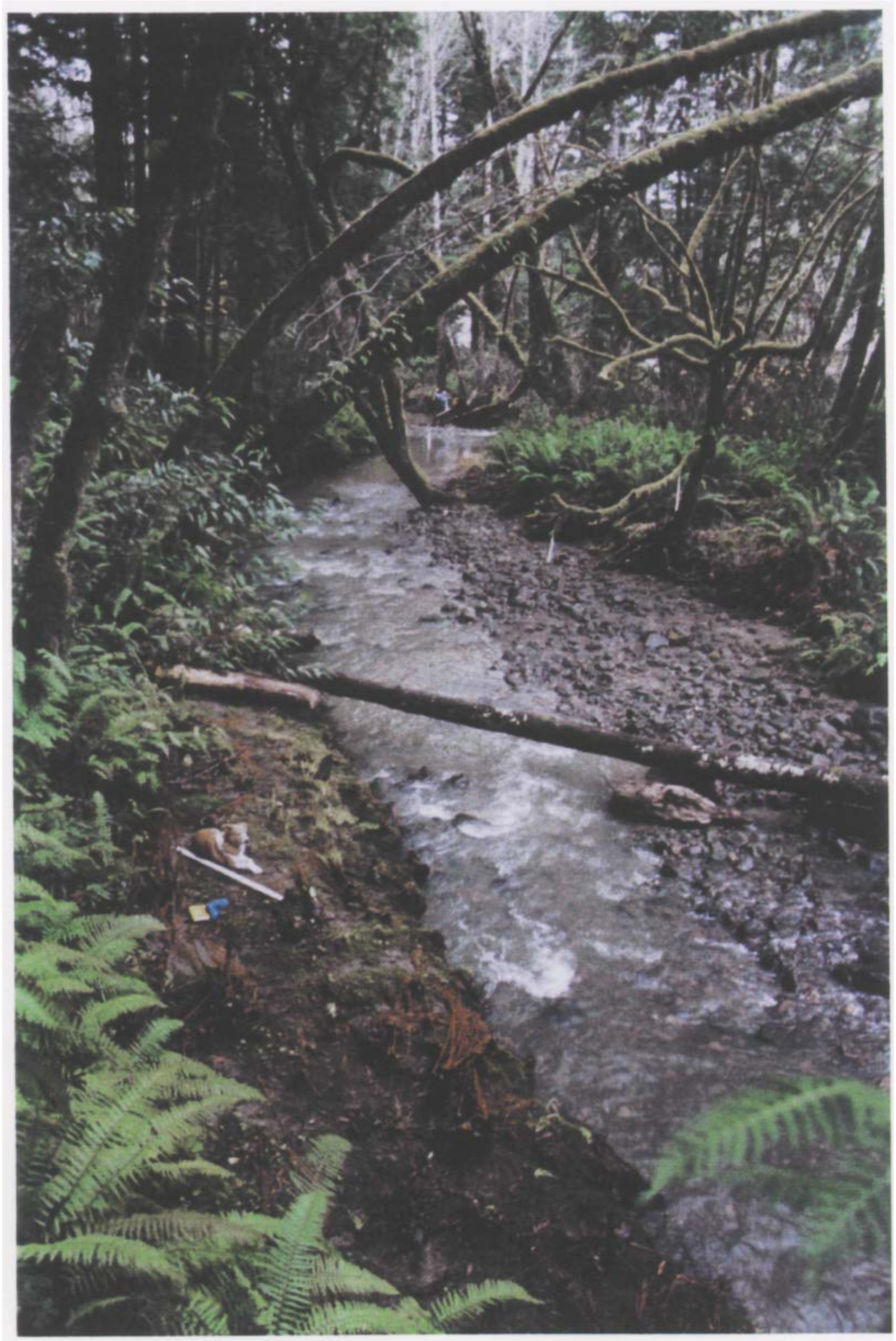
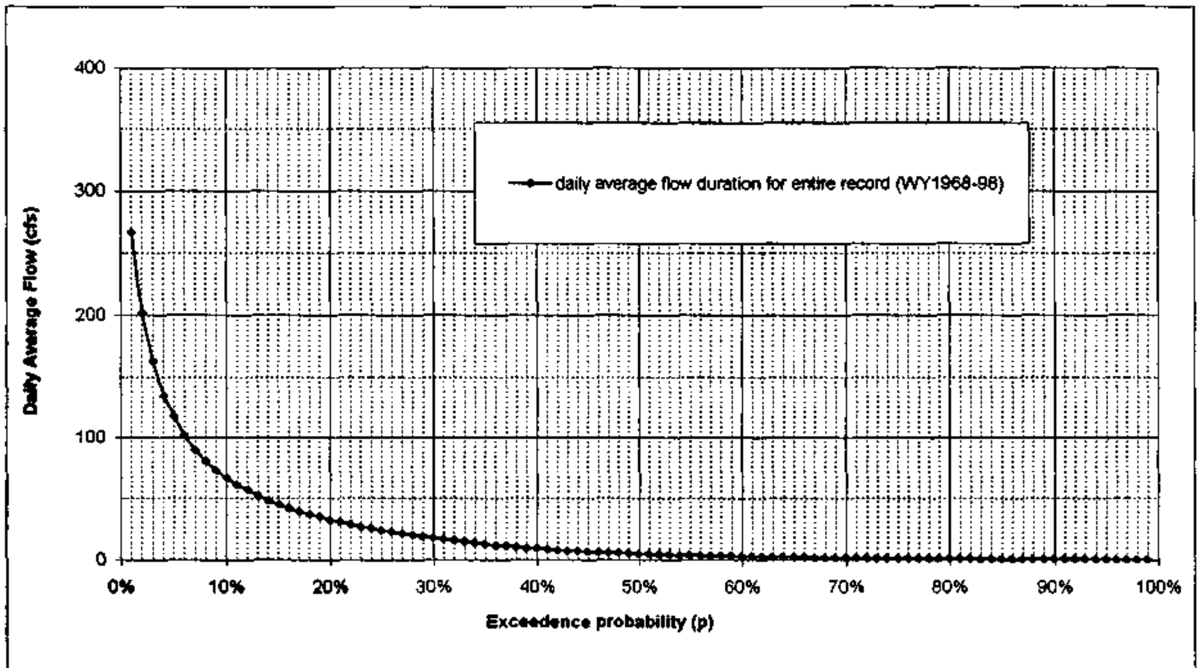
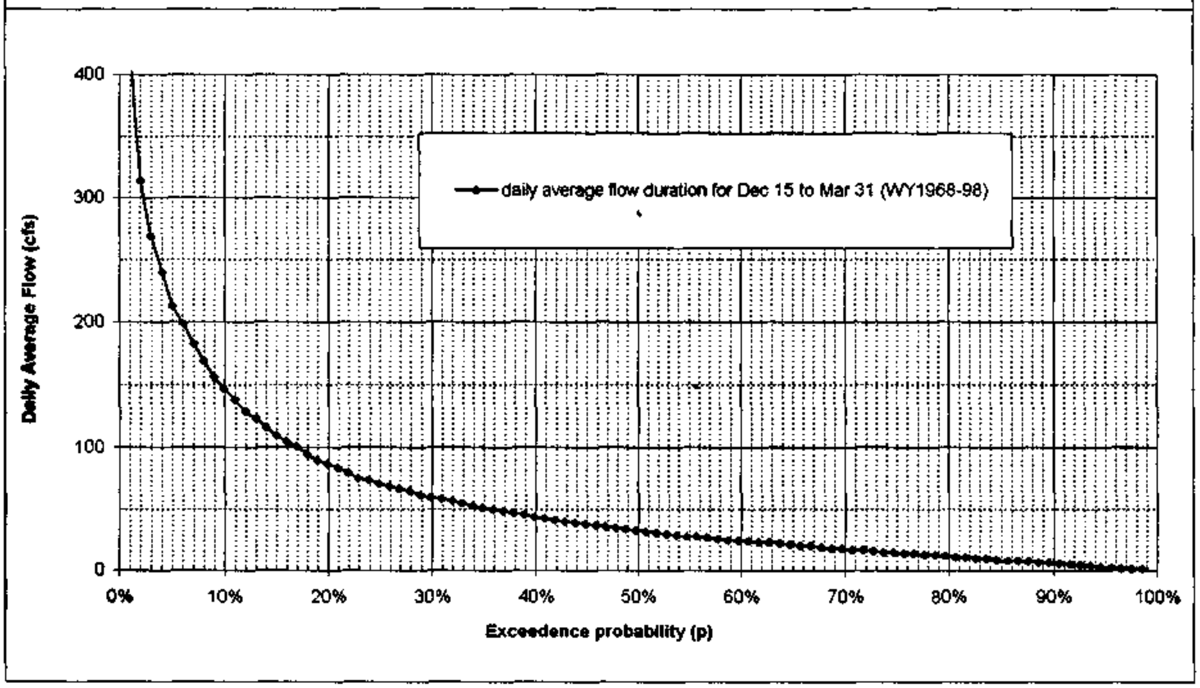


Figure 6. Bob sitting on an active channel bench in Sullivan Gulch, Mad River Basin.





Mean Annual Flow =	24.2 *cfs*
60% Mean Annual Flow =	*14.5 cfs*
Median February Flow =	*32.0 cfs*
10% Exceedence Flow =	*67.0 cfs*
Winter (Dec 15-Mar 31) 20% Exceedence Flow =	*87.0 cfs*
Winter (Dec 15-Mar 31) 40% Exceedence Flow =	*44.0 cfs*

Figure 8. Daily average flow duration curve for Elder Creek (U.S.G.S. Gaging Station No. 11475560 Elder Creek nr Branscomb) for WY1968 through WY1998. Drainage area = 6.5 mi^2.

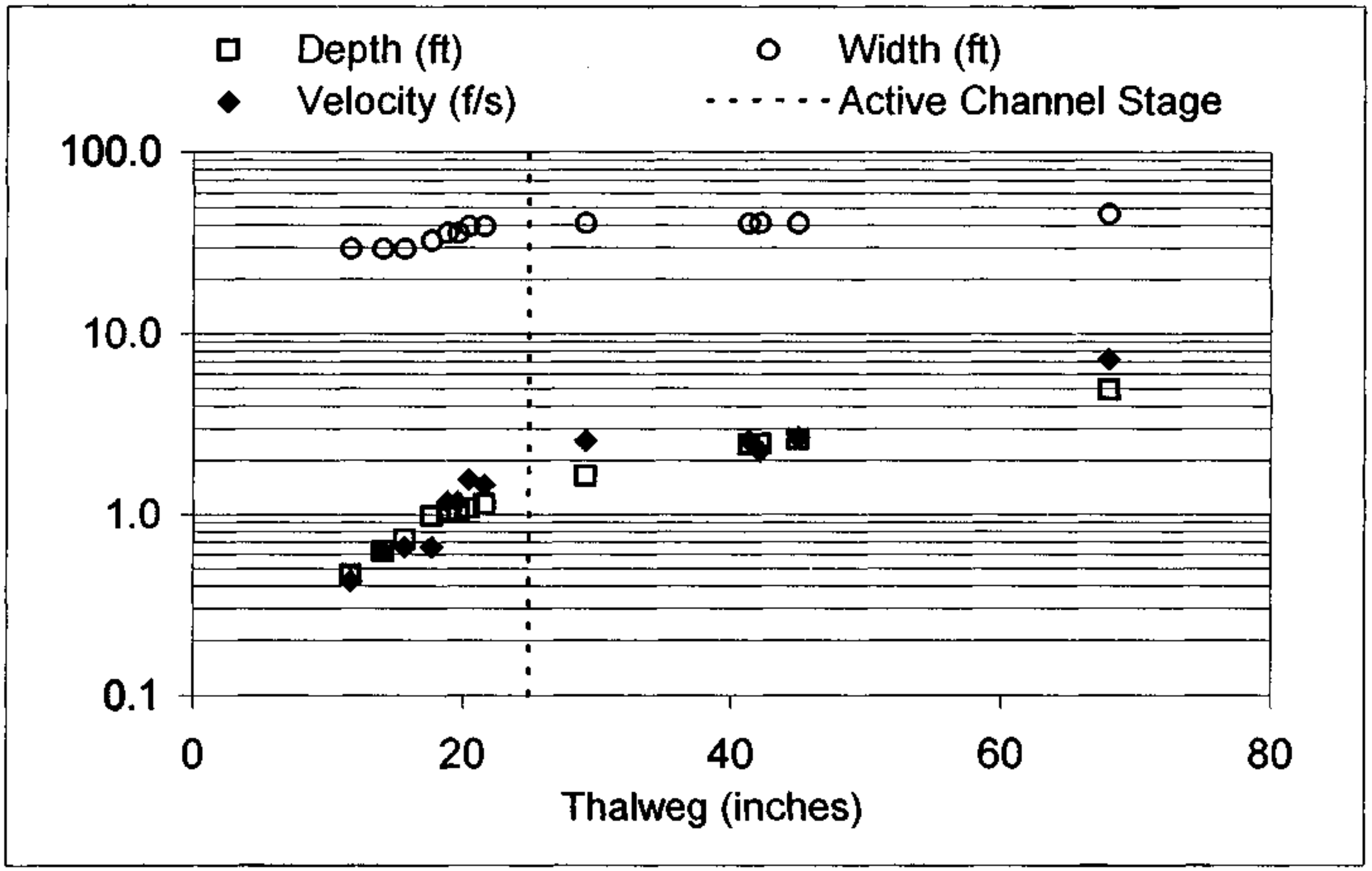


Figure 10. Hydraulic geometry for Spawner Riffle on Elder Creek. A sharp break in slope for average velocity (ft/sec) and depth (ft) occurs at a stage height corresponding to 65 cfs (the top of the active channel); channel width (ft) remains relatively unchanged.

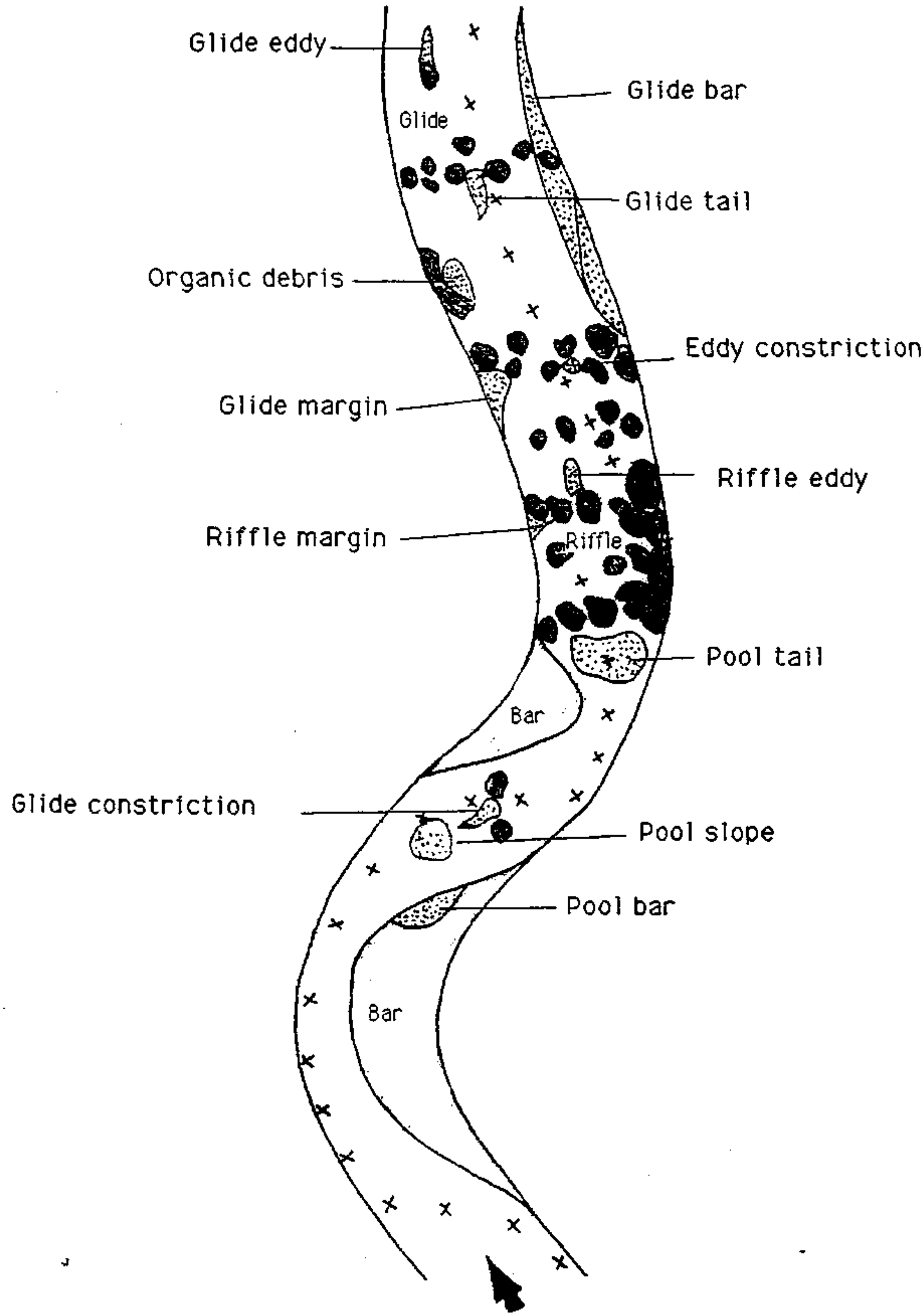


Figure 11. Spawning habitat types in Elder Creek (Trush 1989).

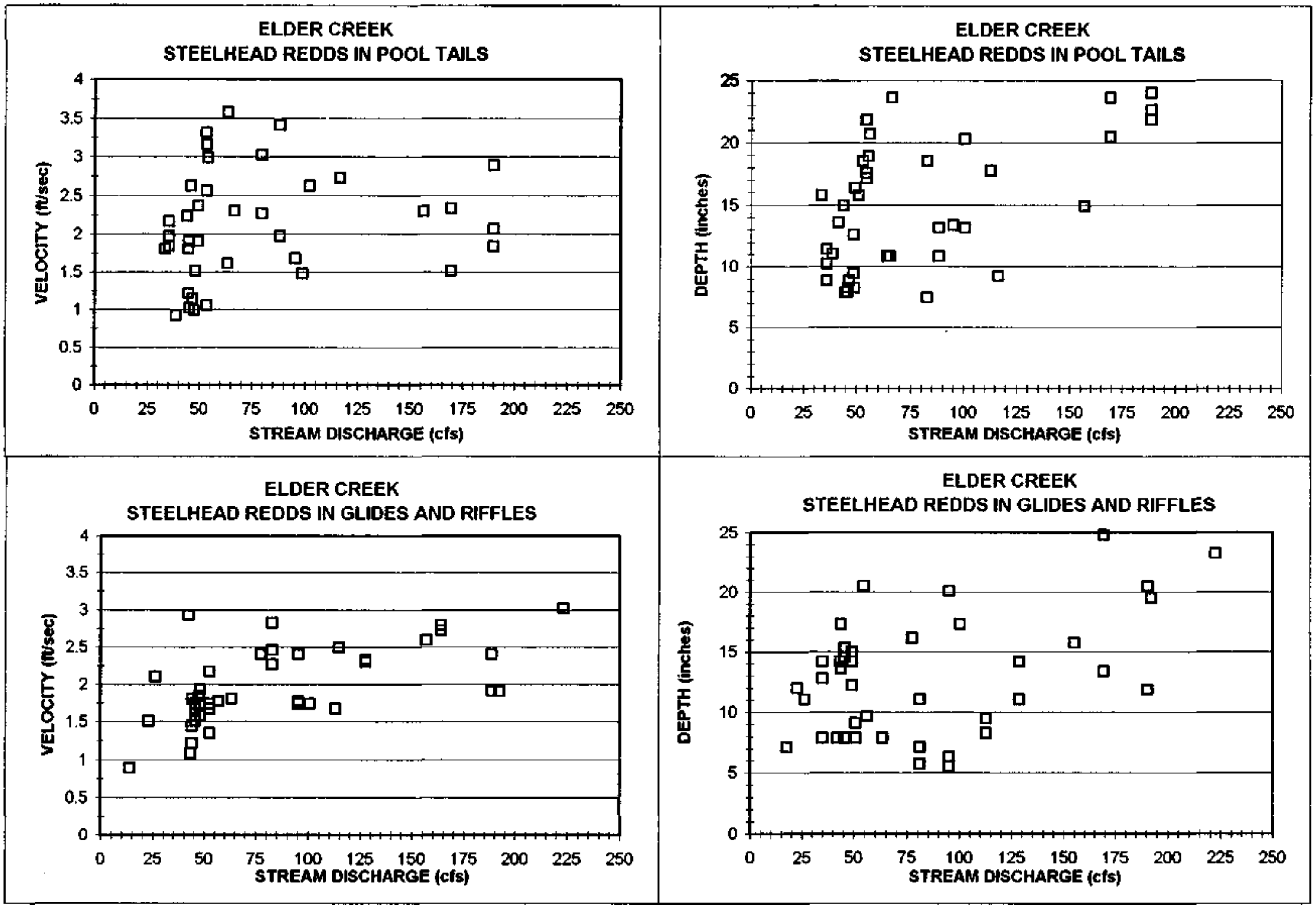


Figure 12. Water depths (ft) and velocities (ft/sec) during redd construction in Elder Creek, CA.

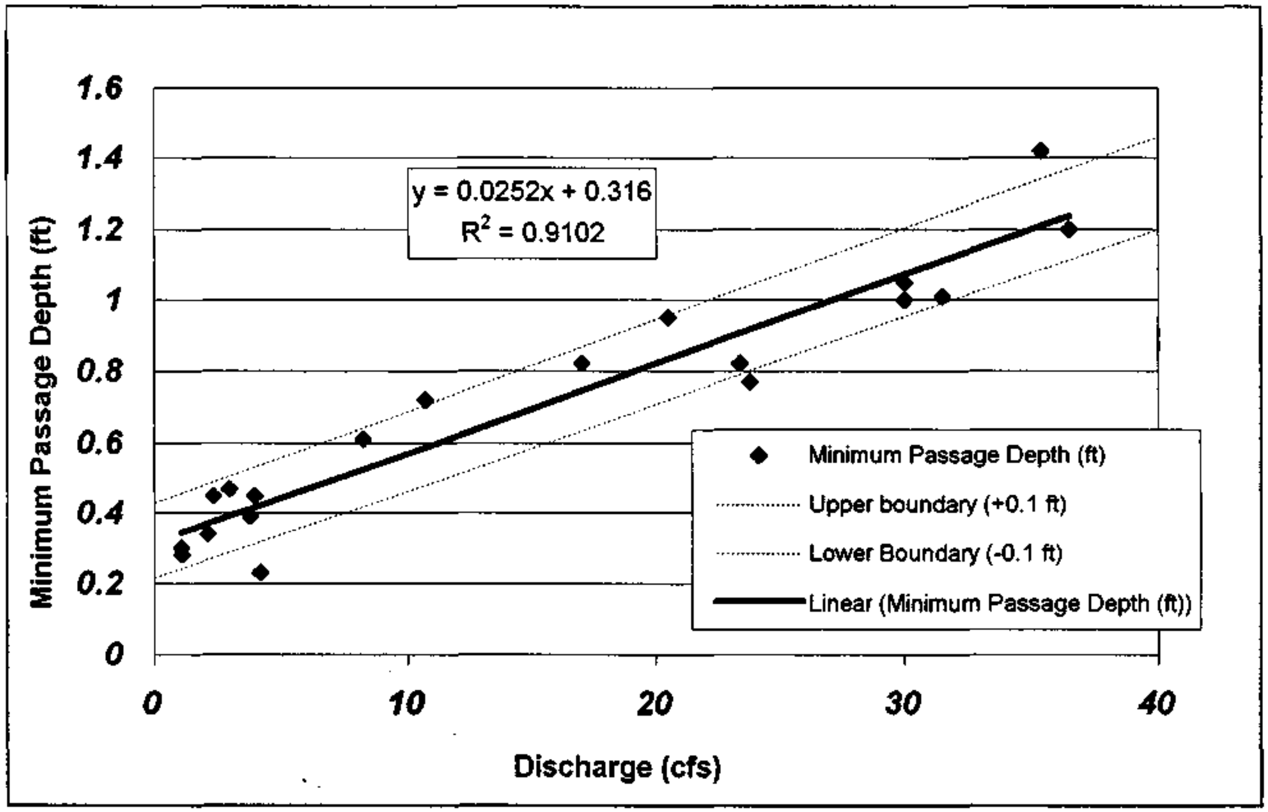


Figure 13. Linear relationship between stream discharge (cfs) and average minimum passage depth (MPD)(ft) at riffles and runs in selected Northcoast California stream channels. This linear relationship ($r^2 = 0.91$) can be used to calculate an MPD for migrating salmonids independent of drainage area. The +0.1 ft and -0.1 ft bands account for most influences of local channel morphology.

Figure 20A. An adult chinook salmon migrating up Sullivan Gulch (2.35 mi^2), Mad River Basin, at 9 cfs. Active channel bench on left bank (top of photo). Predicted MPD for this run is 0.54 ft.

Figure 20B. Female chinook salmon holding at bottom of oblique riffle, Sullivan Gulch (2.35 mi^2), Mad River Basin, at 9 cfs.

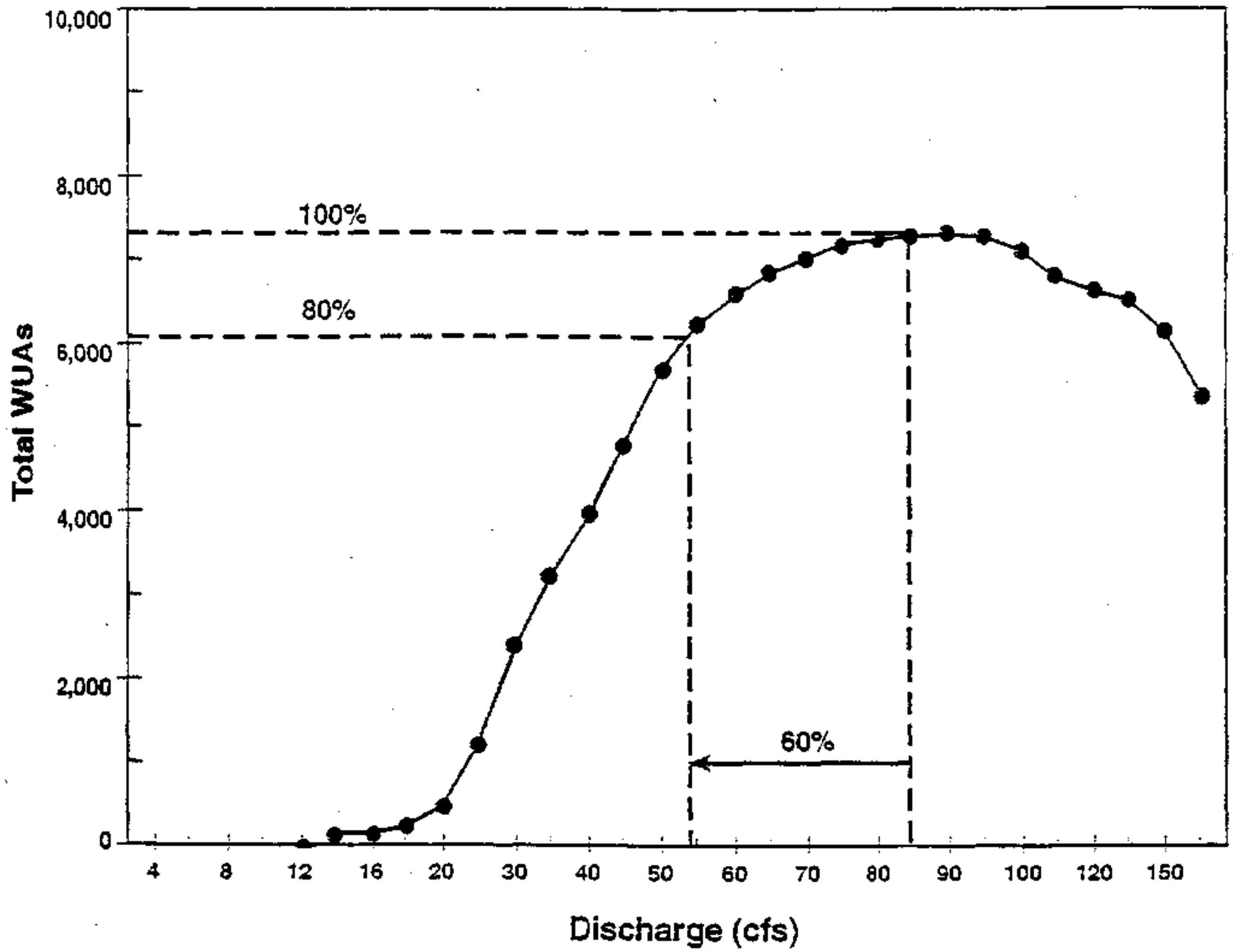


Figure 21. Reprint of Figure 4.1-2 of Attachment B (p. 20) of the *SWRCB Staff Report* (SWRCB 1997) showing the SWRCB method for determining the "optimum spawning flow" defined as the flow that provides the most spawning habitat.

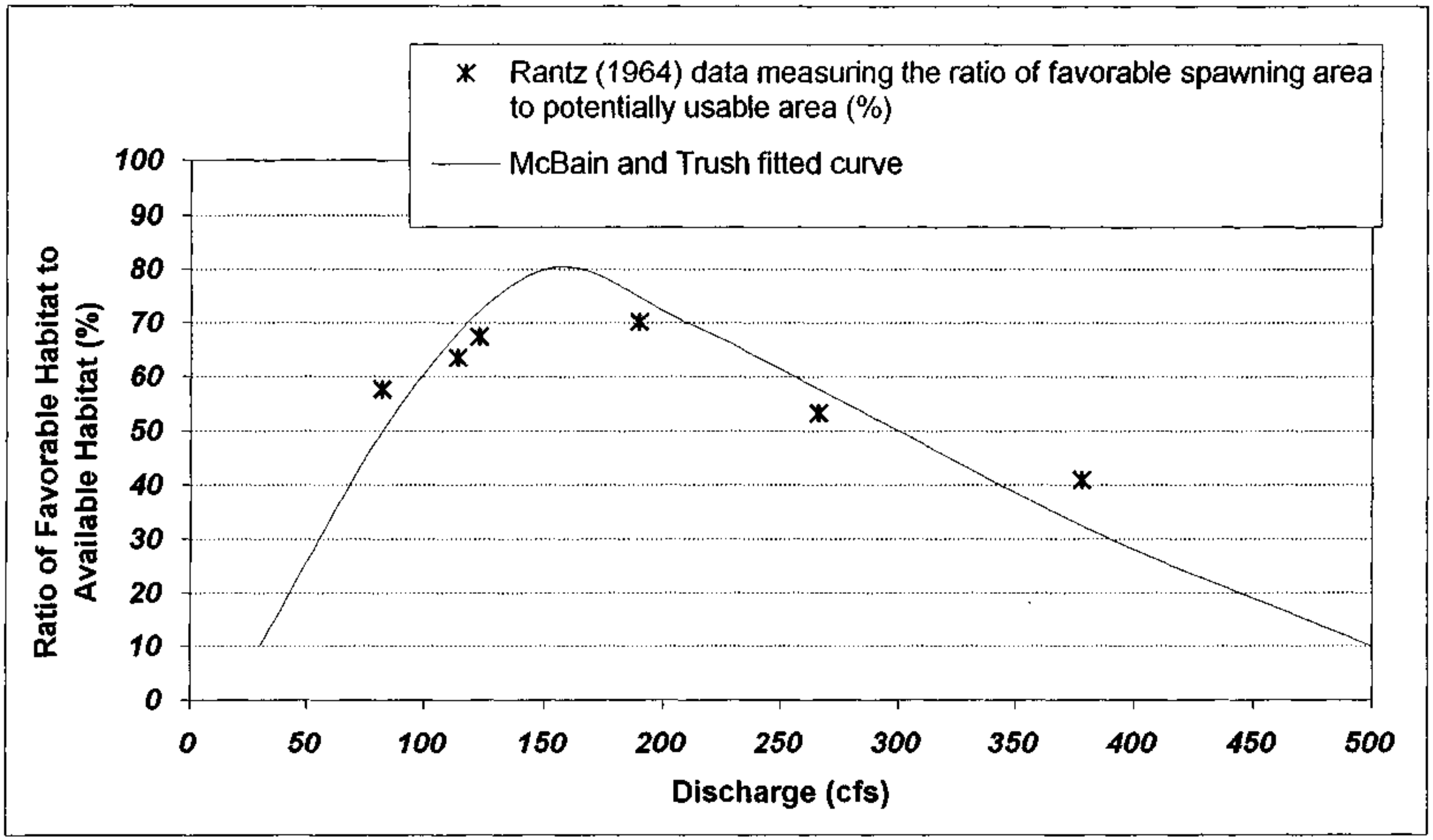


Figure 22. Optimum discharge for spawning habitat in Canon Creek, CA (16.2 mi^2) adapted from Rantz (1964).

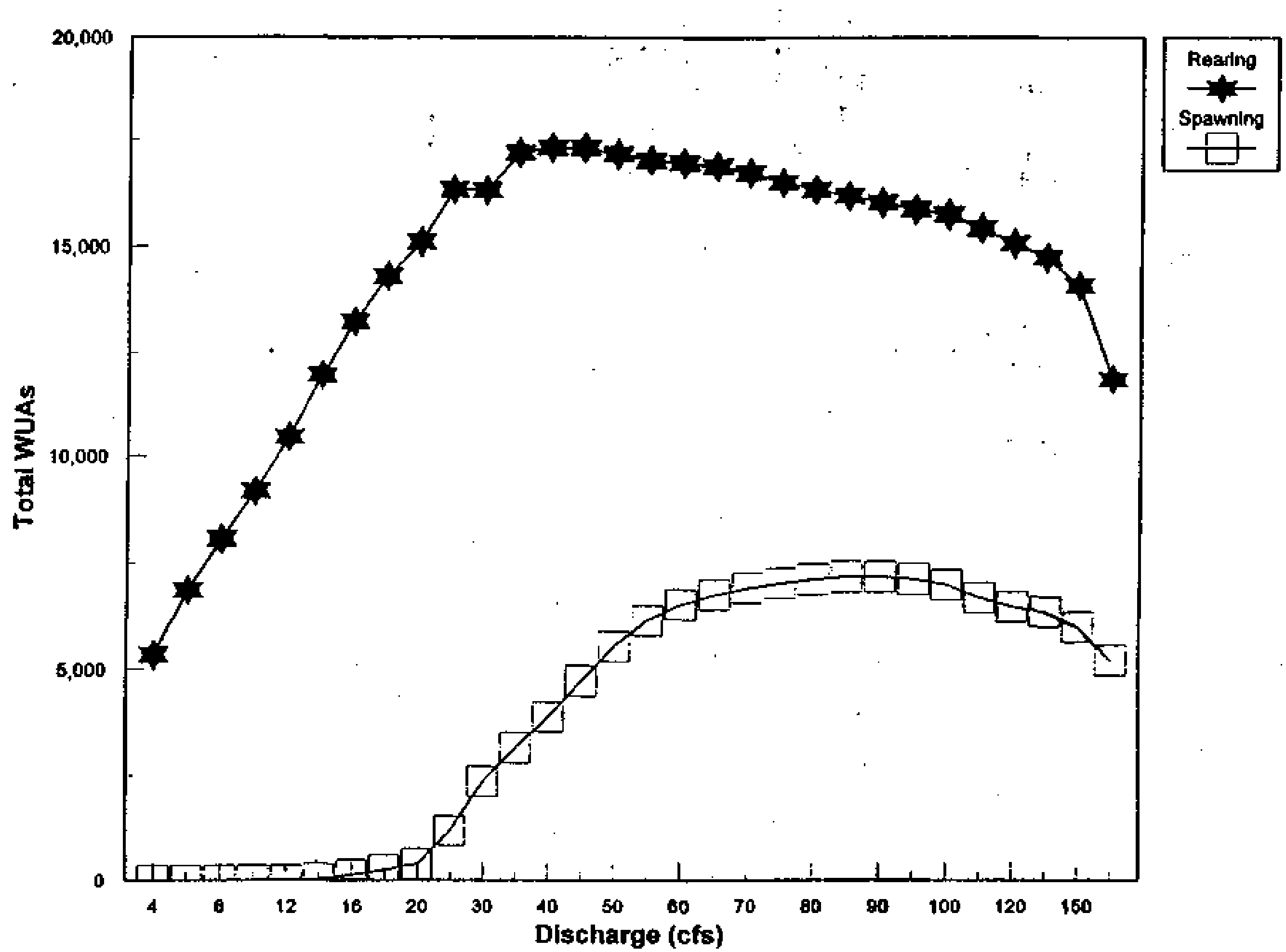


Figure 4.1-1: Total Weighted Usuable Area vs. Discharge at Little Sulphur Study Site on Big Sulphur Creek
(Source: Harding Lawson Associates, 1990)

Figure 23. Weighted Usable Area curve for rearing and spawning habitat in one reach of Big Sulphur Creek, reprinted from Figure 4.1 -1 in SWRCB(1997).

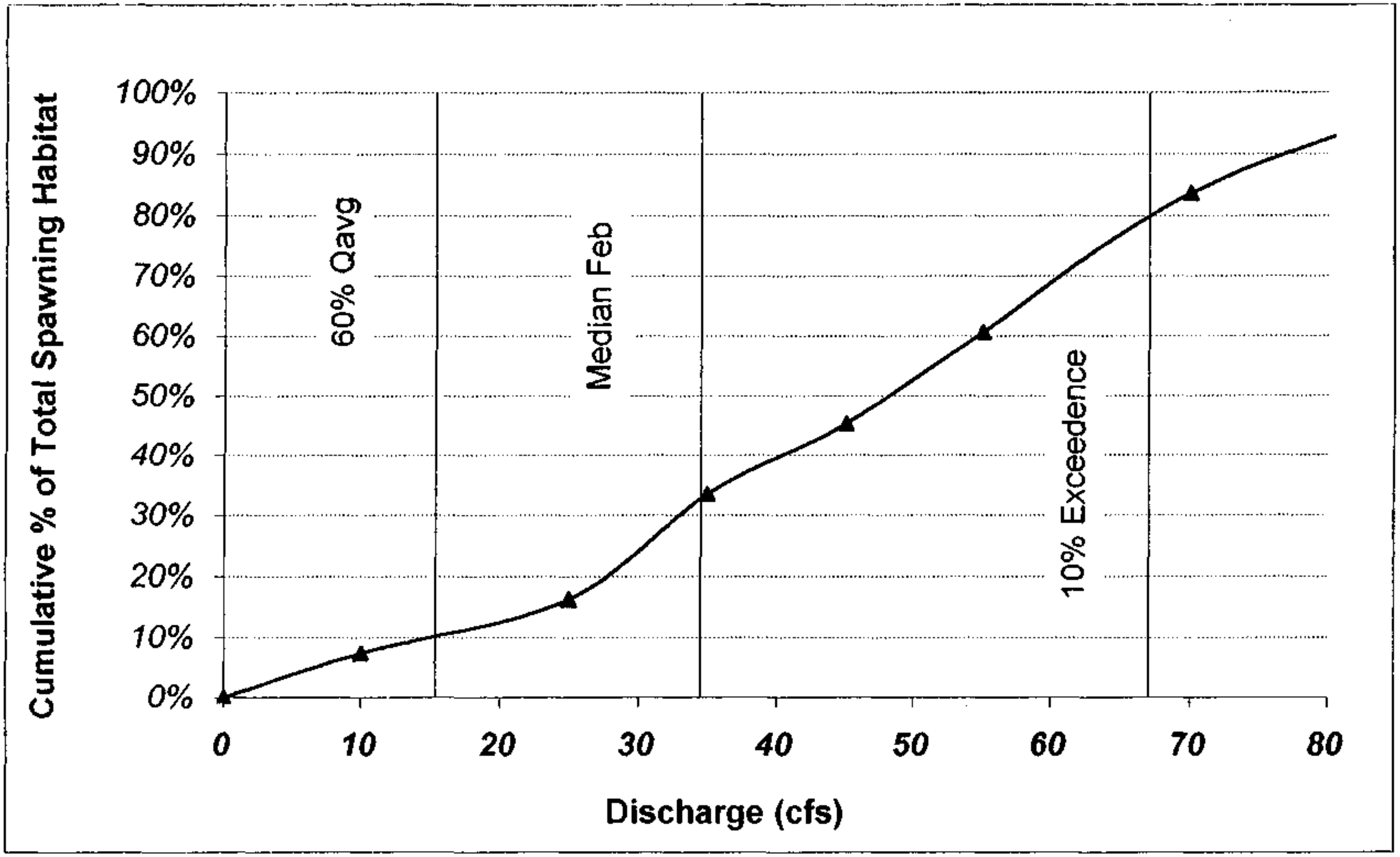


Figure 24. Cumulative percentage of total spawning habitat available with increasing daily average discharge in Elder Creek, South Fork Eel River Basin, with proposed minimum bypass flows indicated.

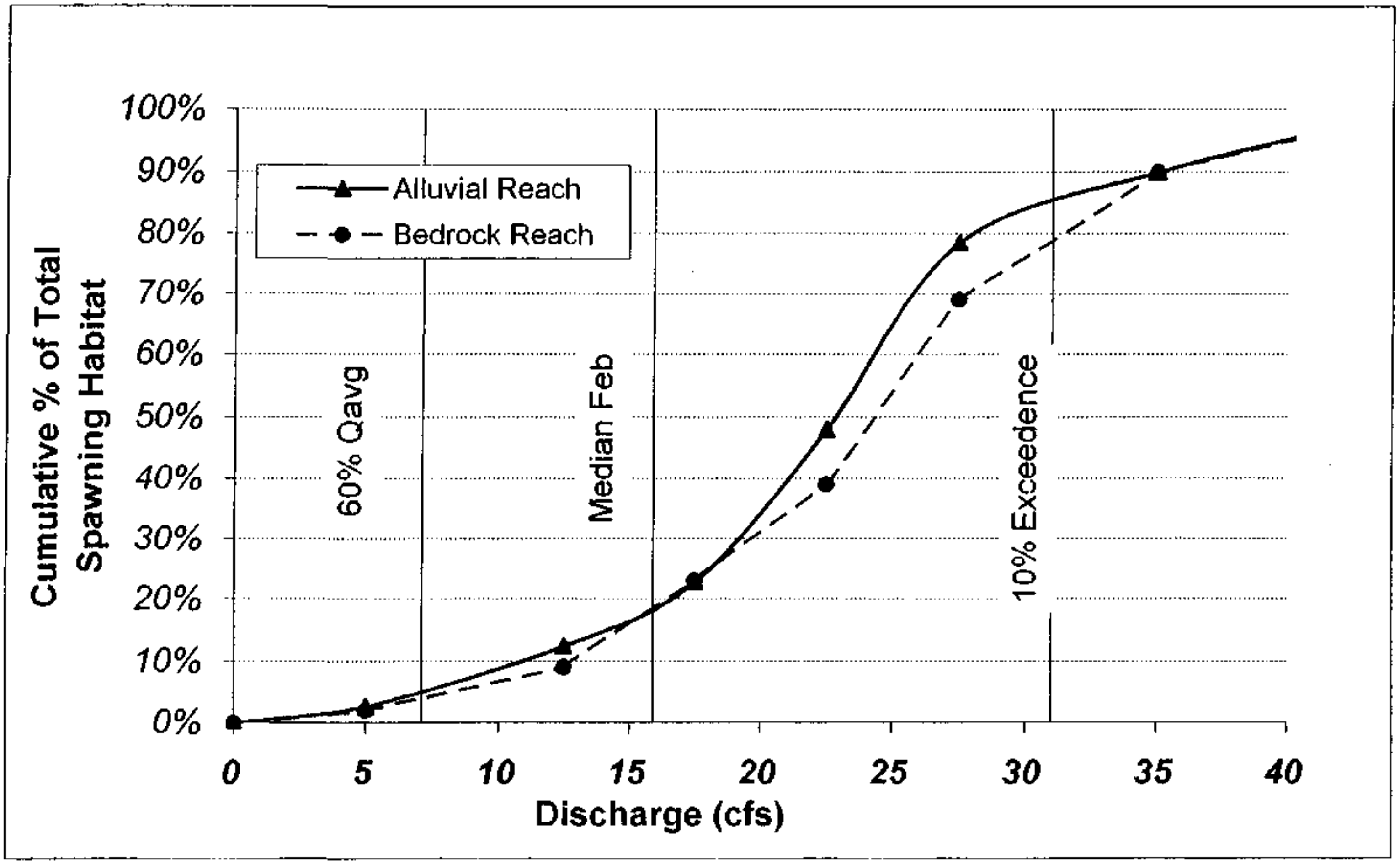


Figure 25. Cumulative percentage of total spawning habitat available with increasing daily average discharges for two reaches in Rock Creek, South Fork Eel River Basin, with proposed minimum bypass flows indicated.

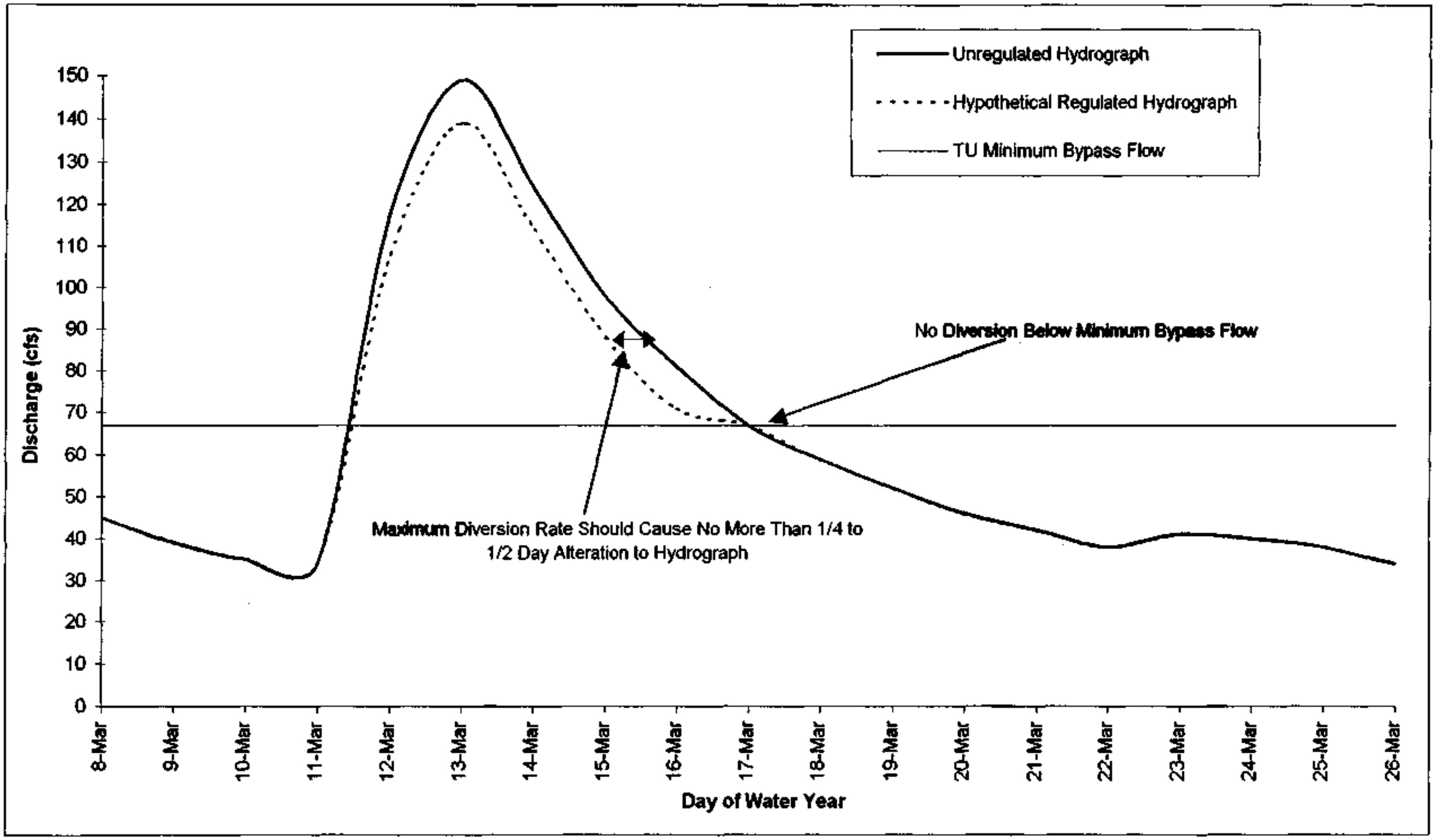


Figure 26. Derivation of Trout Unlimited's maximum diversion rate (cfs).

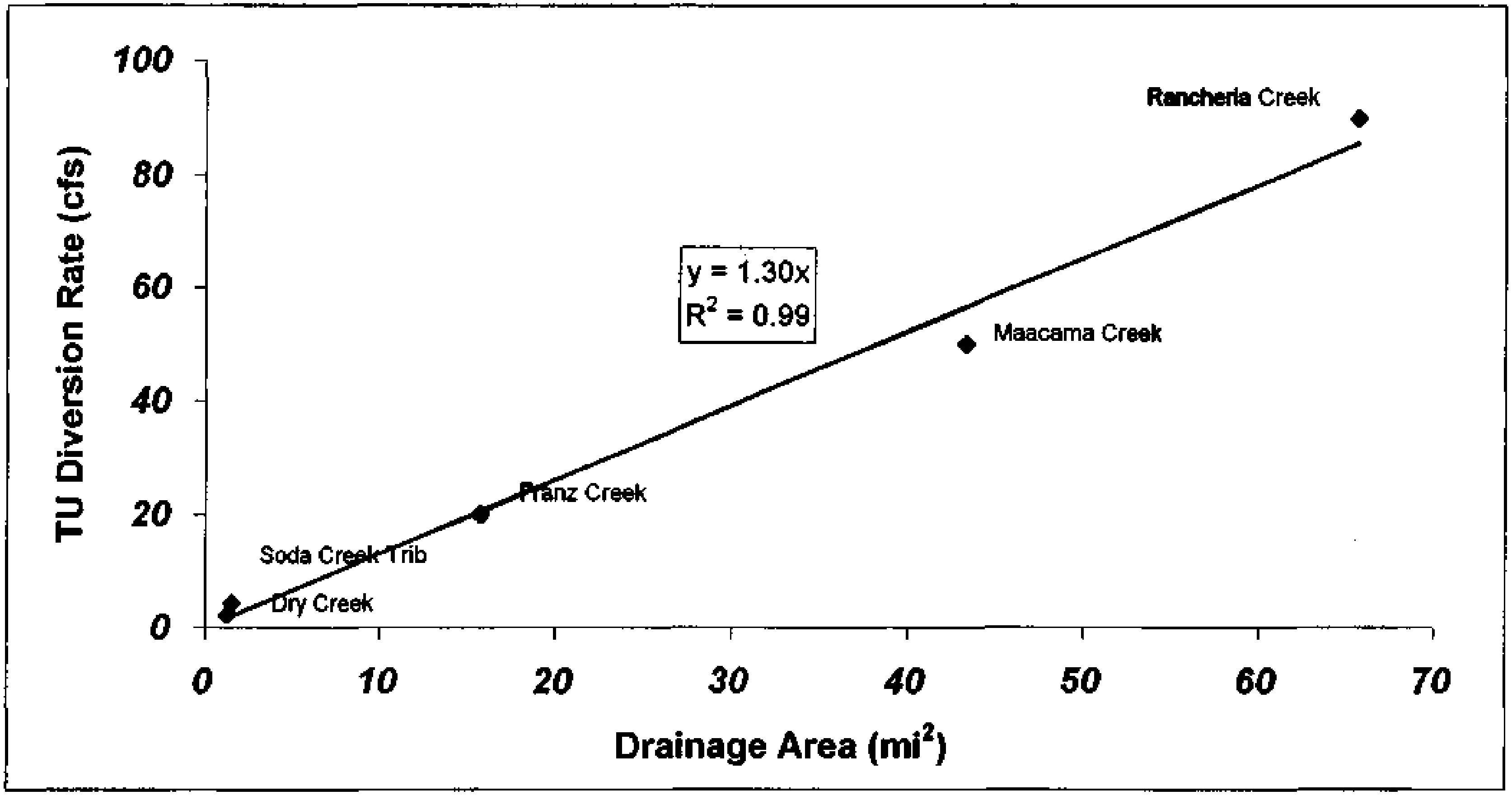


Figure 27. Preliminary maximum diversion rate (cfs) for the middle Russian River Basin.

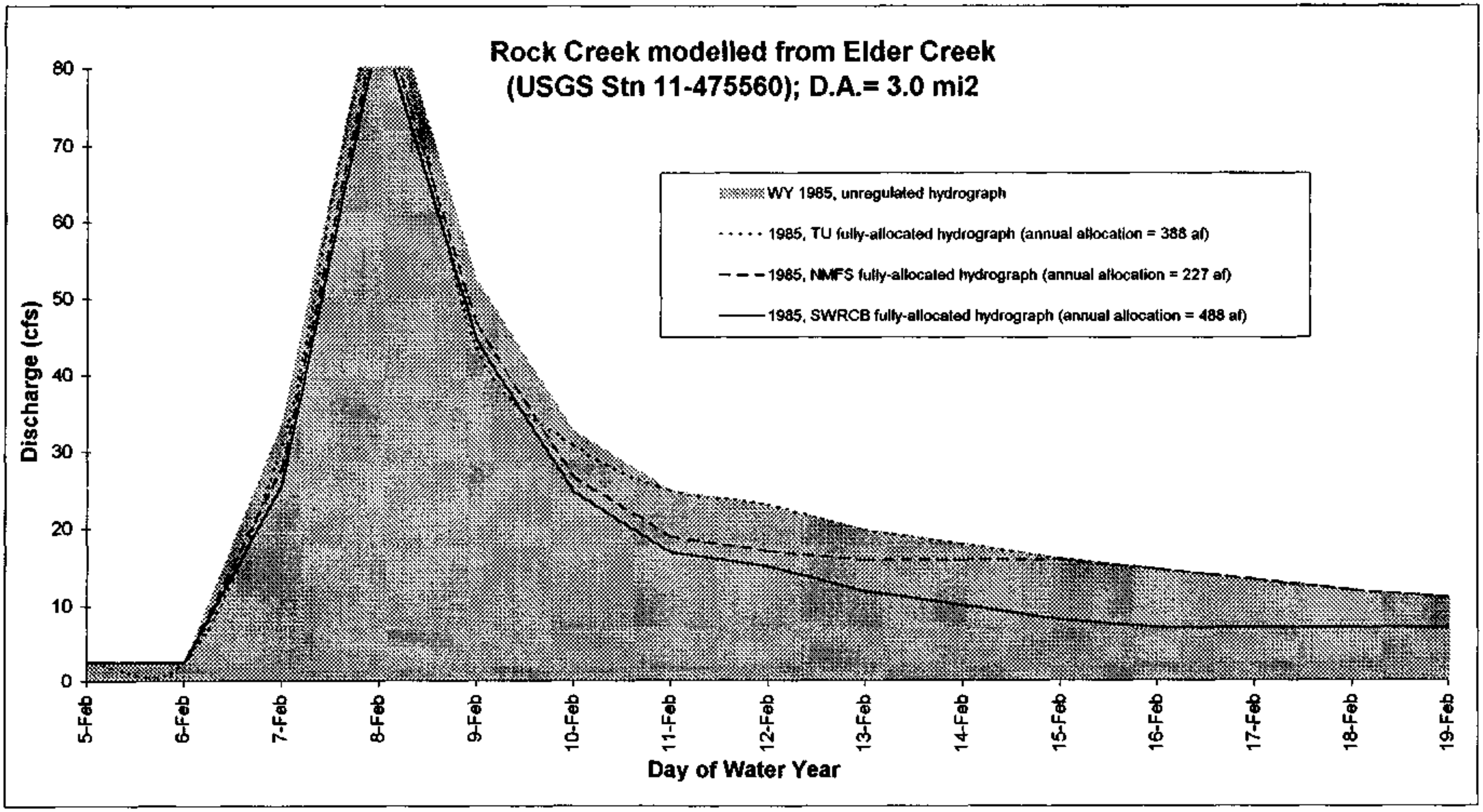


Figure 28. Modeled daily flow diversions by each proposed protocol for a flood hydrograph from Rock Creek (3.0 mi^2), South Fork Eel River Basin.

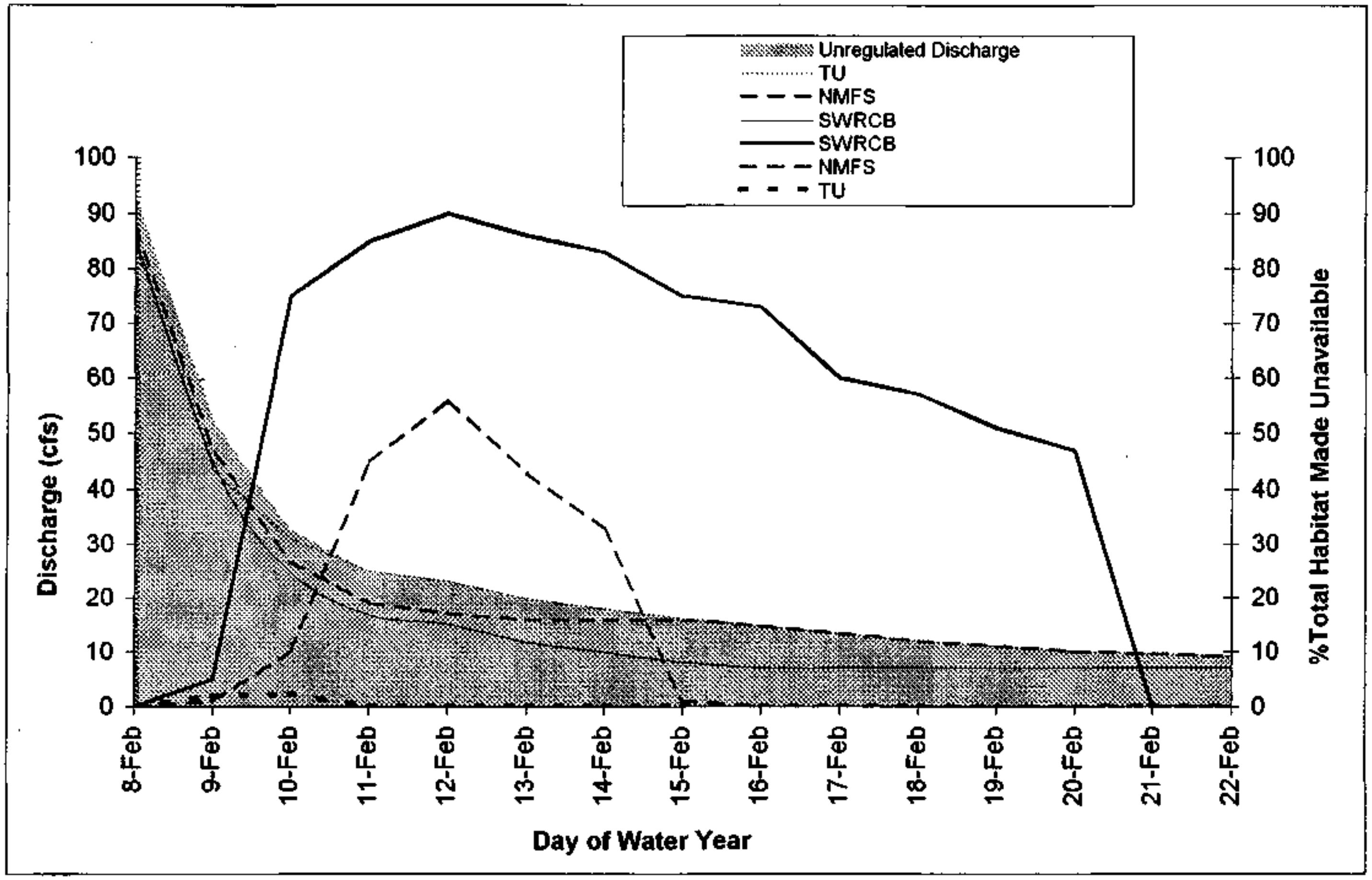


Figure 29. Cumulative spawning habitat losses (%) by each proposed allocation protocol applied to the Rock Creek flood hydrograph.

Fig. 30A

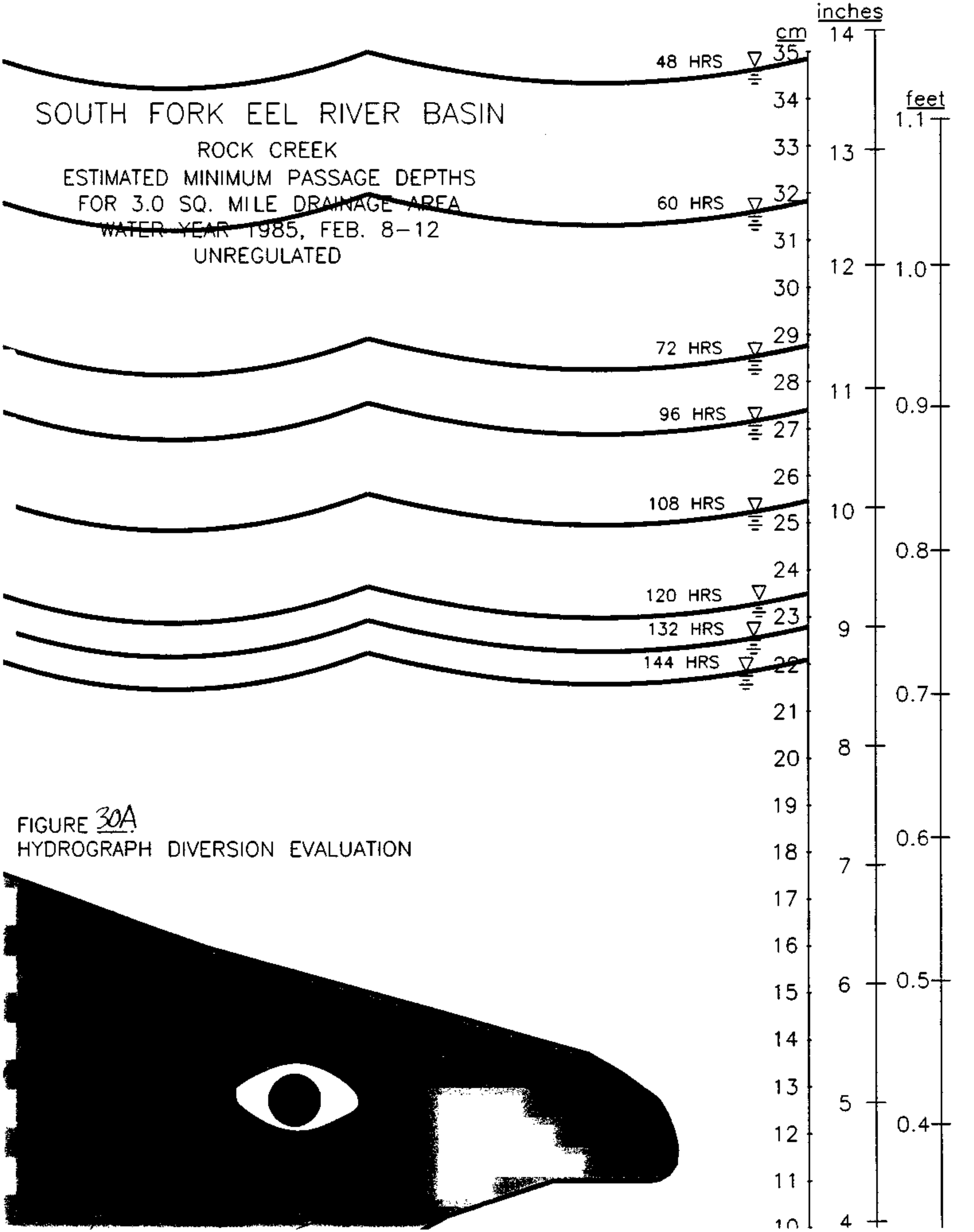


FIGURE 30A
HYDROGRAPH DIVERSION EVALUATION

Fig 30B

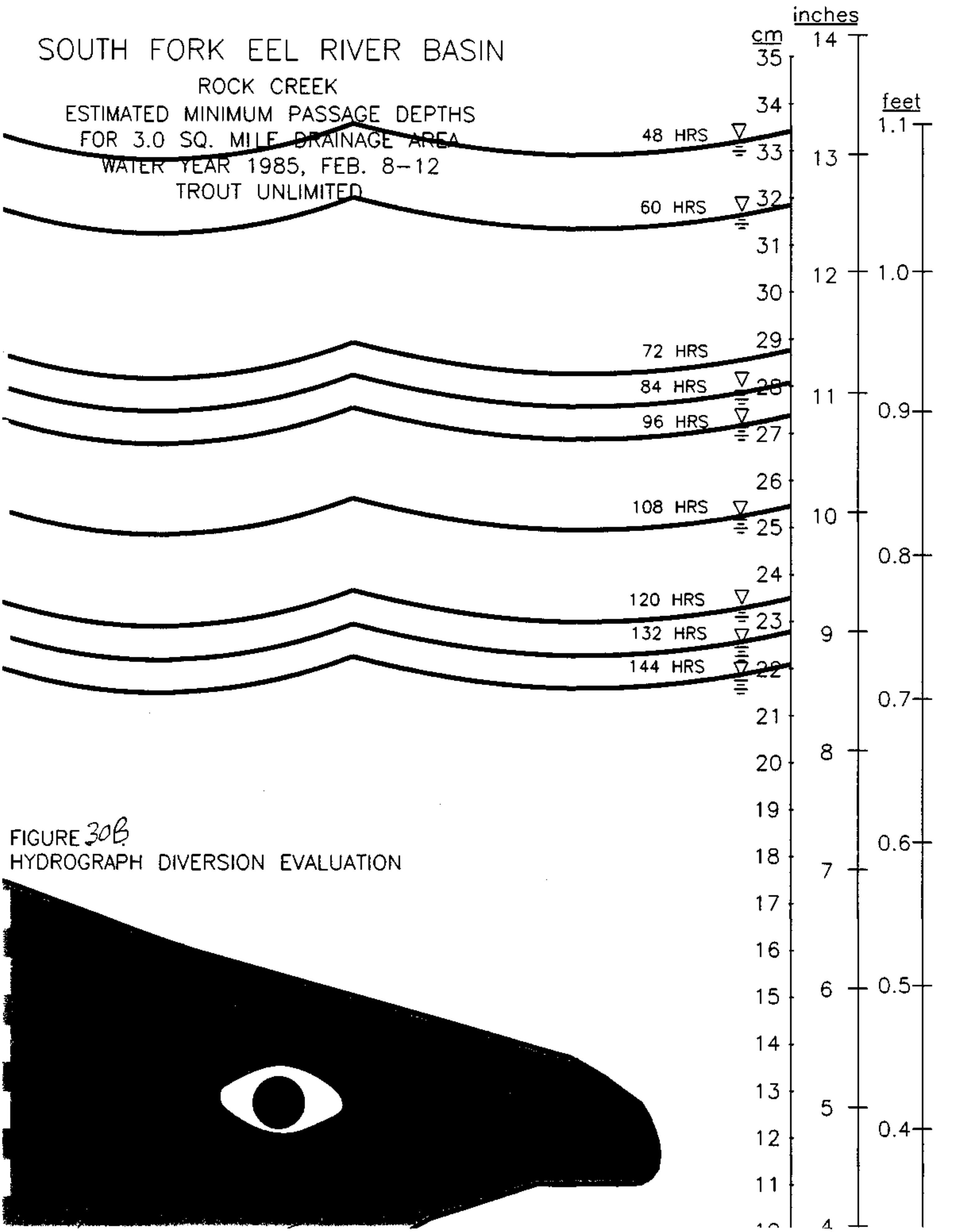


FIGURE 30B
HYDROGRAPH DIVERSION EVALUATION

Fig 30C

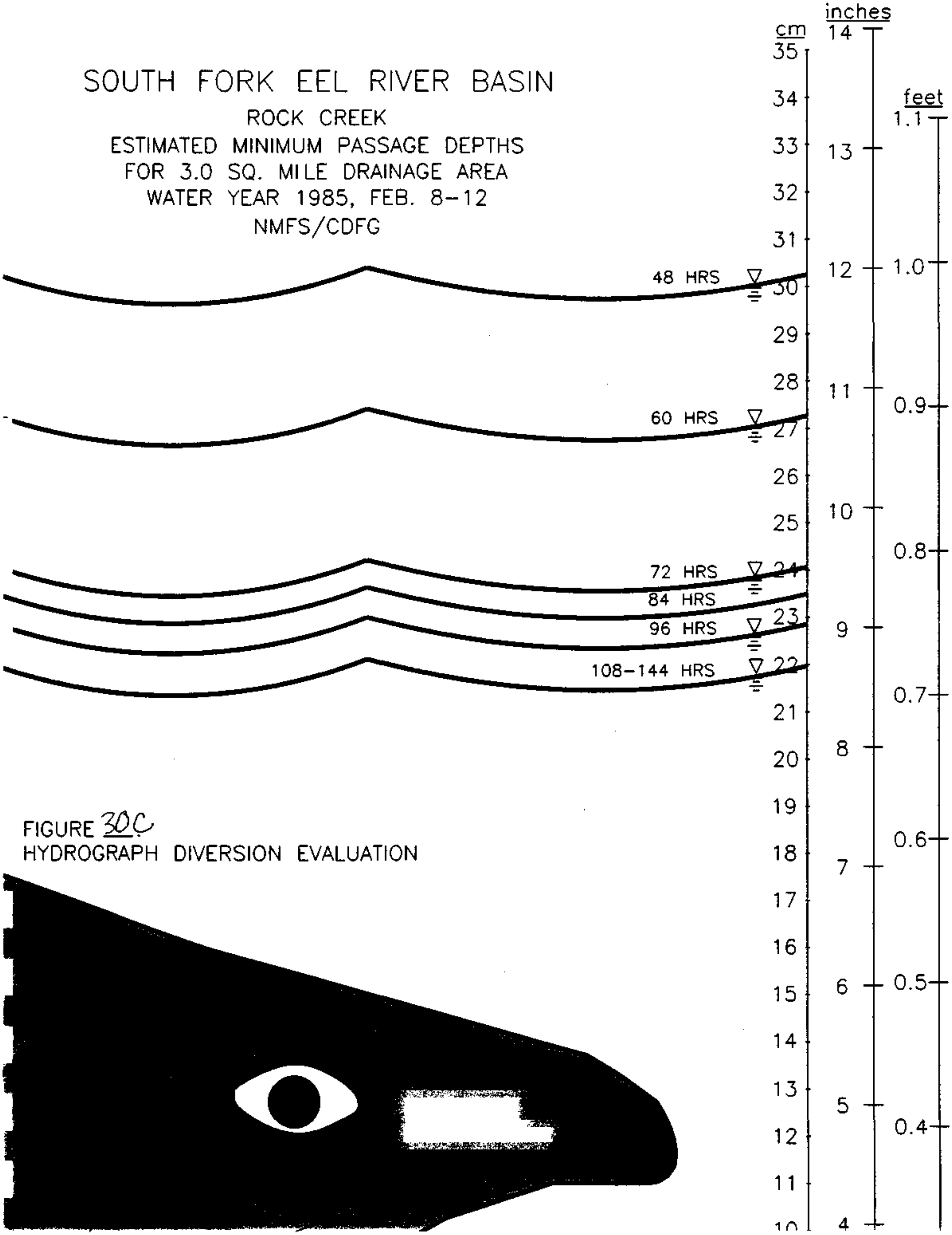


FIGURE 30C
HYDROGRAPH DIVERSION EVALUATION

Fig 30I

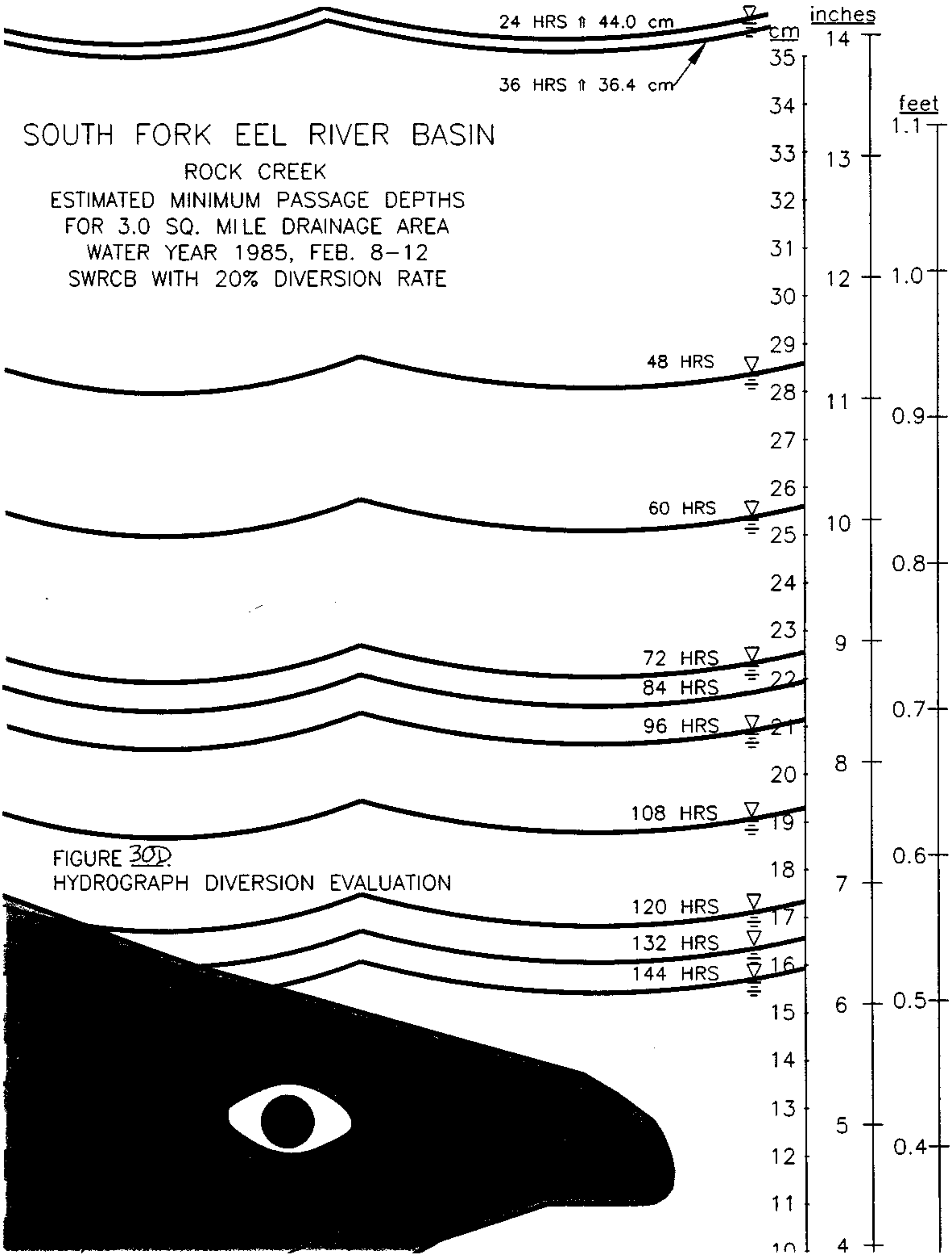


FIGURE 30D
HYDROGRAPH DIVERSION EVALUATION

Fig 30E

SOUTH FORK EEL RIVER BASIN
ROCK CREEK
ESTIMATED MINIMUM PASSAGE DEPTHS
FOR 3.0 SQ. MILE DRAINAGE AREA
WATER YEAR 1985, FEB. 8-12
SWRCB WITH 40% DIVERSION RATE

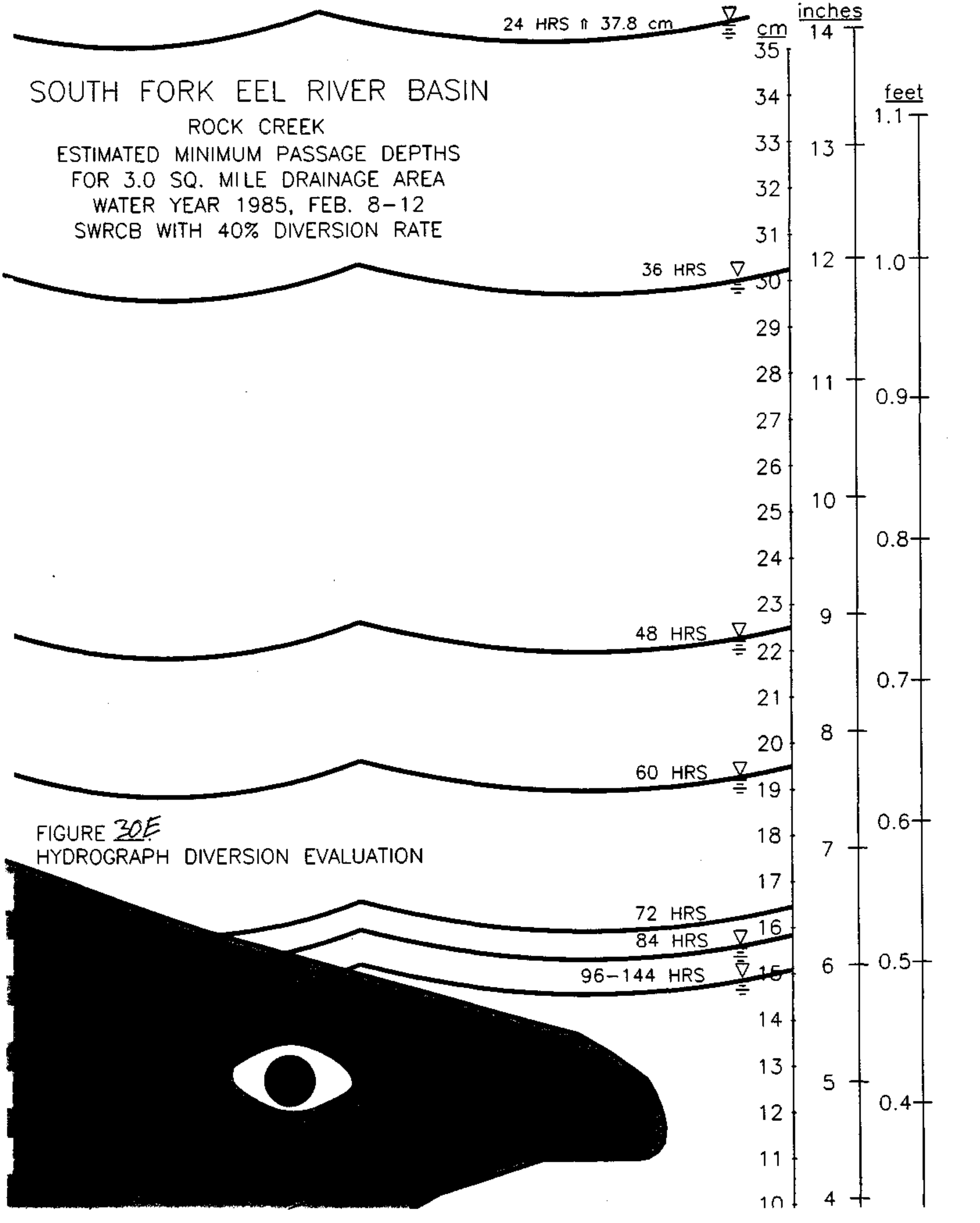


FIGURE 30E
HYDROGRAPH DIVERSION EVALUATION

Fig. 31A

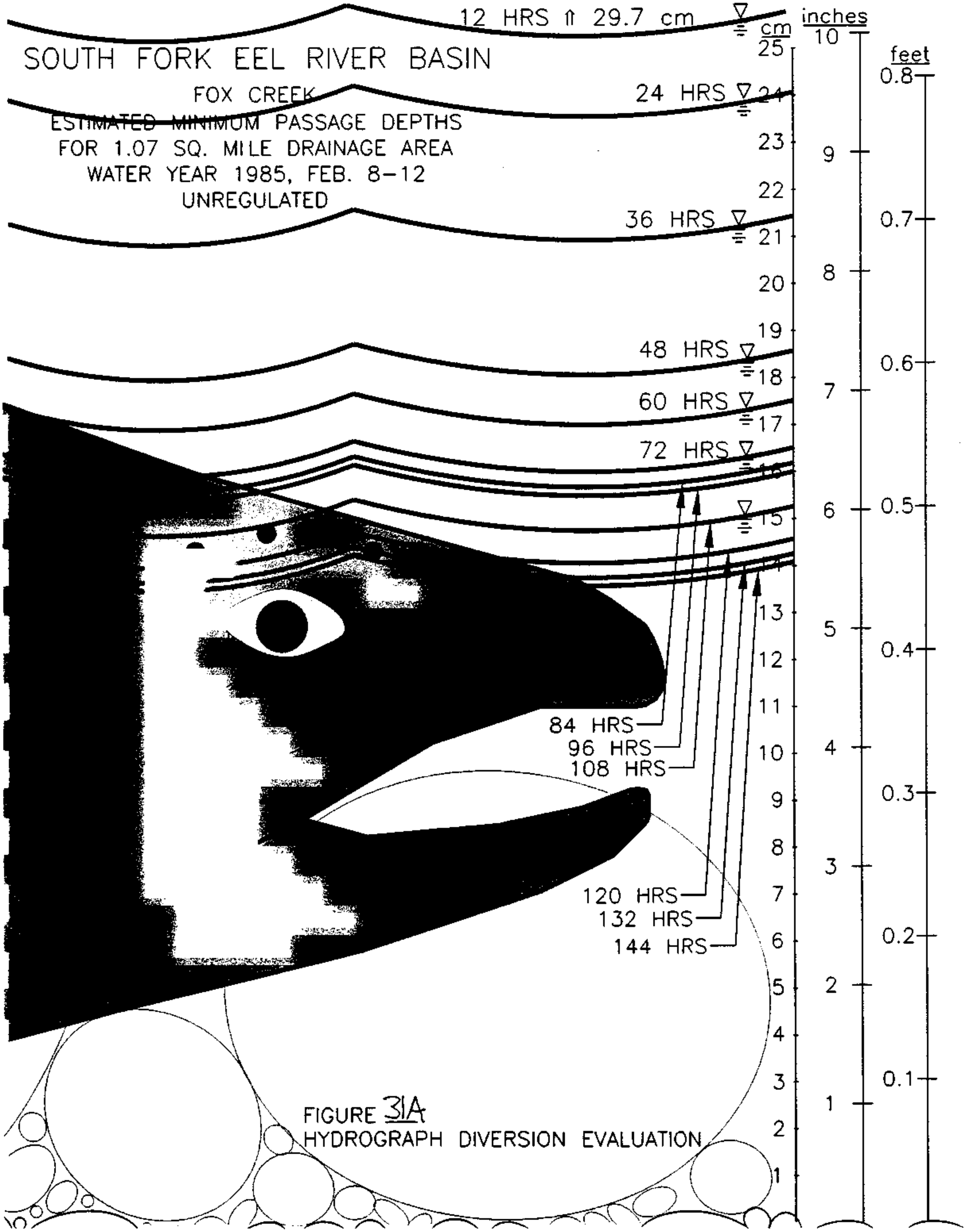


FIGURE 31A
HYDROGRAPH DIVERSION EVALUATION

Fig 31B

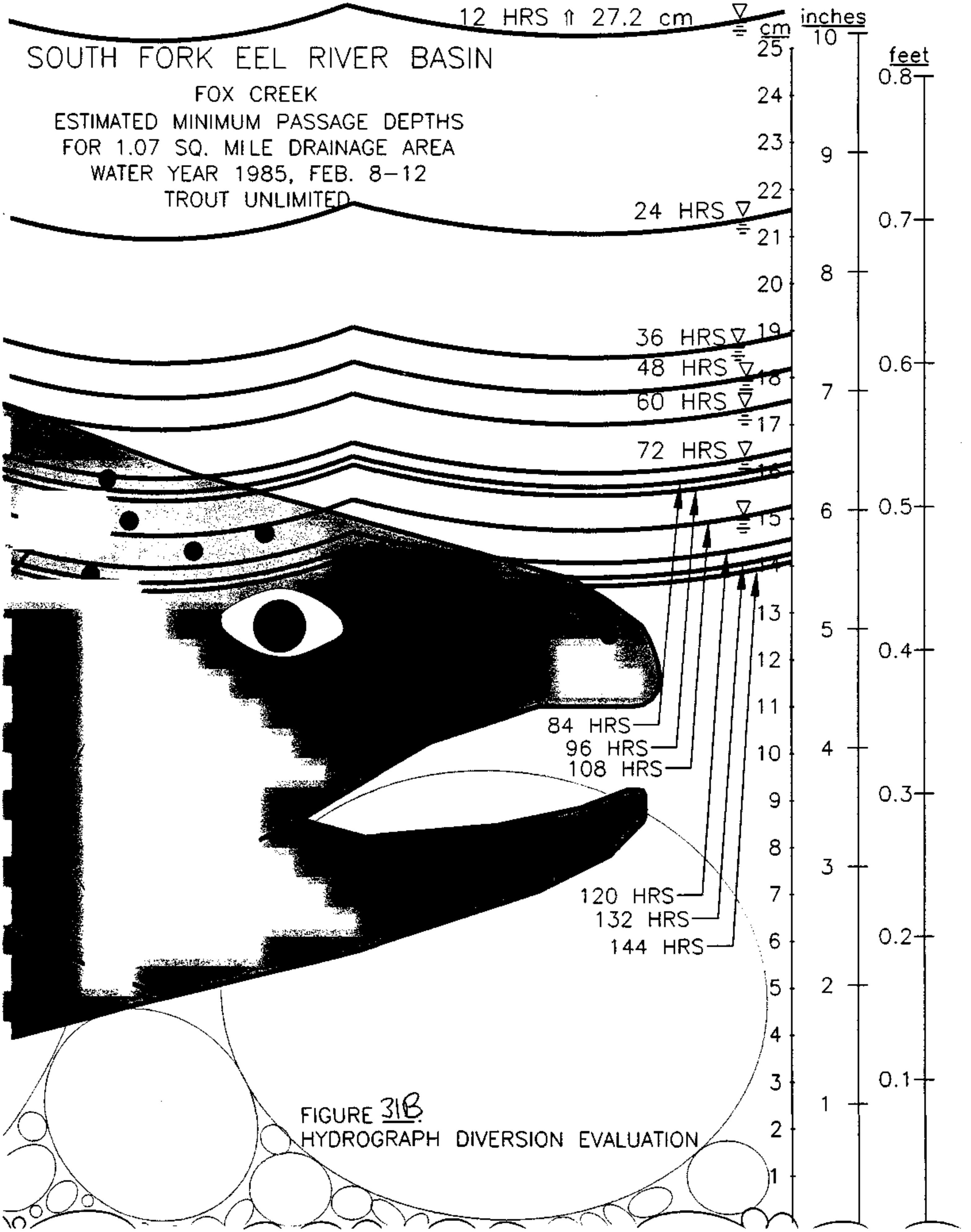


FIGURE 31B.
HYDROGRAPH DIVERSION EVALUATION

Fig 31C

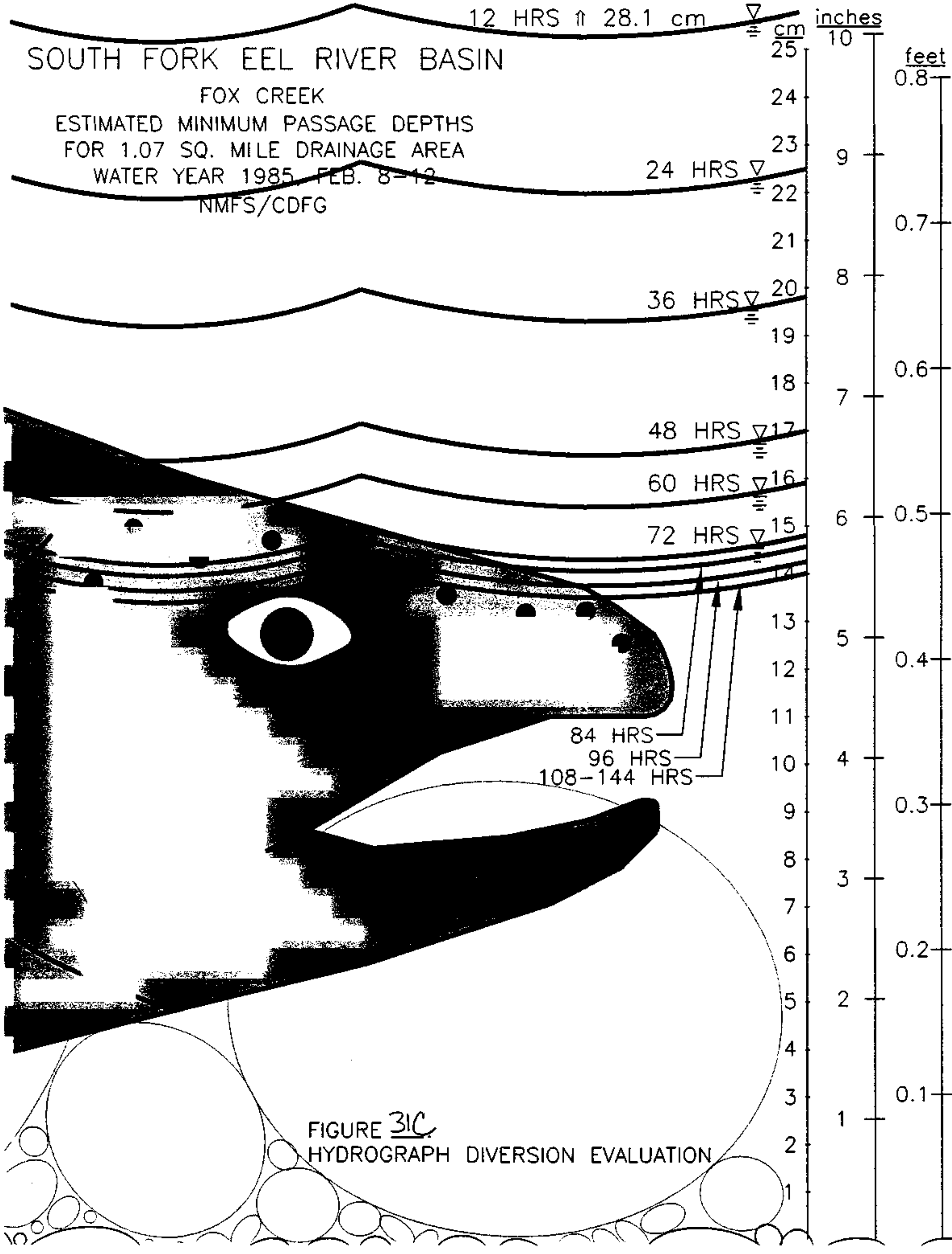


FIGURE 31C
HYDROGRAPH DIVERSION EVALUATION

Fig 31D

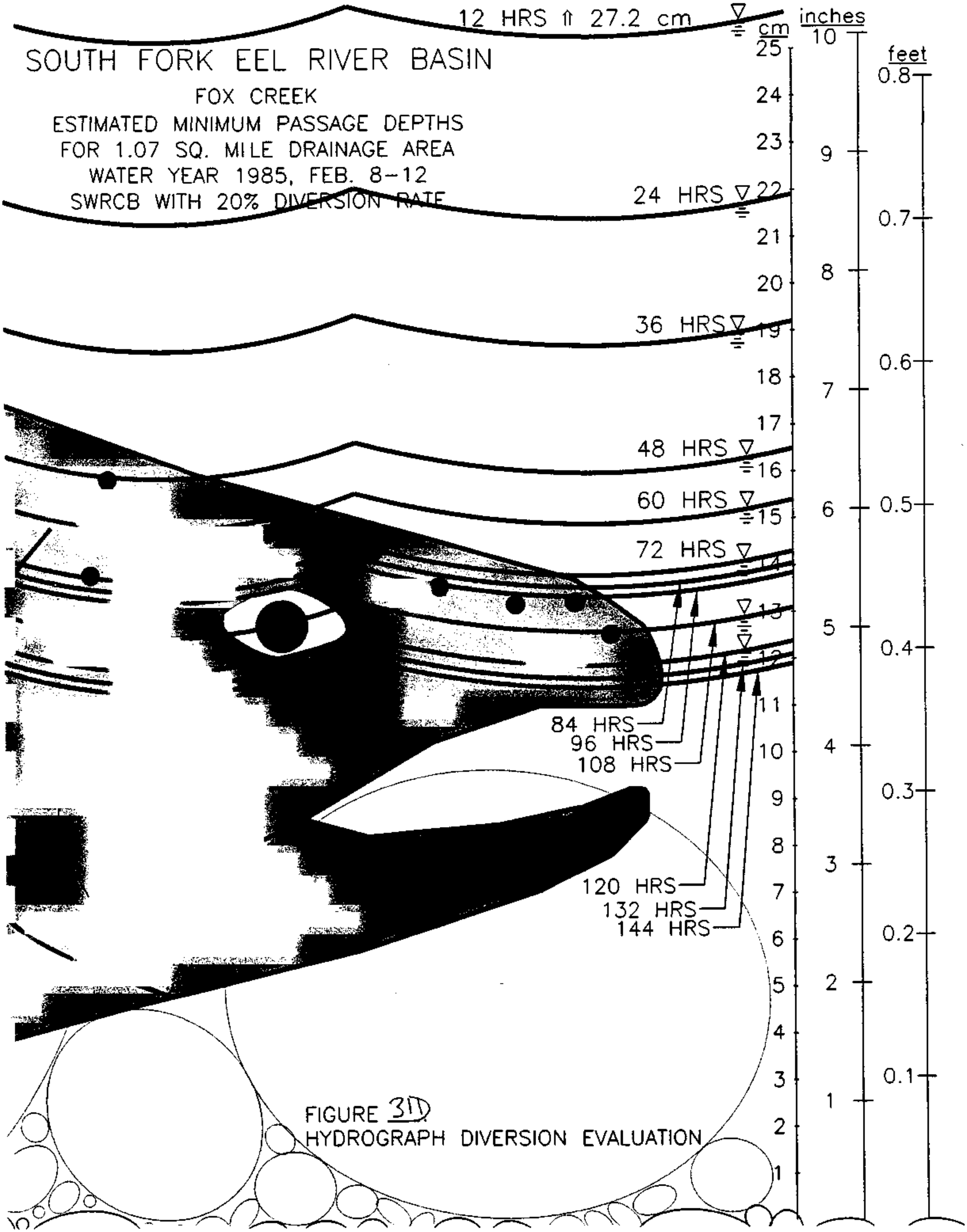


FIGURE 31D
HYDROGRAPH DIVERSION EVALUATION

Fig 31E

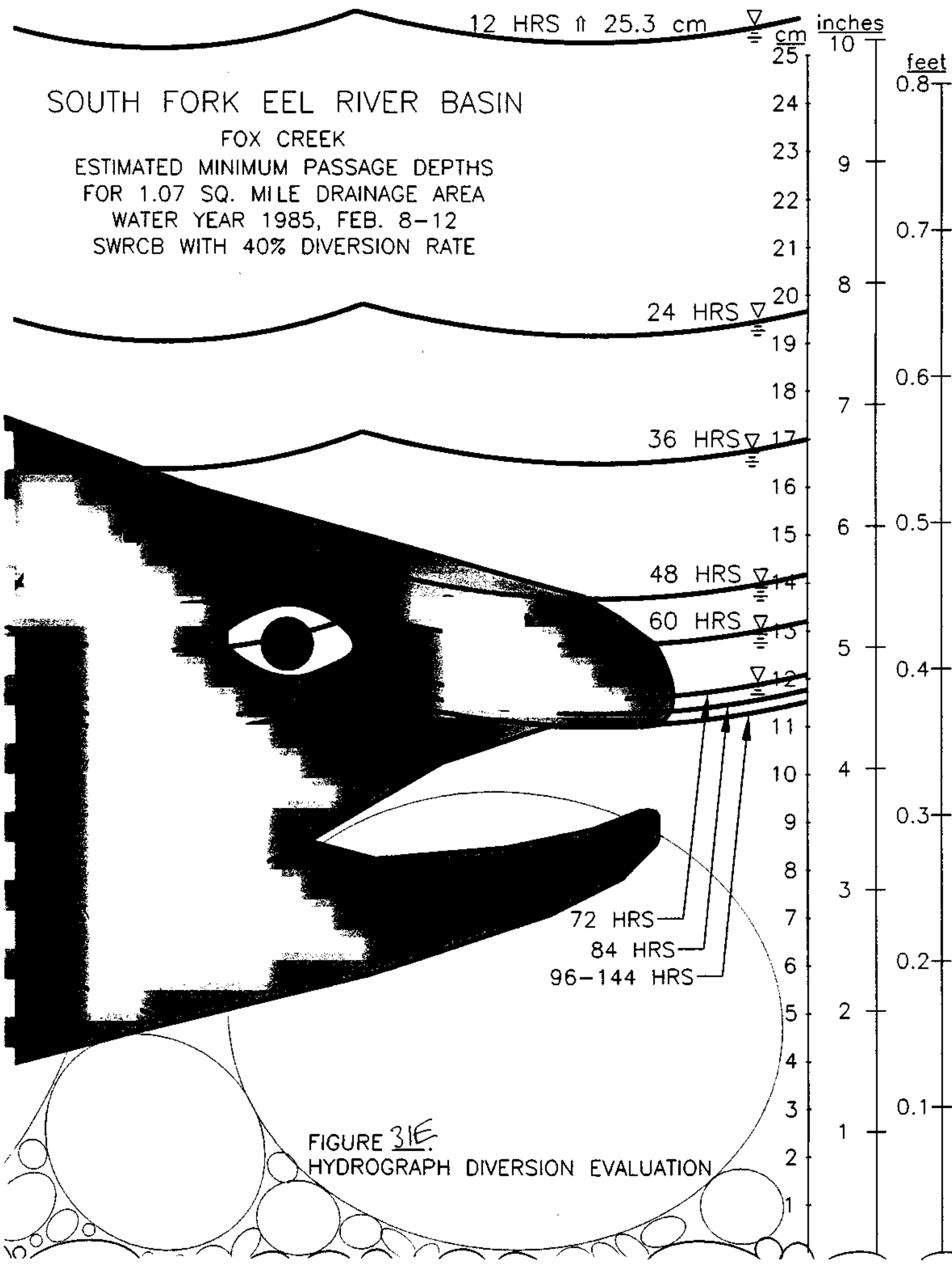


FIGURE 31E.
HYDROGRAPH DIVERSION EVALUATION

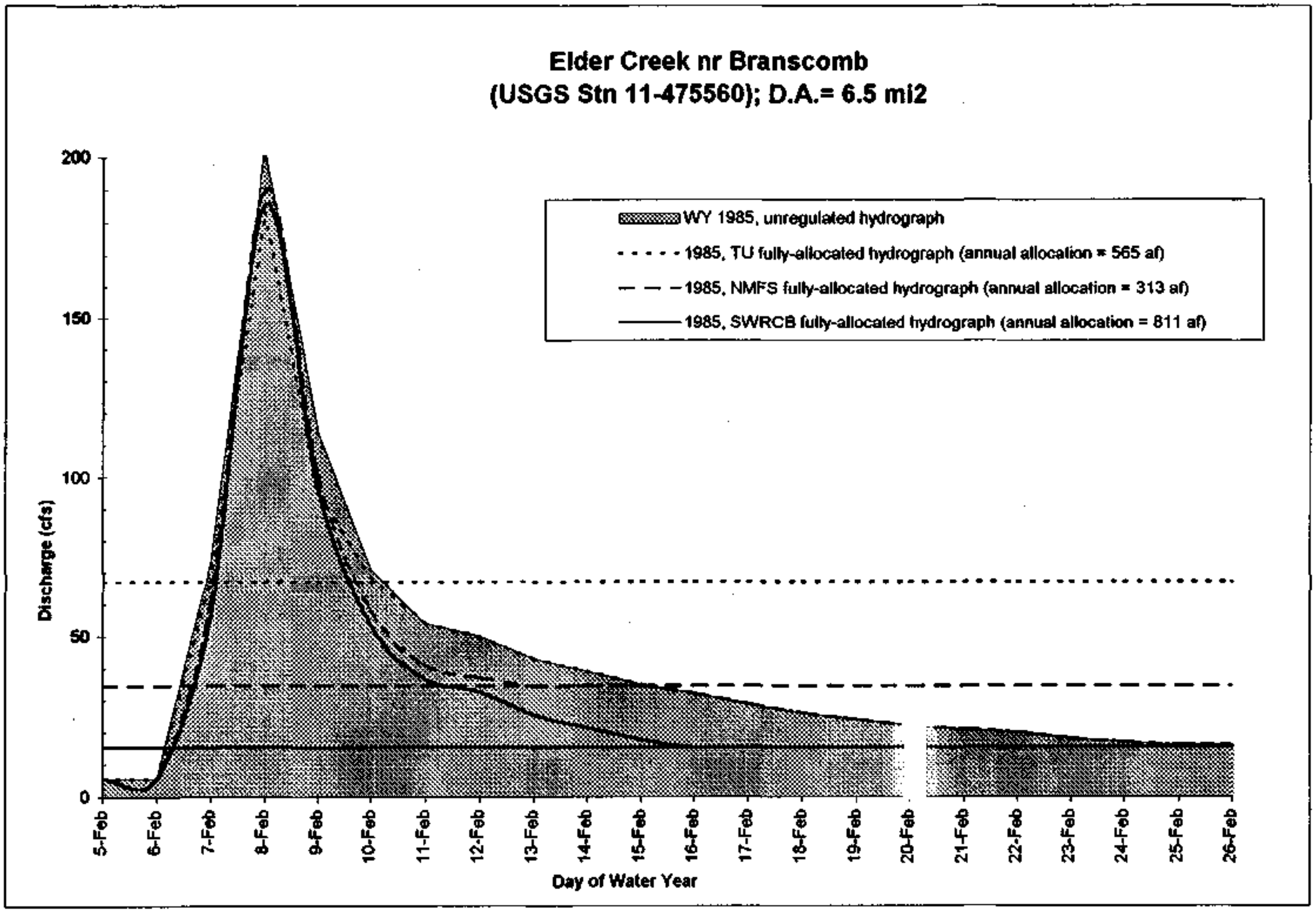


Figure 32. Modeled Elder Creek daily diversions using the three allocation protocols for a flood hydrograph February 5 to 26, WY1985.

Figures 33A-E, 34A-E, and 35A-E have not been drafted

Fig. 36A

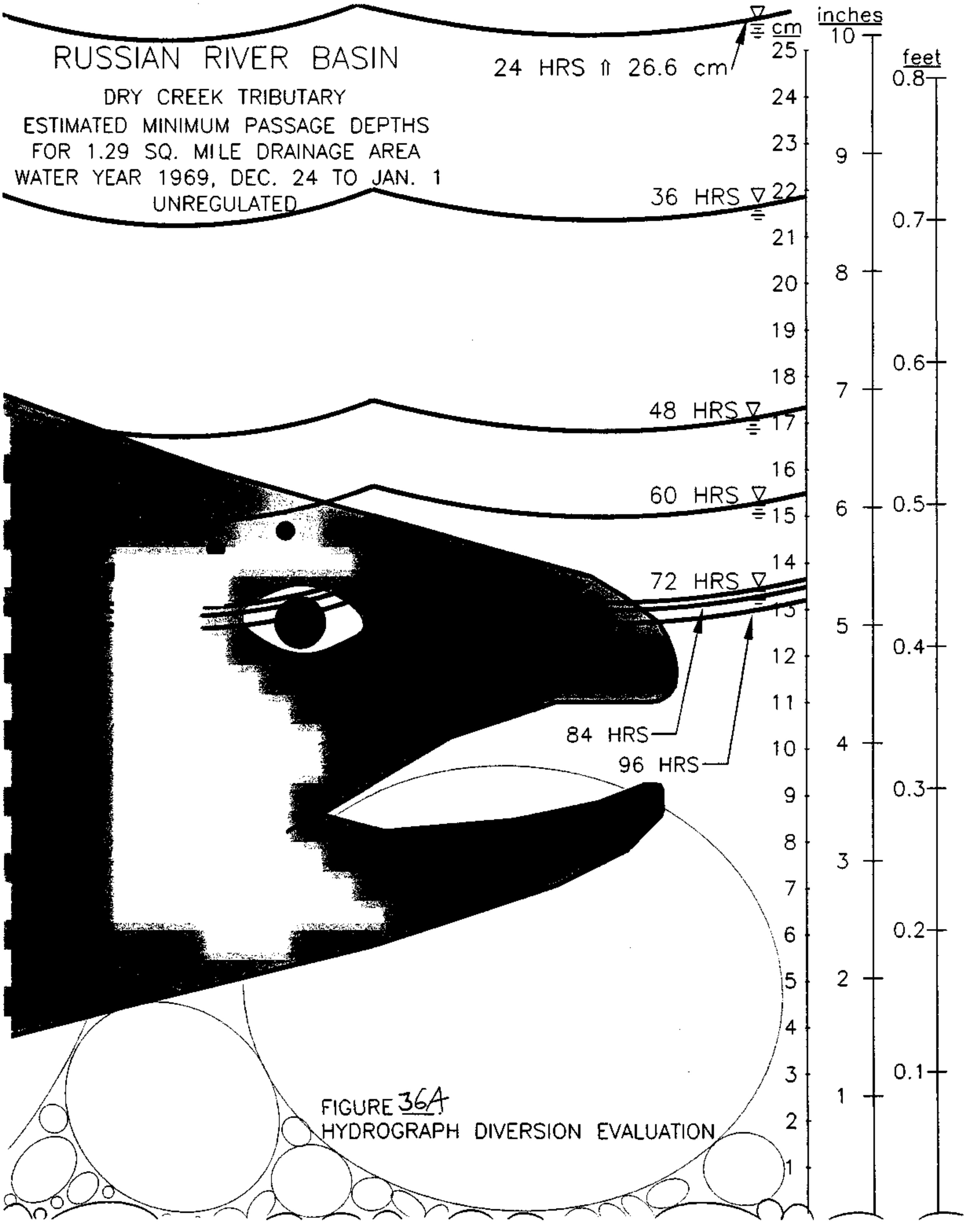


FIGURE 36A
HYDROGRAPH DIVERSION EVALUATION

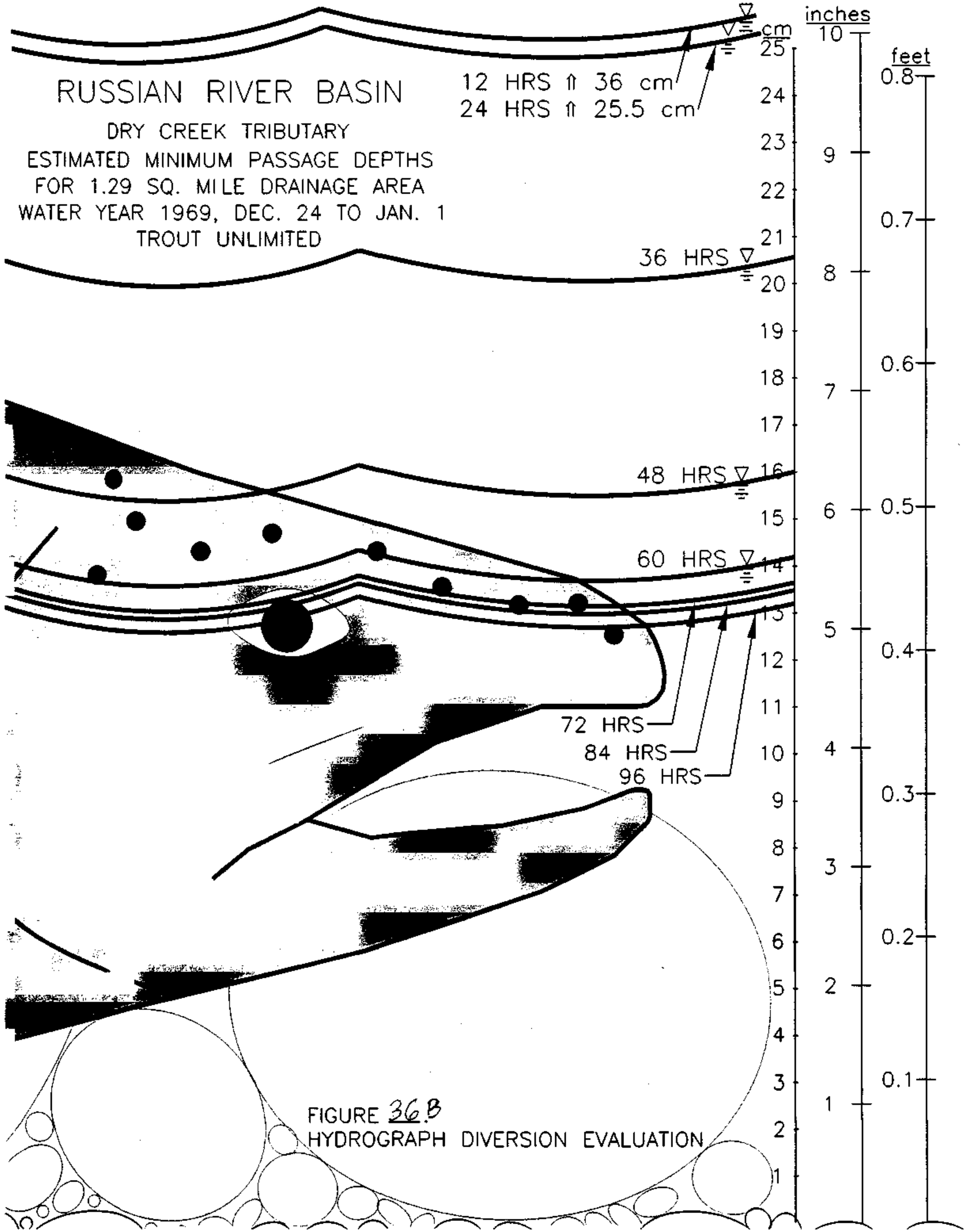


FIGURE 36.B
HYDROGRAPH DIVERSION EVALUATION

Fig 36C

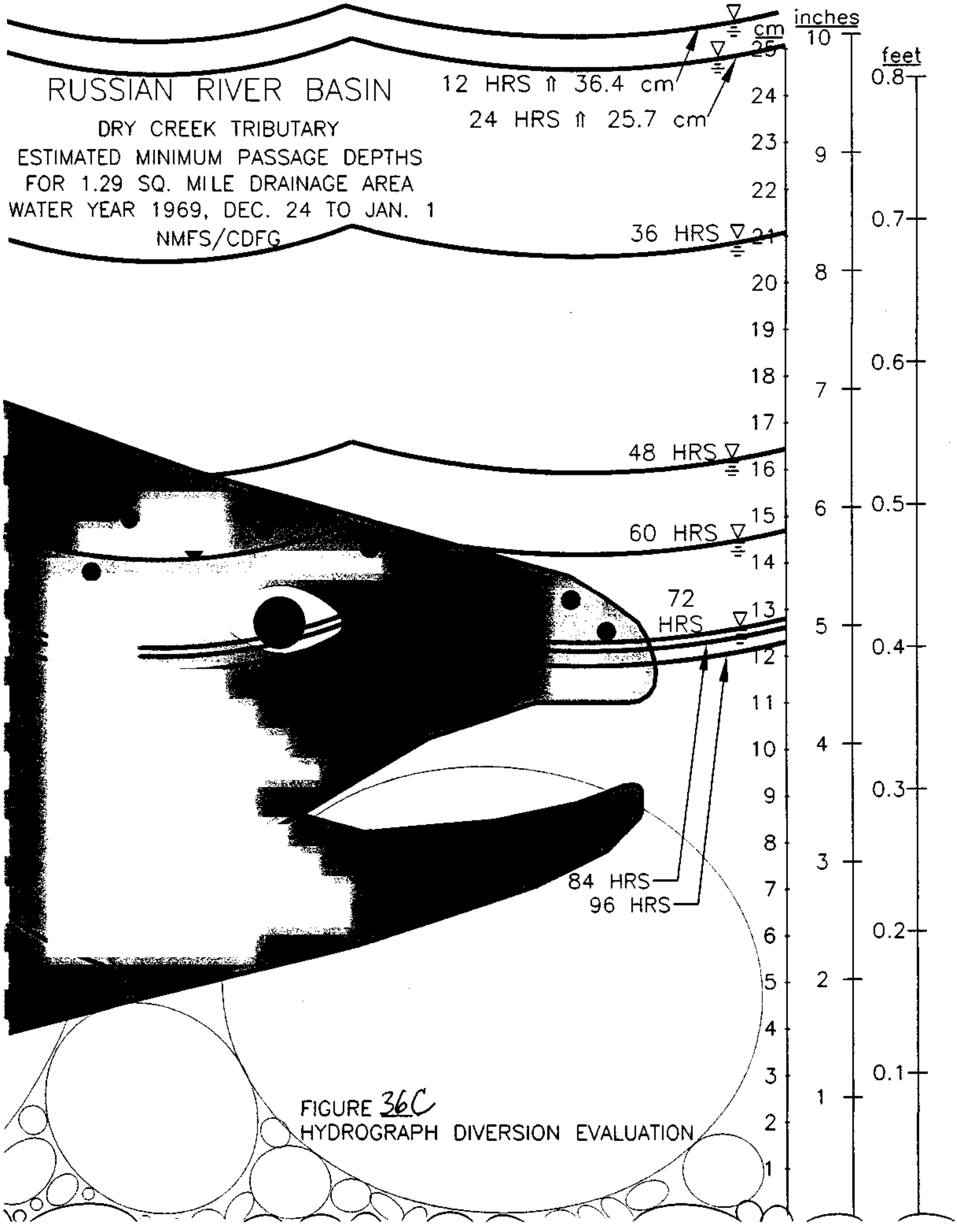


FIGURE 36C
HYDROGRAPH DIVERSION EVALUATION

Fig 36D

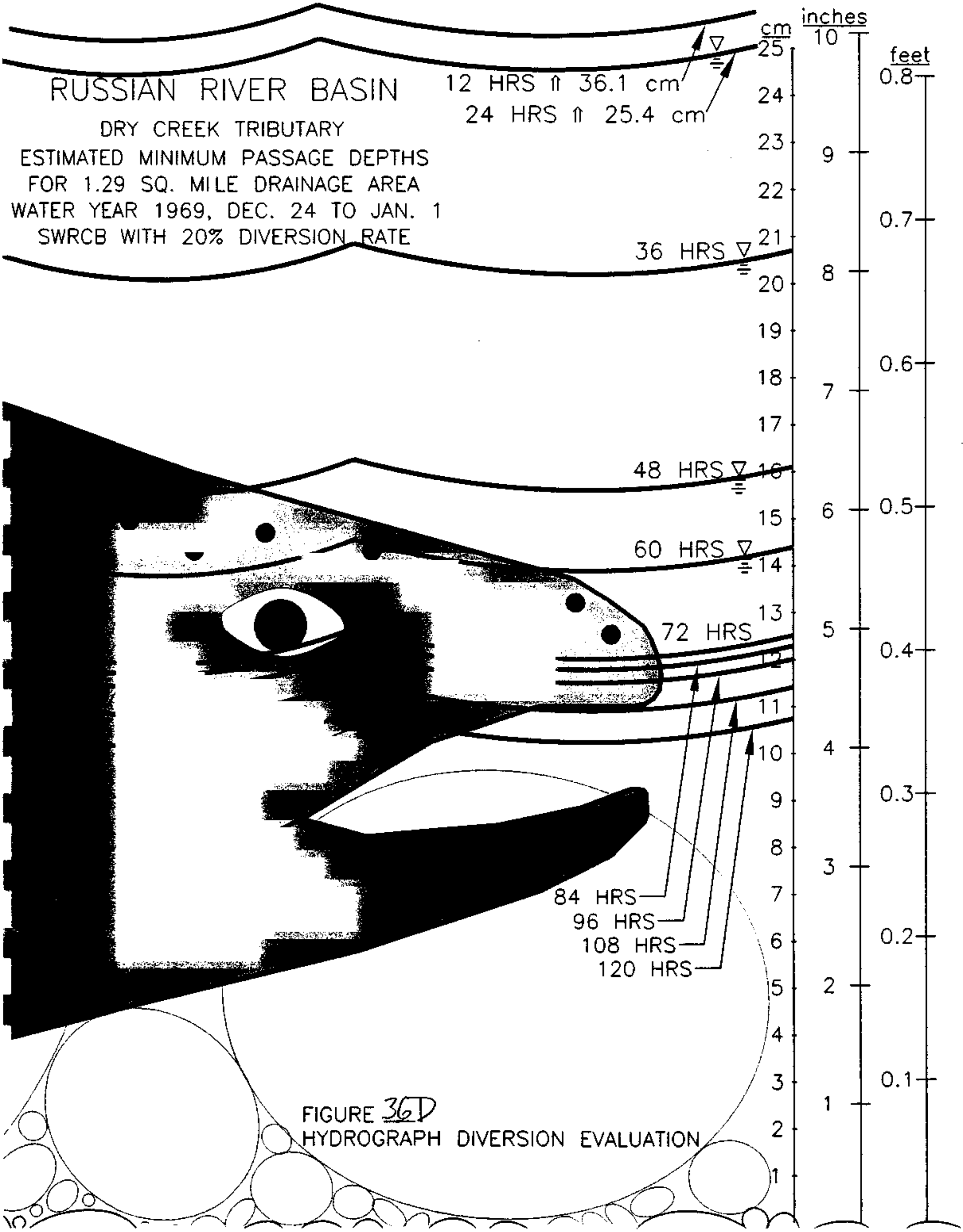


FIGURE 36D
HYDROGRAPH DIVERSION EVALUATION

Fig 37A

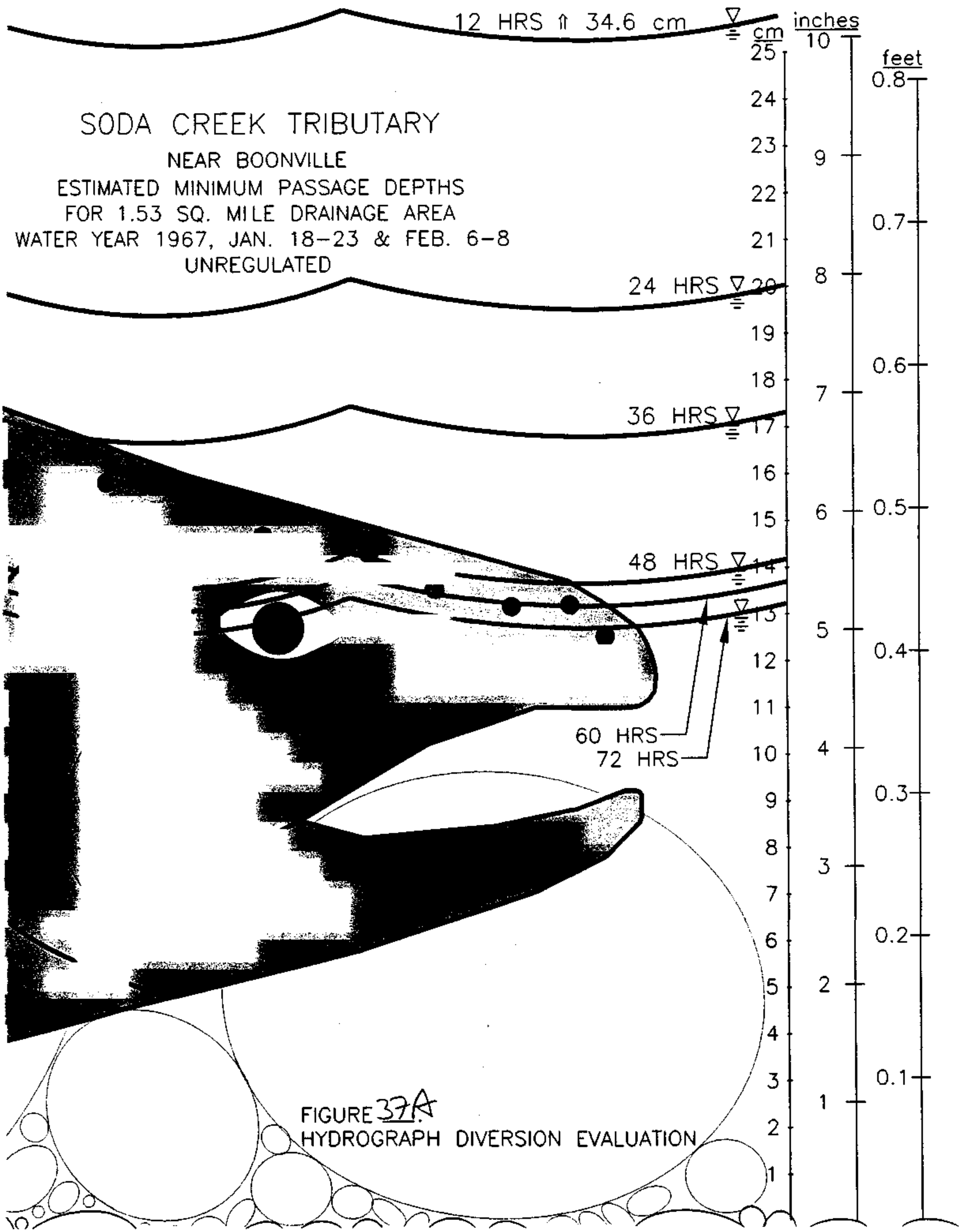


FIGURE 37A.
HYDROGRAPH DIVERSION EVALUATION

Fig 37B

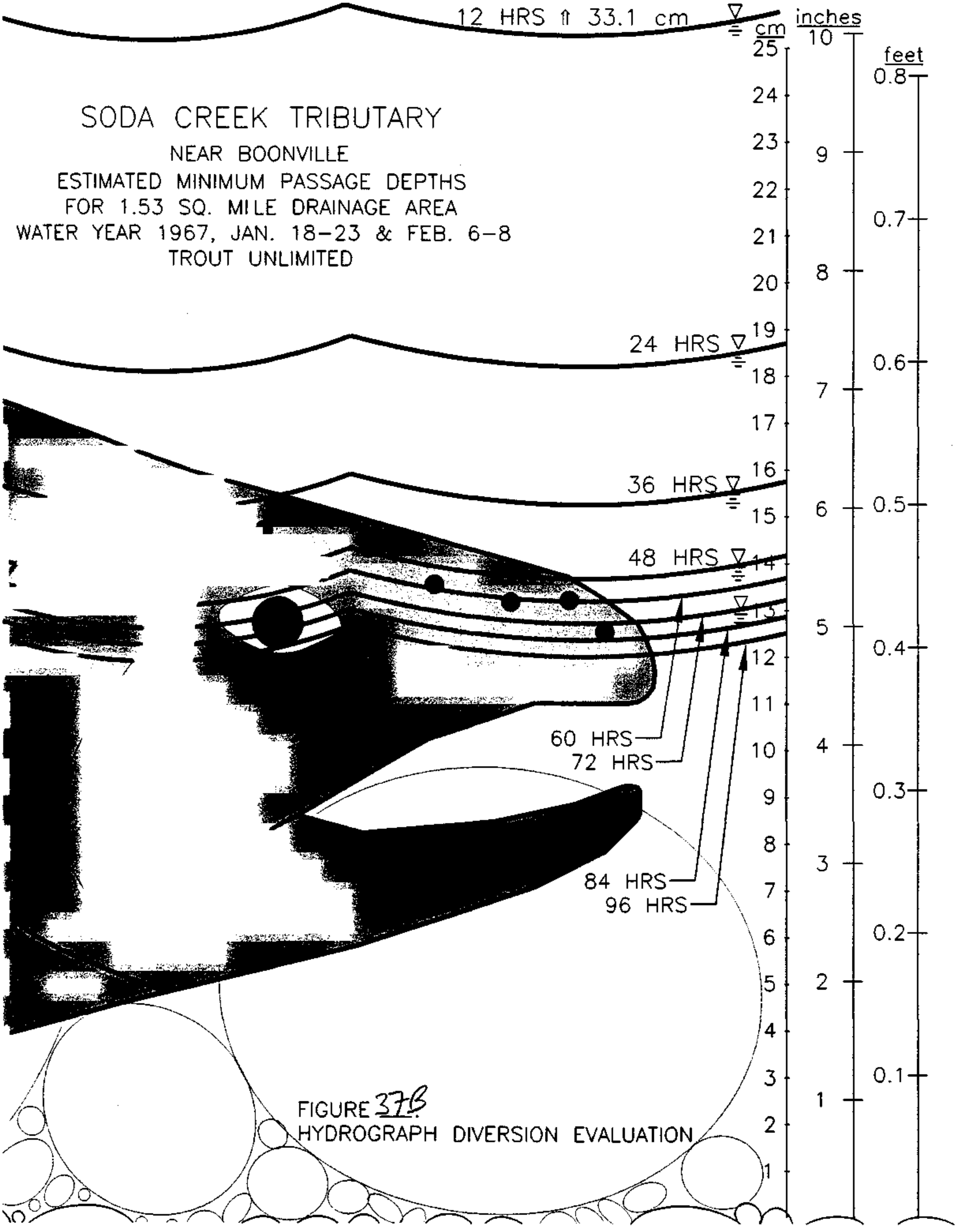


FIGURE 37B
HYDROGRAPH DIVERSION EVALUATION

Fig 37C

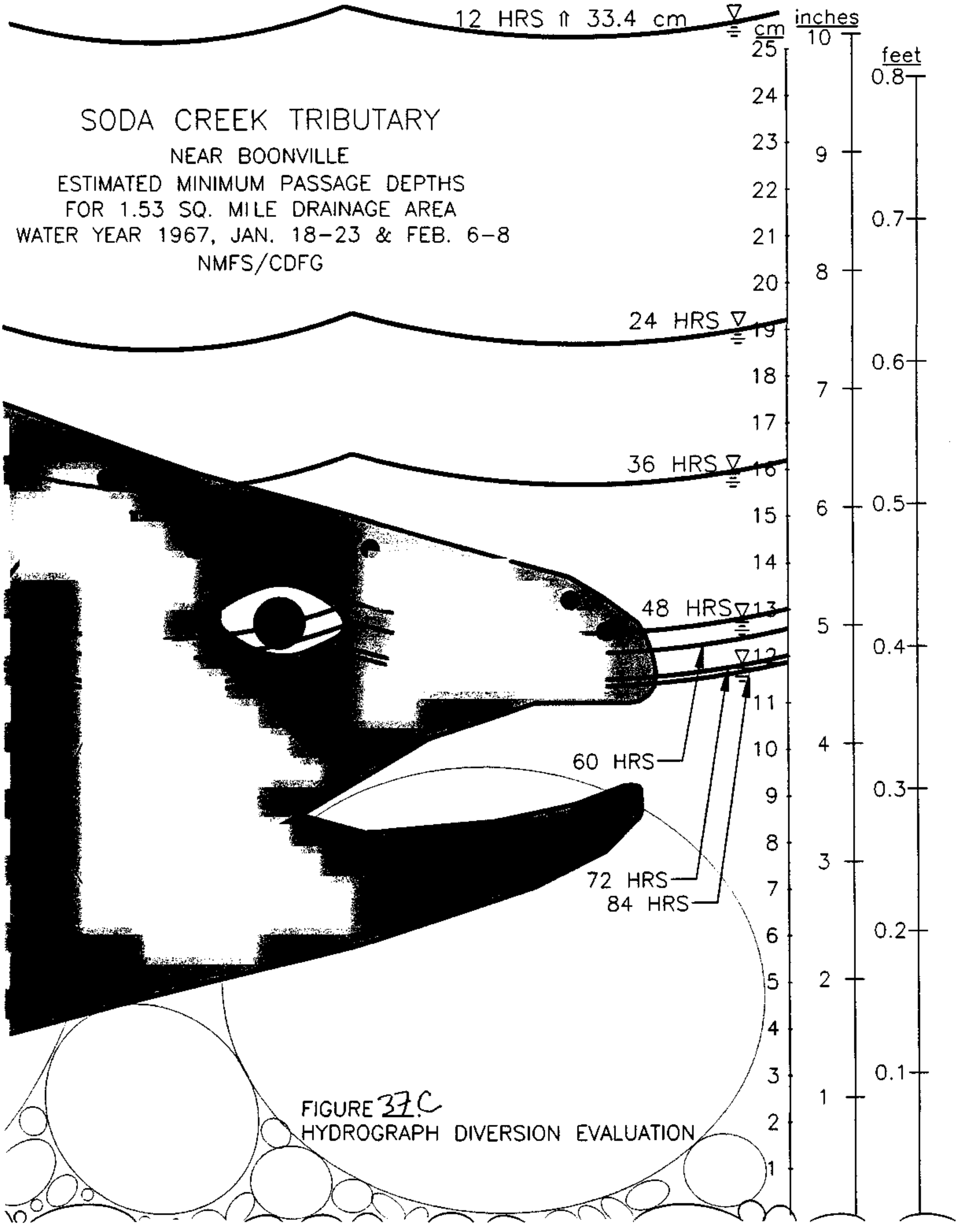


FIGURE 37.C
HYDROGRAPH DIVERSION EVALUATION

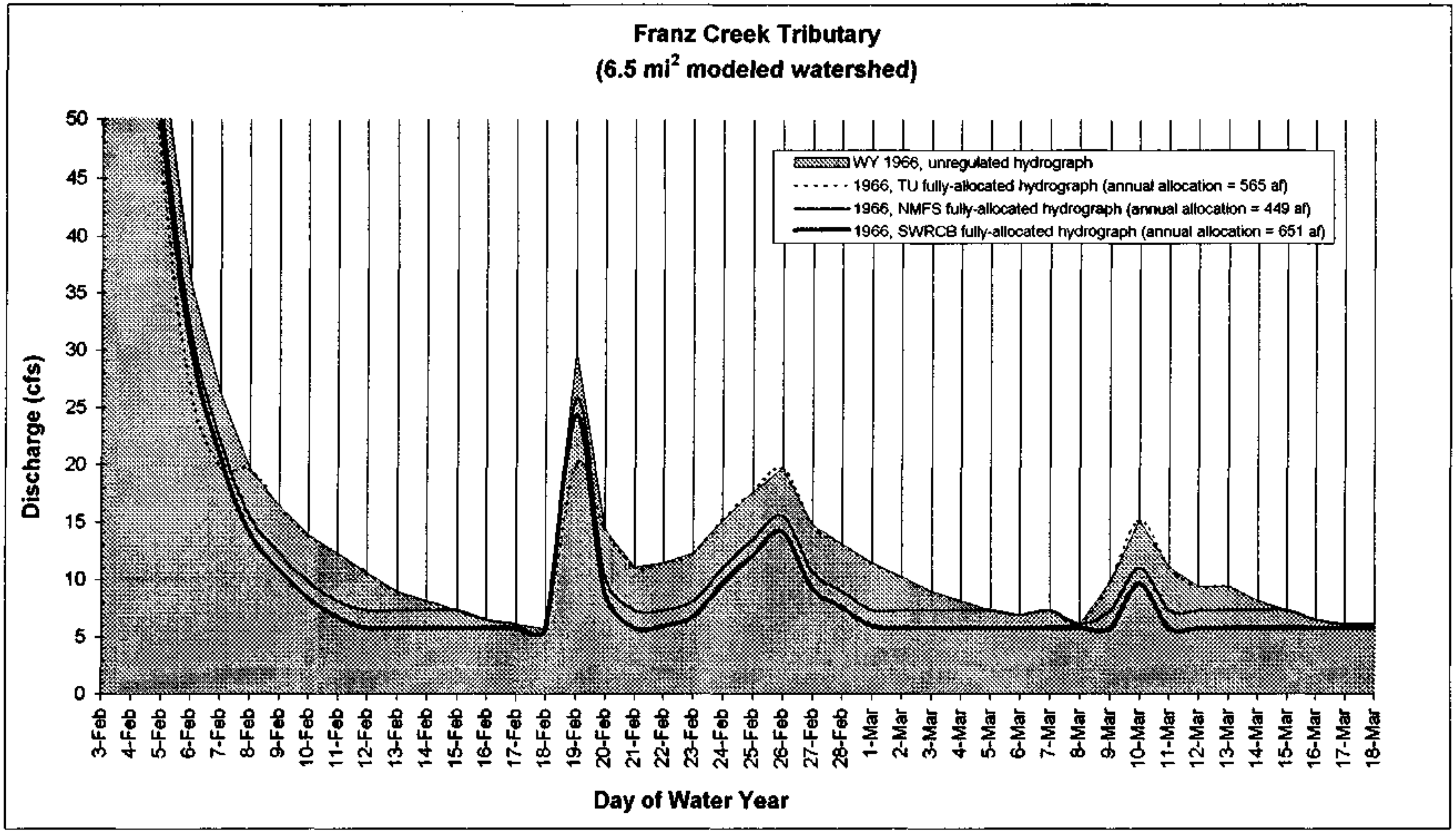


Figure 38A. Daily diversions by the three proposed allocation protocols modeled from the unregulated WY1966 annual hydrograph for a modeled sub-watershed (6.5 mi^2) in Franz Creek, Russian River Basin.

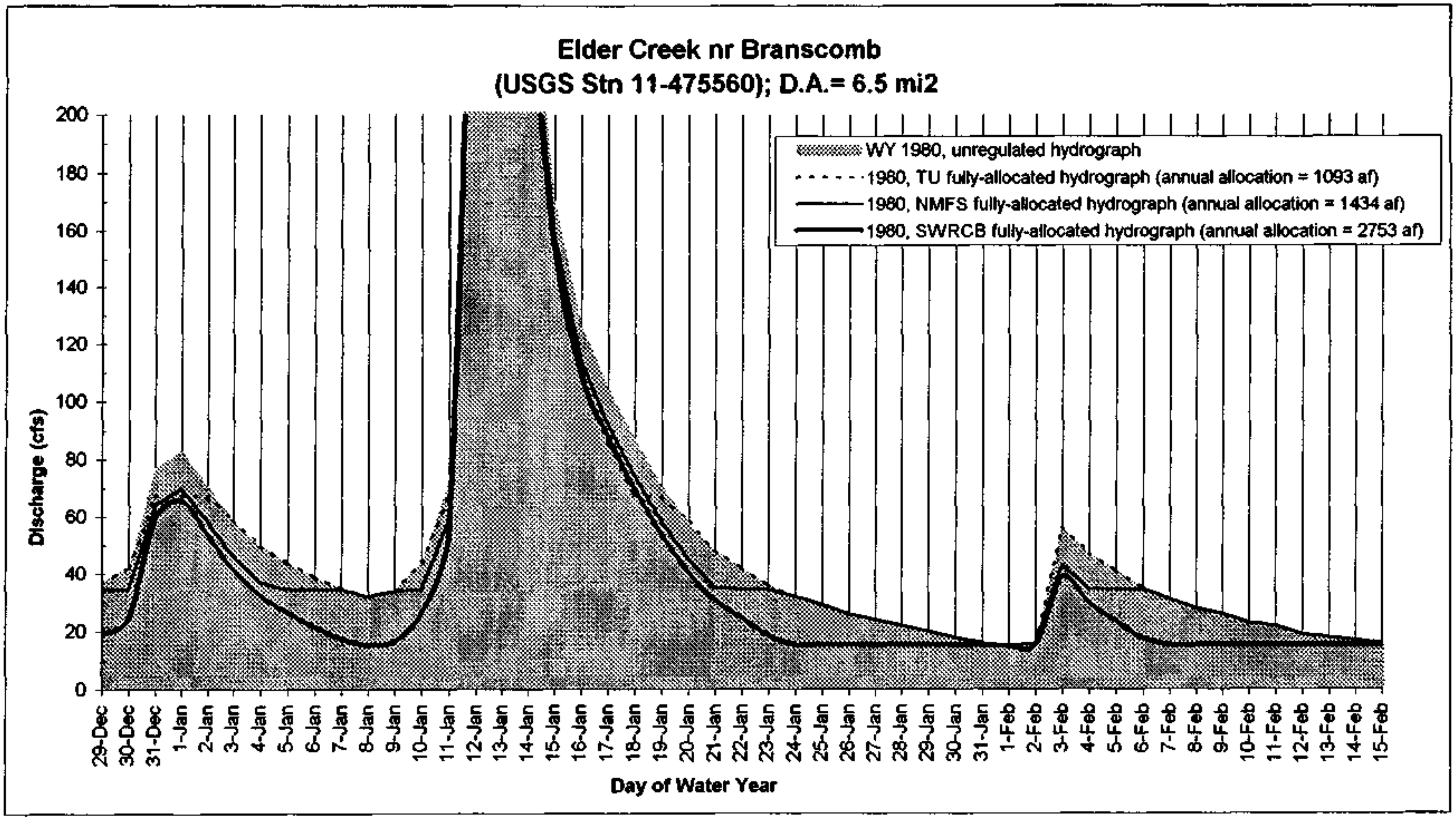


Figure 38B. Daily diversions by the three proposed allocation protocols modeled from the unregulated WY1980 annual hydrograph for Elder Creek (6.5 mi^2), South Fork Eel River Basin.

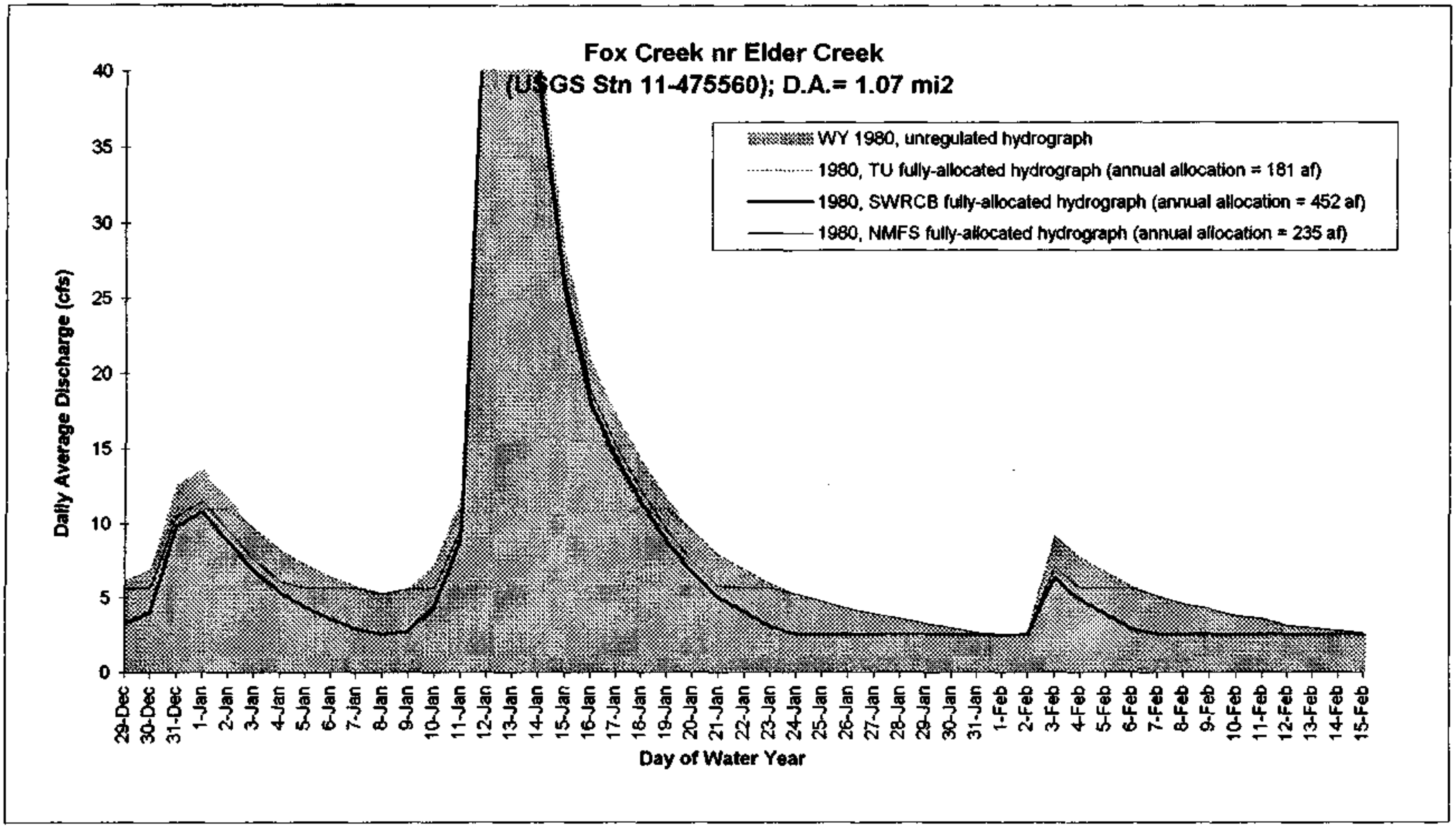


Figure 38C. Daily diversions by the three proposed allocation protocols modeled from the unregulated WY1980 annual hydrograph for Fox Creek (1.07 mi^2), South Fork Eel River Basin.

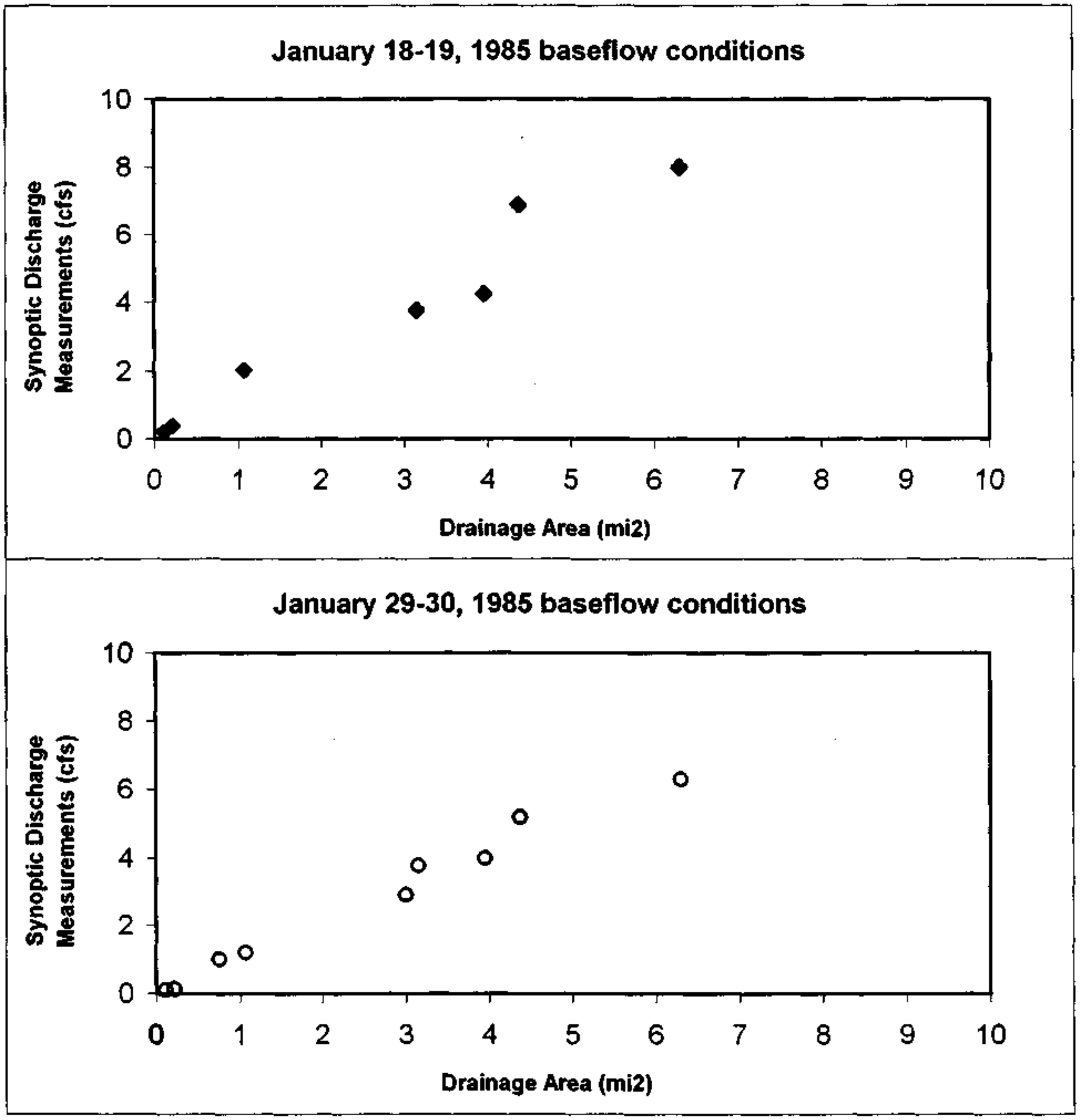


Figure 39. Synoptic baseflow measurements (cfs) in the South Fork Eel River Basin.

APPENDICES

Appendix 1. Letter from Steve Edmondson, National Marine Fisheries Service to William Trush, PhD, McBain and Trush, dated March 31, 2000.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
777 Sonoma Ave, Room 325
Santa Rosa, California 95404

March 31, 2000 F/SWR4:SE

William Trush,
Ph.D. McBain and
Trush P.O.Box 663
Arcata, CA 95521

Dear Bill:

Thanks for the call on March 16. I'm very encouraged by our conversation and appreciate the time you're taking to provide the documents we discussed oh the 16th. I look forward to receiving that information and to sharing ideas with you. I think the presentation of your recommended flow allocation protocol at the SWRCB technical workshop on January 31 was useful and indicates our mutual interest in providing greater protection for salmonids by modifying the diversion and bypass flow guidelines adopted by SWRCB. It appears that the principal difference between your protocol and the NMFS draft guidelines is the minimum bypass flow guideline. You have recommended a minimum bypass flow equivalent to the 10% daily average flow exceedence; NMFS has recommended a minimum bypass flow equal to the February median flow. To help us evaluate the relative merits of your flow guidelines, please provide us with additional clarification on the following aspects of your recommended minimum bypass flow.

1. In your memo, dated January 10, 2000, and in your presentation, you described the "Active Channel" as a morphologically distinct and readily identifiable portion of the stream channel, the boundaries of which are approximated by the stage height equivalent to the 10% daily average flow exceedence. You stated that all spawning and egg incubation occur within the Active Channel. In your January 10 memo you state, *"An individual salmonid spends its entire freshwater life within this inner channel in dry years and wet; only rarely (if ever) does it venture outside. Diversions that reduce naturally occurring flows confined within this inner channel will begin to de-water riffles, abandon side channels, impede upstream migration, and encourage riparian encroachment."* While it is true that salmonids spend most or all of their time within the "active channel", it could also be said that salmonids spawn and reside <u>within</u> the boundaries defined by the bankful channel or even the flood plain. Table 1 below shows the approximate percentage of time that your recommended minimum flow level is reached between December 15 and March 31 in several Russian River tributaries. Please explain why the upper boundaries of the Active Channel is a justifiable lower limit for water diversions, when natural flows generally do not wet the upper margins of the Active Channel during most of the time each winter. What data corroborate that spawning and incubation occur near the top margin of the active channel?

Table 1. 10% Annual Daily Average Flow and associated percent exceedence values during the winter diversion period (Dec l5-Mar 31).

Stream	USGS Gage No.	10% Annual Daily Average Flow (cfs)	Percent Exceedence during Dec 15 - Mar 31
Maacama Creek	11463900	177	27
Pena Creek	11465150	92	27
Santa Rosa Creek	11465800	38	27
Big Sulphur Creek	11463170	86	25.5 (13.1 mi^2)
Big Sulphur Creek	11463200	248	28.5 (85 mi^2)

2. As indicated above, we are trying to understand the biological rationale for the need to adopt a minimum flow equivalent to the 10% annual average daily exceedence flow. We understand that salmonids ascend streams and spawn in headwater tributaries at relatively high flows (e.g., flows near or exceeding the 10% annual average daily exceedence flow). You have also stated that, for individual fish, spawning is completed within a matter of days and that relatively high flows are needed to facilitate upstream and downstream movements. We recognize that flows exceeding the February median flow are probably needed to facilitate movements and spawning in headwater tributaries. Accordingly, NMFS draft guidelines maintain intermediate *(i.e.,* flows between the February median and the 10% annual daily average exceedence flow) and high flows by limiting the cumulative rate of withdrawal for any point on a stream. What is unclear is the rationale for the necessity to maintain the minimum bypass flow at a level equivalent to the flow that facilitates movements and spawning, when movement and spawning flows can be conserved by limiting the cumulative rate of withdrawal. This would entail limiting both the rate of instantaneous withdrawal for individual projects as well as the number of projects. We have contrasted NMFS and your recommended minimum flow guidelines, under scenarios that limit the rate of instantaneous withdrawal to 15% and 20% of the "winter 20% exceedence flow", and found a relatively minor difference in the duration of flows higher than the February median (Table 2). For the 21 years of record on Maacama Creek, your minimum flow protocol would annually provide an average of fifty (50) days when flow exceeded February median; the NMFS guideline with a maximum withdrawal

rate of 15% of the "winter 20% exceedence flow" provides an annual average of 40 days each winter when flows are greater than February median. With respect to "intermediate" flows, for the period of record on Maacama Creek, your minimum flow protocol would annually provide an average of five (5) additional days of "intermediate flows" over the NMFS guideline with a maximum withdrawal rate of 15% of the "winter 20% exceedence flow", and six (6) additional days of intermediate flows if the NMFS guideline employs a maximum withdrawal rate of 20% of the "winter 20% exceedence flow". This reduction in the number of days of higher flow appears to be the principal difference in protection afforded by your protocol and the NMFS guidelines. The significance of this difference is difficult to ascertain, given the lack of information concerning the relationship between migratory movements of adult anadromous salmonids during the spawning period and stream flow in headwater streams. Please provide any data that you might have that documents the relationship between spawning of anadromous salmonids and stream flow as it relates to annual flow duration.

Table 2. Number of days with flows greater than the February median at the Maacama Creek gage during winter (December 15-March 31) under historic conditions (1961-1981) and under a scenario with maximum theoretical water withdrawals consistent with NMFS draft guidelines.

Year	Historic Conditions	NMFS Guidelines	Percentage of high flow days retained by NMFS guidelines
1961	42	29	69
1962	43	35	81
1963	36	27	75
1964	12	9	75
1965	46	35	76
1966	51	34	67
1967	43	37	86
1968	41	33	80
1969	75	67	89
1970	69	55	80
1971	50	36	72
1972	26	13	50
1973	79	65	82

Table 2 continued

Year	Historic Conditions	NMFS Guidelines	Percentage of high flow days retained by NMFS guidelines
1974	84	68	81
1975	53	48	91
1976	4	1	25
1977	0	0	~
1978	72	57	79
1979	36	31	86
1980	61	49	80
1981	36	27	75
Mean[1]:	50	40	
Median[1]:	46	36	

[1] excluding 1976-1977

3. Flushing flows equivalent to $Q_{1.5}$ or Q_2 (unimpaired flows with a recurrence interval of 1.5 or 2 years) would be protected because maximum cumulative withdrawal rates of 15% of the "winter 20% exceedence flow" is an insignificant and very small fraction of $Q_{1.5}$ and Q_2. Do you agree that limiting the maximum cumulative rate of withdrawal to 15% of the "winter 20% exceedence flow" would be sufficiently protective of flushing flows in tributaries of coastal watersheds?

4. During the January 31 workshop you distributed and presented a figure illustrating alternative water withdrawal scenarios in Elder Creek (USGS Stn 11-475560) during early February for an unspecified year (Figure 1) In that figure the rate of withdrawal under the Trout Unlimited proposal appears to taper off to zero before flows reach the TU minimum flow level. This contrasts with your depiction of withdrawals under the SWRCB and NMFS proposals, which withdraw a constant rate of water until the minimum flow is reached. Please explain why the TU proposal has a gradually reduced withdrawal rate on the descending limb of Figure 1 when flows are higher than the TU minimum bypass flow?

5. In our telephone conversation on March 16, 2000 you suggested that implementation of NMFS draft guidelines may result in an approximately 45 to 50% reduction in available spawning habitat for salmonids. Our agency's draft guidelines are designed to avoid

impacts by protecting spawning habitats that could potentially support successful incubation and fry emergence. Bjornn and Reiser (1991) include water depth above the redd, and surface water discharge and velocity as some of the important variables upon which successful incubation of embryos and fry emergence depend. They state that permeability (the ability of particles in the redd to transmit water per unit of time) and *apparent velocity* (volume of water passing through a given area of redd per unit of time) are two commonly used measures of the suitability of a redd for successful incubation of salmonid embryos. Addressing the relationship between apparent velocity and surface flows, Bjornn and Reiser (1991) state,

> *Apparent velocity of water in redds may increase or decrease with the depth (and quantity) of the surface water (Reiser and White 1981a). Early evidence of this was reported by Wickett (1954), who found a direct relation between gage-height readings in a stream and subsurface flow. Chapman et al. (1982) also observed decreases in apparent velocity when flow decreased from 1,982 to 1,019 m2/s in the Columbia River.*

The NMFS recommendation to prohibit withdrawals when flows are less than the February median is intended to protect sustained surface flows that pass over incubating eggs deposited in streambed gravels. It is intended to maximize effective spawning habitat as described by Nestler et al. (1989). Although we recognize that under certain circumstances, incubation can take place in temporarily dewatered areas, the minimum flow standard that you have advocated would protect areas of streambed that are wetted only 25% of the time during the winter and would be dewatered during much of any 37+ consecutive day period of spawning and incubation. NMFS recommendation to limit withdrawals to a fraction of the "winter 20% exceedence flow" ensures the protection of flushing flows and only a modest reduction in the total number of days with intermediate flows needed to facilitate fish passage. We are unable to determine how implementing NMFS draft guidelines could result in a 45 to 50% reduction in effective spawning habitat, and/or areas that would potentially support successful incubation and emergence of fry. Because of guidelines concerning cumulative rates of withdrawal, such a reduction would not be possible even during years with especially high flows.

Please provide the above information at your earliest convenience in order to promote resolution of issues concerning instream flow needs and diversion guidelines to protect anadromous salmonids in coastal watersheds.

Sincerely,

Steven Edmondson
Fishery Biologist

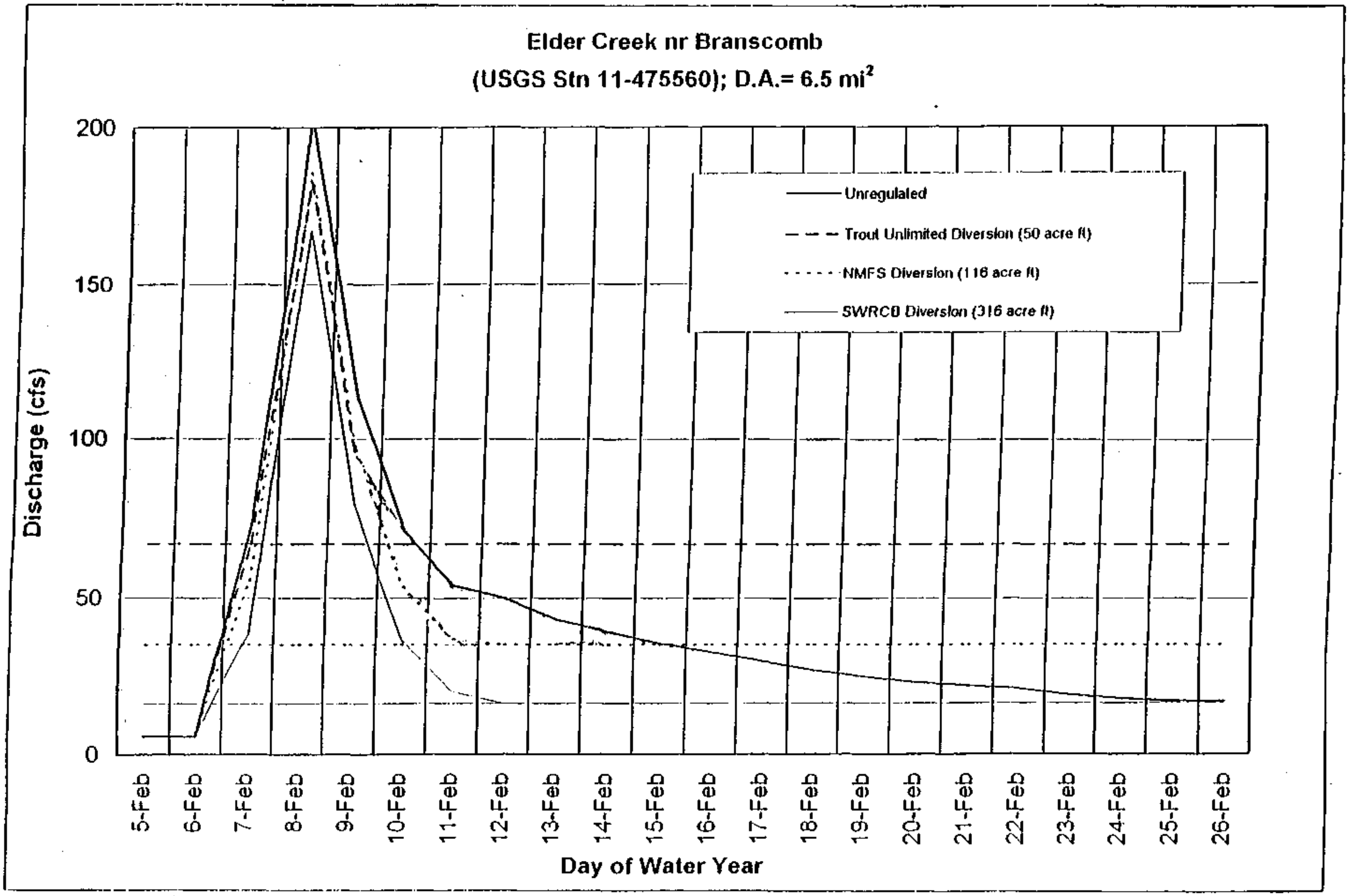
cc: R. Roos-Collins, National Heritage Inst.
P. Moyle, CSU,
Davis M. Kondalf, CSU, Berkeley
J. Johns, SWRCB
N. Bonsignore, Wagner & Bonsignore
J. Steele, CDFG, Sacramento
W. Cox, CDFG, Yountville
F. Smith, Carmichael, CA

<u>Literature Cited</u>

Bjornn, T.C., and D.W. Reiser. 1991. Habitat Requirements of salmonids in streams. pp 83-138. Am. Fish. Soc. Special Publ. 19: 83-138.

Nestler, J.M., R.T. Milhous, and J.B. Layzer. 1989. Chapter 12. Instream habitat modeling techniques. pp. 296-315, In [Gore, J.A. and G.E. Petts, eds.] Alternatives in Regulative River Management. CRC Press. Baca Raton, FL.

Figure 1.



Elder Creek nr Branscomb
(USGS Stn 11-475560); D.A.= 6.5 mi²
Unregulated
Trout Unlimited Diversion (50 acre ft)
NMFS Diversion (116 acre ft)
SWRCB Diversion (316 acre ft)
Discharge (cfs)
200
150
100
50
0
5-Feb
6-Feb
7-Feb
8-Feb
9-Feb
10-Feb
11-Feb
12-Feb
13-Feb
14-Feb
15-Feb
16-Feb
17-Feb
18-Feb
19-Feb
20-Feb
21-Feb
22-Feb
23-Feb
24-Feb
25-Feb
26-Feb
Day of Water Year

Appendix 2. Original TU Position Published in the May 4, 1999 Commentary.

No water can be diverted nor natural runoff impaired before December 15 and after March 31. Water can be diverted only within a prescribed range, or "window", of flows between December 15 and March 31. This window has a lower limit equivalent to the 10% exceedence flow on an unimpaired daily average flow duration curve and an upper limit equivalent to 70% of the unimpaired bankfull discharge. The daily rate of water diversion shall not exceed an approved rate. All diversions will be subject to these restrictions whether anadromous salmonids occupy or could occupy the stream channel, or whether streamflow is perennial or intermittent. All downstream locations potentially impeding migratory access by adult and juvenile anadromous salmonids must be identified in the water right review process, then an explicit procedure followed to adequately assess potential cumulative adverse impacts from the existing diversion structure (if applicable) and the proposed water right application. No new in-channel reservoirs on anadromous, or potentially anadromous, salmonid stream channels will be permitted. Operation of existing in-channel reservoirs that diminish the downstream supply of coarse bed material will have an approved operational plan for annually replacing an equivalent volume of coarse bed material into the downstream channel.

We also recommend the following compliance, enforcement, and effectiveness monitoring provisions:

Guidelines for consistent implementation monitoring should be drafted and required by SWRCB as part of the water right application process. For commercial diversions, a licensed engineer should provide an annual compliance report including documentation of daily withdrawals with a data logger. Random selection and evaluation of the compliance reports should be conducted annually. Guidelines for this evaluation, as well as actions and/or penalties for non-compliance, also should be in the water right application. Effectiveness monitoring is critical, but should not be the direct responsibility of the water users. The SWRCB (jointly with other agencies) should devise and implement an effectiveness monitoring program as part of an ongoing adaptive management plan. Provisions in this plan must show a demonstrable feedback loop from future monitoring results to potential rule changes. This program would immediately include setting maximum allowable diversions for specific tributary watersheds, particularly those presently (or shortly) considered at or near over-allocation. Otherwise, downstream cumulative adverse impacts cannot be assessed in pending water right applications.

Appendix 3. Modeled Annual Diversions from Selected Watersheds.

Annual diversion volumes (ac-ft) and hydrographs for:

1. Dry Creek Tributary (1.27 mi^2) WY1968 and WY1969;
2. Elder Creek (6.5 mi^2) WY1980 through WY1989;
3. Fox Creek (1.07 mi^2) WY1980 through WY1989.
4. Franz Creek (15.7 mi^2) WY 1964 through WY1968;
5. Franz Creek sub-watershed (6.5 mi^2) WY1964 through WY1968;
6. Franz Creek sub-watershed (1.07 mi^2) WY1964 through WY1968;

Table A. Summary of annual diversion volumes for each diversion protocol:

Dry Creek Tributary nr Hopland (Stn 11-4640.5; DA=1.3 mi^2)

	1958	1969	average annual allocation
SWRCB Annual Allocation (af) =	203	304	253
NMFS Annual Allocation (af) =	56	126	91
TU Annual Allocation (af) =	69	147	108

Elder Creek (Stn 11-475560; DA=6.5 mi^2)

	1960	1961	1982	1983	1984	1986	1988	1987	1988	1989	
SWRCB Annual Allocation (af) =	2,753	2,014	2,503	3,309	2,240	811	2,461	2,347	1,352	2,081	2,187
NMFS Annual Allocation (af) =	1,434	937	1,340	2,304	1,184	313	1,505	1,123	574	941	1,166
TU Annual Allocation (af) =	1,093	355	2,471	3,447	1,515	565	1,438	530	978	904	1,330

Fox Creek (modeled from Elder Creek, Stn 11-475560; DA=1.1 mi^2)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	
SWRCB Annual Allocation (af) =	452	331	411	544	368	133	404	386	222	342	359
NMFS Annual Allocation (af) =	235	154	220	377	194	51	247	184	94	154	191
TU Annual Allocation (af) =	181	59	408	568	250	94	237	87	161	150	219

Franz Creek nr Kellogg (11-463940; DA=15.7 mi^2)

	1964	1965	1966	1967	1968	
SWRCB Annual Allocation (af) =	300	1,179	1,587	1,193	1,514	1,154
NMFS Annual Allocation (af) =	206	809	1,089	855	1,031	798
TU Annual Allocation (af) =	288	912	1,192	1,821	912	1,025

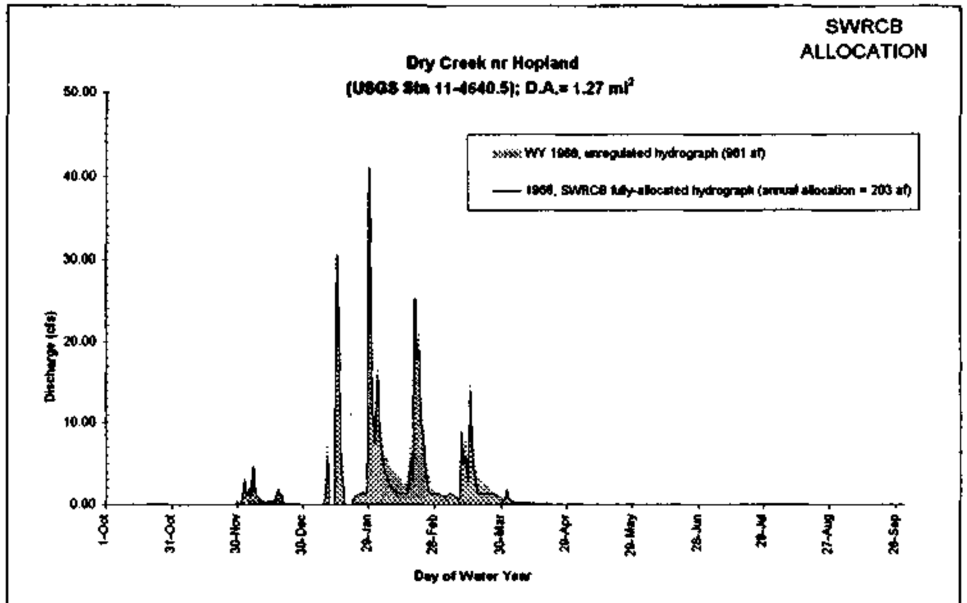
Franz Creek nr Kellogg (modelled at 6.5 mi^2)

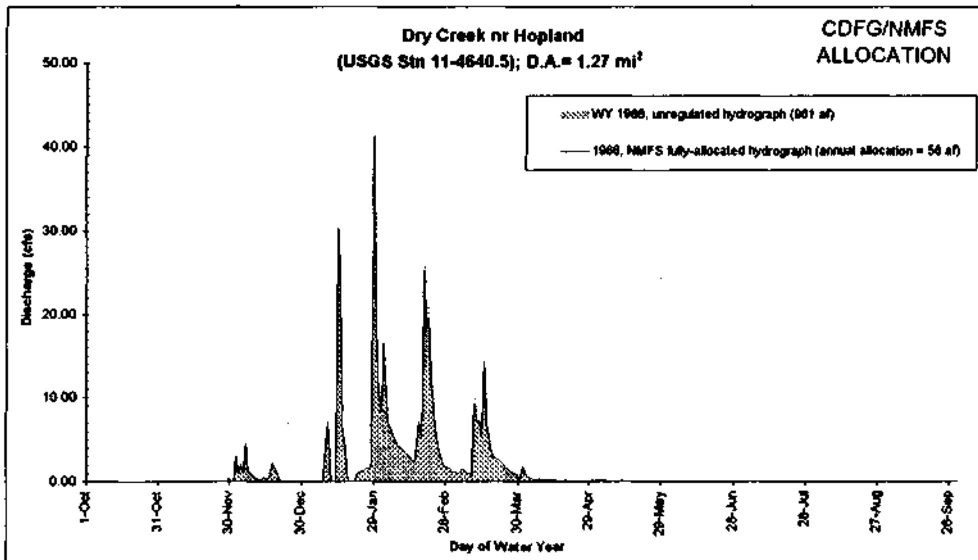
	1964	1965	1966	1967	1968	
SWRCB Annual Allocation (af) =	123	484	651	490	490	447
NMFS Annual Allocation (af) =	85	334	449	353	353	314
TU Annual Allocation (af) =	184	566	565	1,130	1,130	715

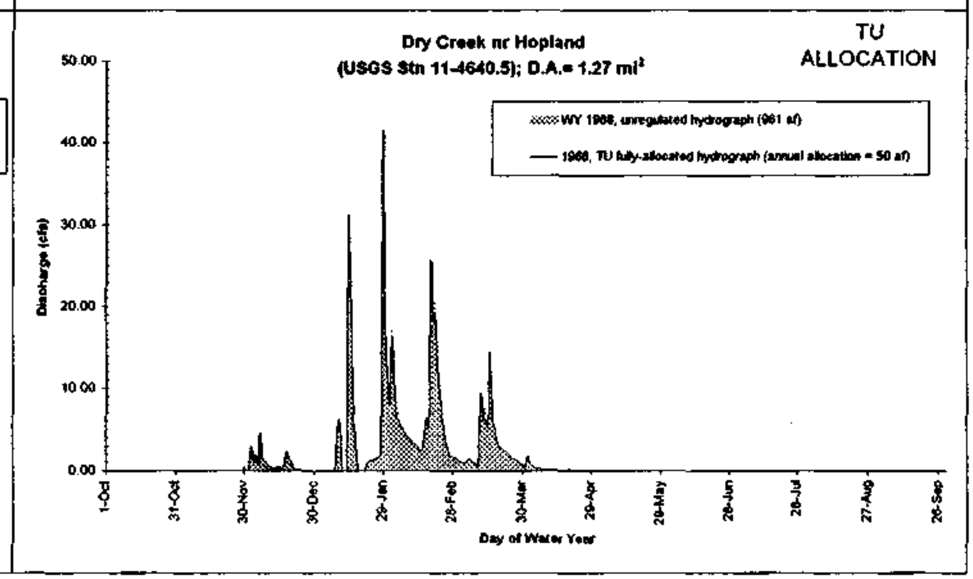
Franz Creek nr Kellogg (modelled at 1.1 mi^2)

	1964	1965	1966	1967	1968	
SWRCB Annual Allocation (af) =	20	80	108	81	103	79
NMFS Annual Allocation (af) =	14	55	74	58	71	55
TU Annual Allocation (af) =	26	82	81	163	82	87

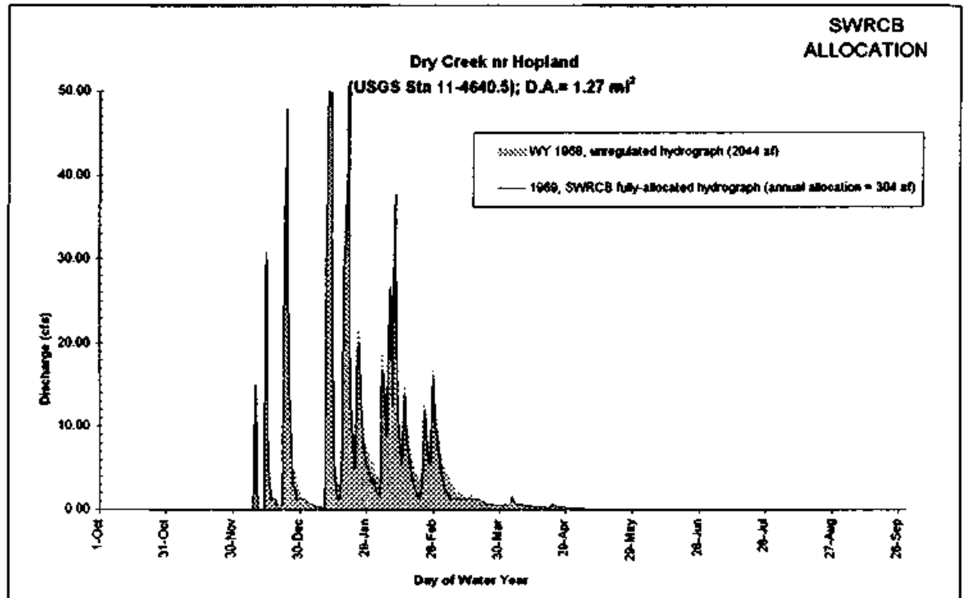
STREAM:	**Dry Creek Tributary**		
BASIN:	**Russian River**		
GAGING STATION:	**Dry Creek Tributary nr Hopland (Stn 11-4640.5.)**		
WATER YEAR	WY 1968		
DRAINAGE AREA	1.3 mi2		
QAVG FOR YEAR =	1.4 cfs		
60%QAVG =	1.3 cfs		
QMEDIANFEB =	7.2 cfs		
Q10%Ex =	8.2 cfs		
Q20%WINTER EX =	11.0 cfs		
Q20%(Q20%) =	2.2 cfs		
Q15%(Q20%) =	1.7 cfs		
TU Rate =	1.7 cfs		
Unregulated Annual Yield =	961 af	% of Total	
SWRCB Annual Allocation=	203 af	21%	
NMFS Annual Allocation=	56 af	6%	
TU Annual Allocation=	69 af	7%	

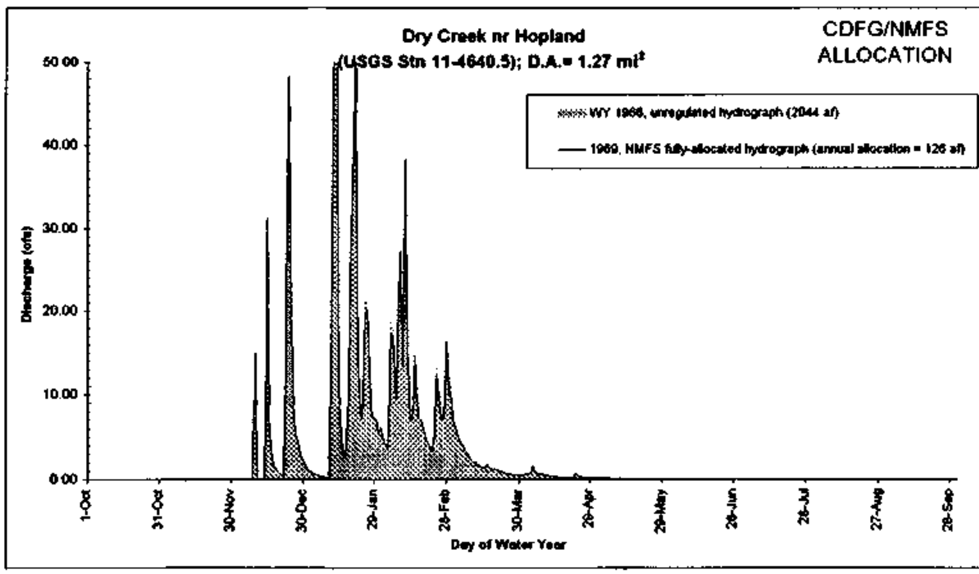


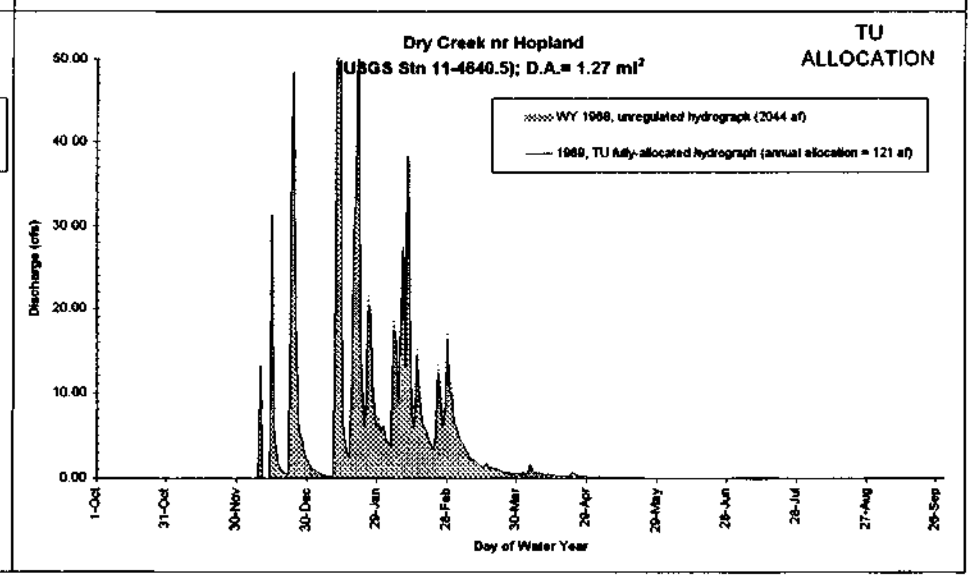




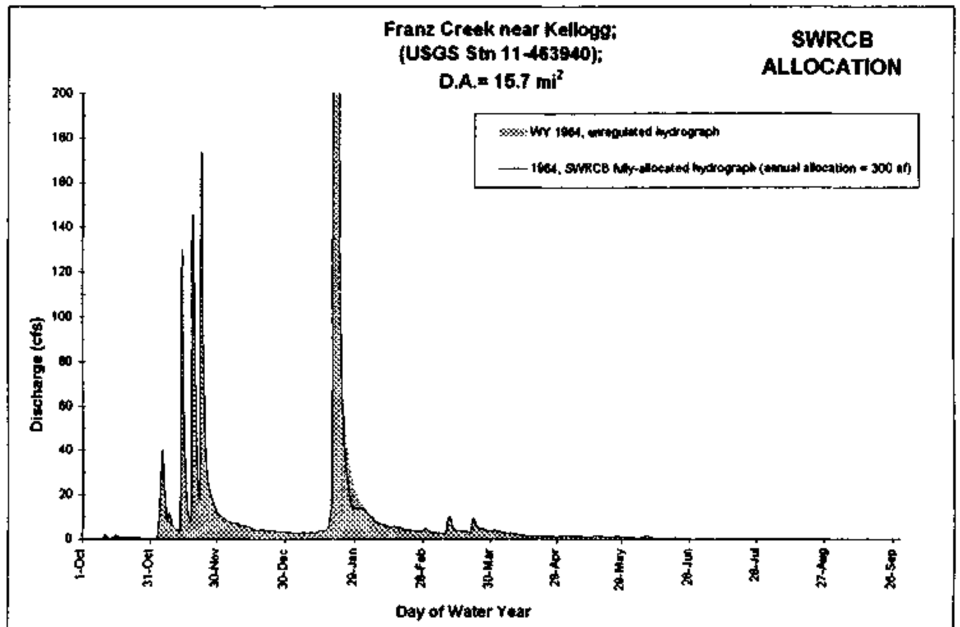
STREAM:	Dry Creek Tributary	
BASIN:	Russian River	
GAGING STATION:	Dry Creek Tributary nr Hopland (Stn 11-4640.5.)	
WATER YEAR	WY 1969	
DRAINAGE AREA	1.27 mi2	
QAVG FOR YEAR =	2.9 cfs	
60%QAVG =	1.3 cfs	
QMEDIANFEB =	7.2 cfs	
Q10%Ex =	6.2 cfs	
Q20%WINTER EX =	11.0 cfs	
Q20%(Q20%) =	2.2 cfs	
Q15%(Q20%) =	1.7 cfs	
TU Rate =	1.7 cfs	
Unregulated Annual Yield =	2,044 af	% of Total
SWRCB Annual Allocation=	304 af	15%
NMFS Annual Allocation=	126 af	6%
TU Annual Allocation=	147 af	7%

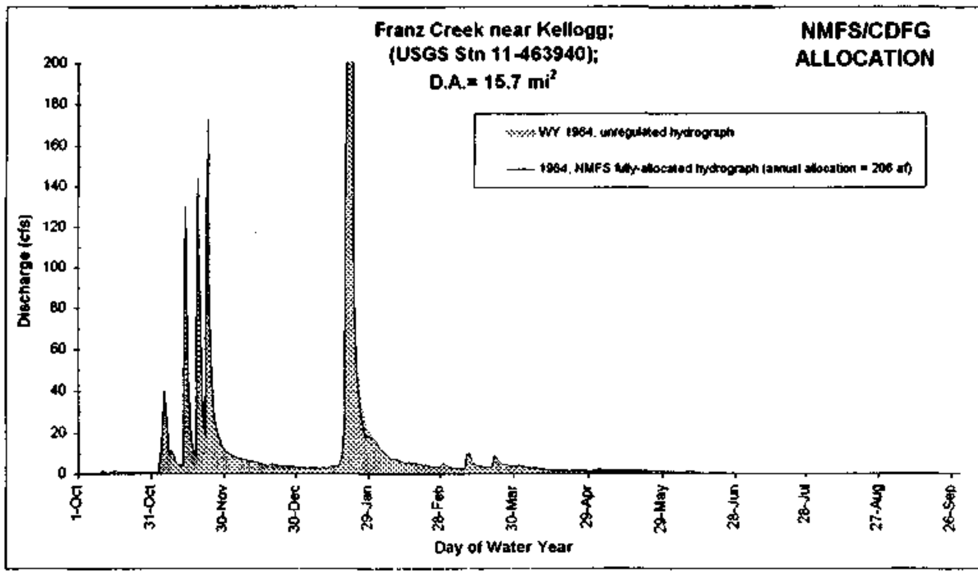


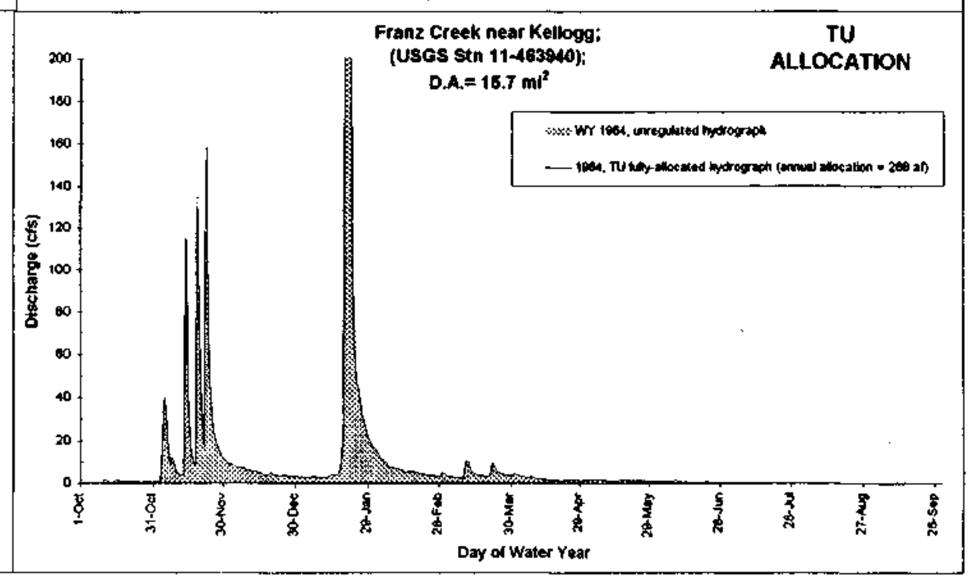




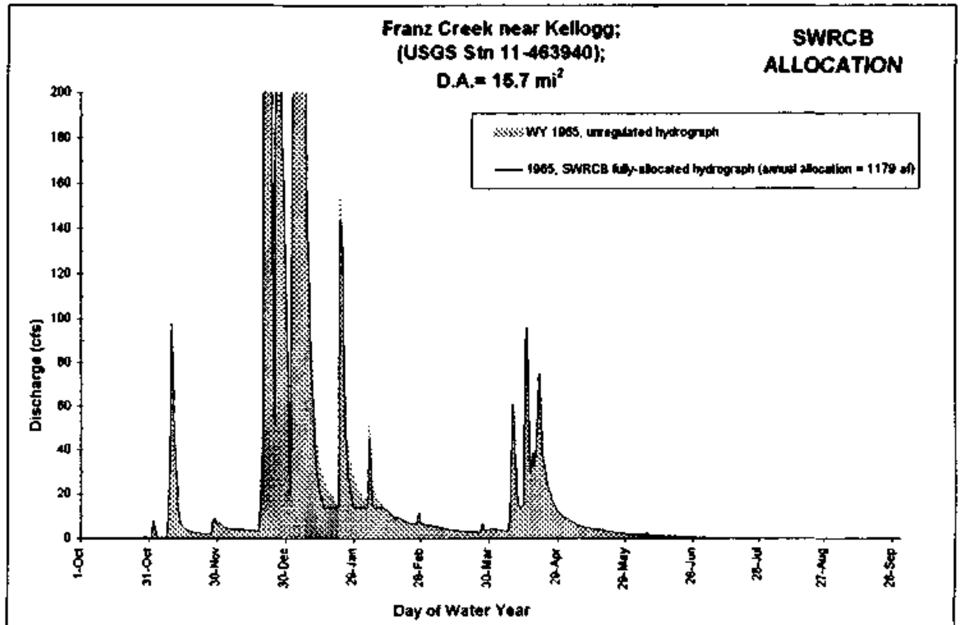
STREAM:	**FRANZ CREEK**	
BASIN:	**RUSSIAN RIVER BASIN**	
GAGING STATION:	Franz Creek nr Kellogg (11-463940)	
WATER YEAR	WY 1964	
DRAINAGE AREA	15.7 Mi2	
$Q_{AVG\ FOR\ YEAR}$ =	8.2 cfs	
$60\%Q_{AVG}$ =	14.1 cfs	
$Q_{MEDIANFEB}$ =	18.0 cfs	
$Q_{10\%Ex}$ =	48.0 cfs	
$Q_{20\%WINTER\ EX}$ =	67.0 cfs	
$Q_{20\%(Q20\%)}$ =	13.4 cfs	
$Q_{15\%(Q20\%)}$ =	10.0 cfs	
TU Rate =	15.0 cfs	
Unregulated Annual Yield =	3,484 af	% of Total
SWRCB Annual Allocation=	300 af	9%
NMFS Annual Allocation=	206 af	6%
TU Annual Allocation=	288 af	8%

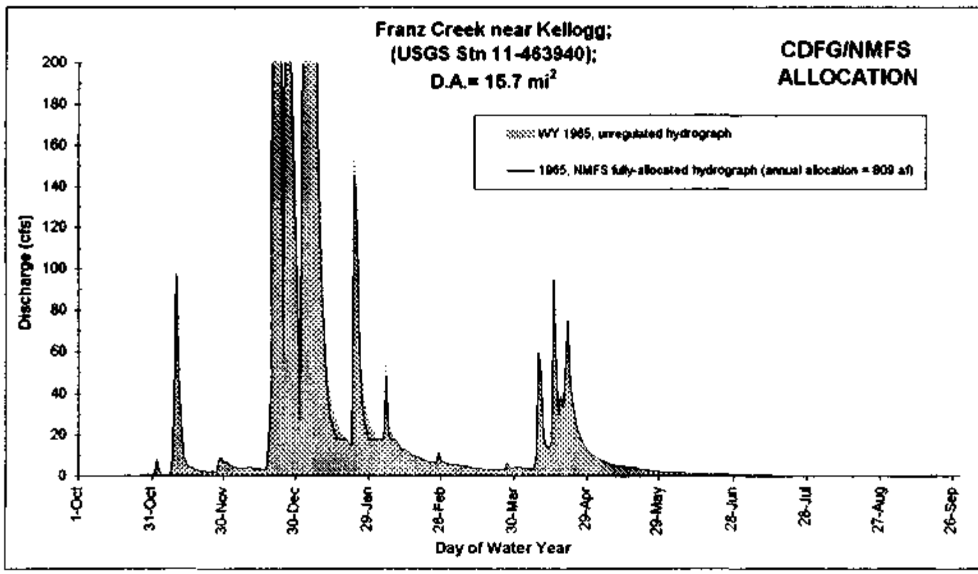


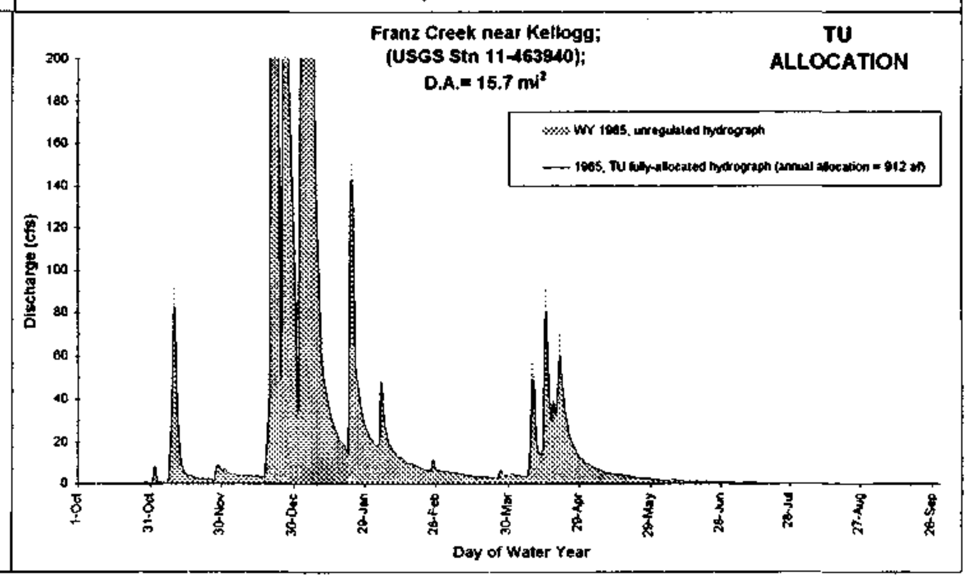




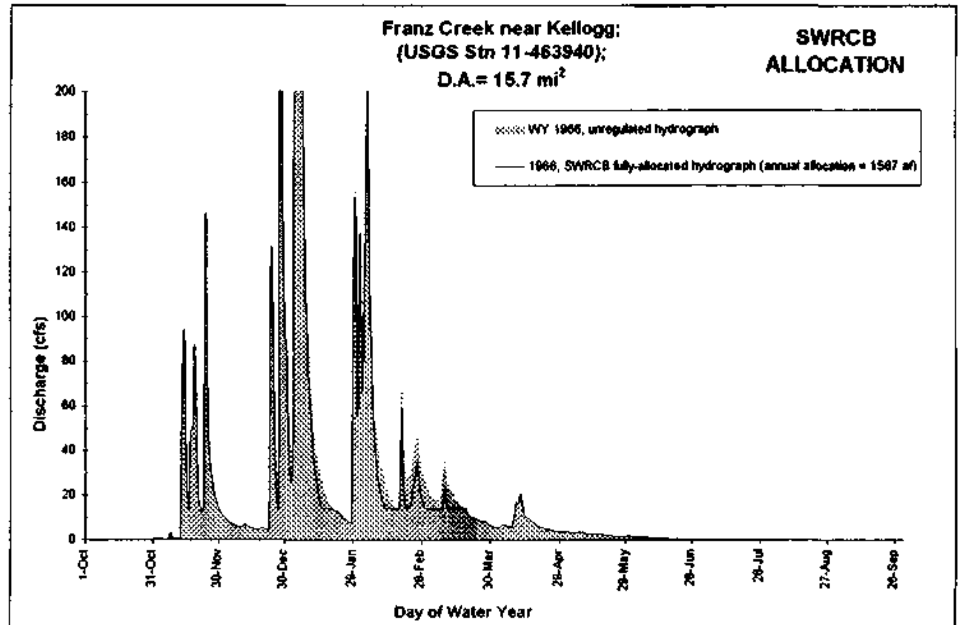
STREAM:	**FRANZ CREEK**	
BASIN:	**RUSSIAN RIVER BASIN**	
GAGING STATION:	Franz Creek nr Kellogg (11-463940)	
WATER YEAR	WY 1965	
DRAINAGE AREA	15.7 Mi2	
$Q_{AVG\ FOR\ YEAR}$ =	31.0 cfs	
60%Q_{AVG} =	14.1 cfs	
$Q_{MEDIANFEB}$ =	16.0 cfs	
$Q_{10\%Ex}$ =	48.0 cfs	
$Q_{20\%WINTER\ EX}$ =	67.0 cfs	
$Q_{20\%(Q20\%)}$ =	13.4 cfs	
$Q_{15\%(Q20\%)}$ =	10.0 cfs	
TU Rate =	15.0 cfs	
Unregulated Annual Yield =	19,719 af	% of Total
SWRCB Annual Allocation=	1,179 af	6%
NMFS Annual Allocation=	809 af	4%
TU Annual Allocation=	912 af	5%

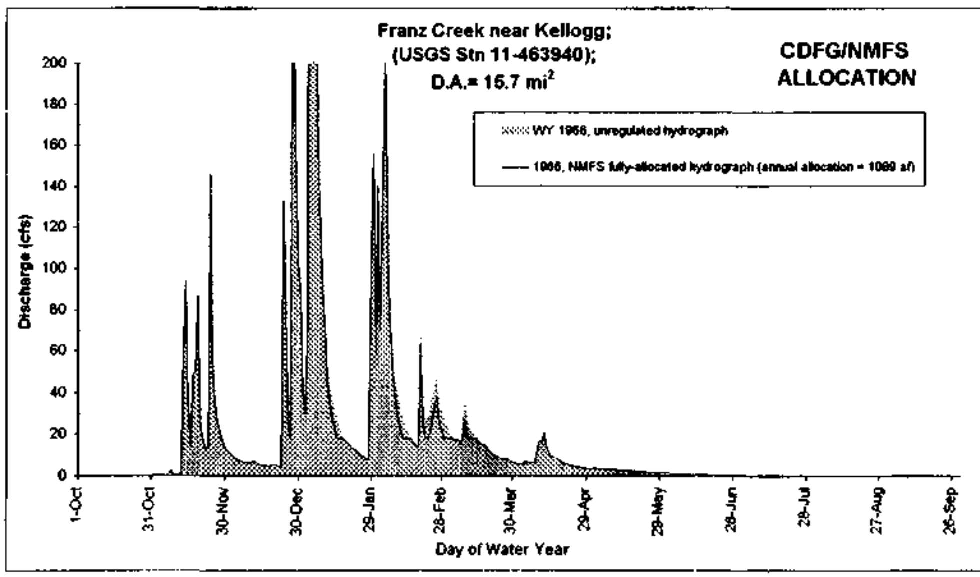


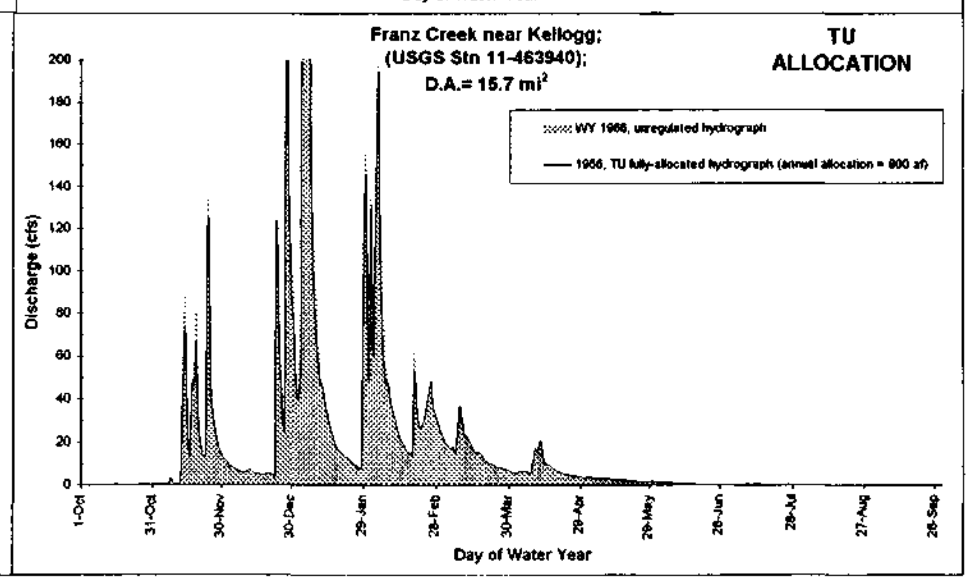




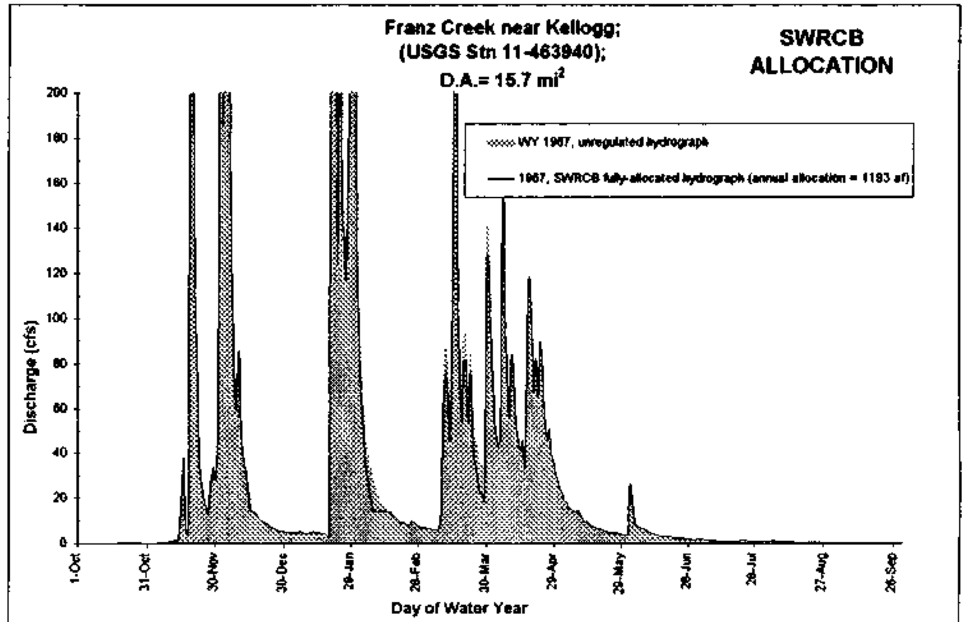
STREAM:	**FRANZ CREEK**	
BASIN:	**RUSSIAN RIVER BASIN**	
GAGING STATION:	Franz Creek nr Kellogg (11-463940)	
WATER YEAR	WY 1966	
DRAINAGE AREA	15.7 Mi2	
$Q_{AVG\ FOR\ YEAR}$ =	21.8 cfs	
$60\%Q_{AVG}$ =	14.1 cfs	
$Q_{MEDIANFEB}$ =	18.0 cfs	
$Q_{10\%Ex}$ =	48.0 cfs	
$Q_{20\%WINTER\ EX}$ =	67.0 cfs	
$Q_{20\%(Q20\%)}$ =	13.4 cfs	
$Q_{15\%(Q20\%)}$ =	10.0 cfs	
TU Rate =	20.4 cfs	
Unregulated Annual Yield =	13,348 af	% of Total
SWRCB Annual Allocation=	1,587 af	12%
NMFS Annual Allocation=	1,089 af	8%
TU Annual Allocation=	1,192 af	9%

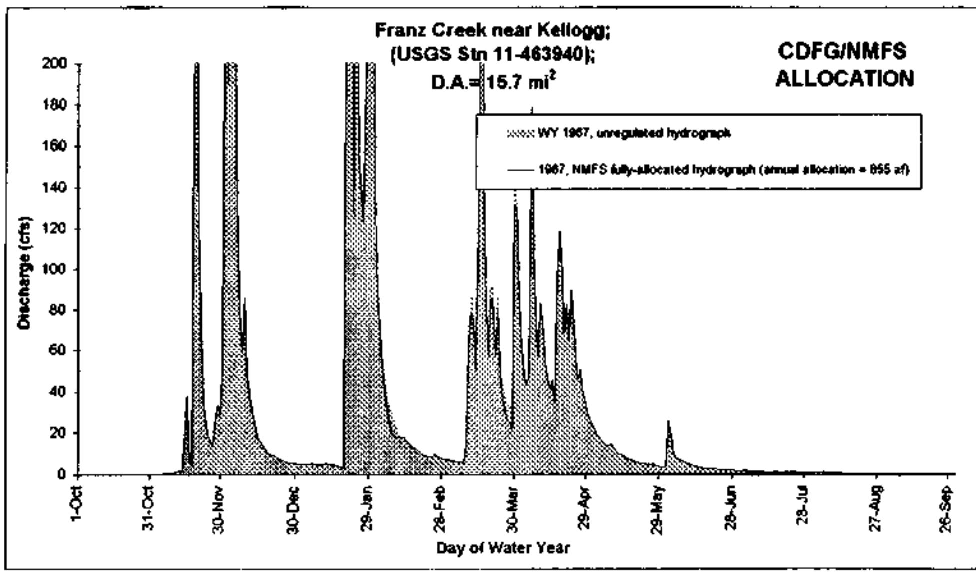


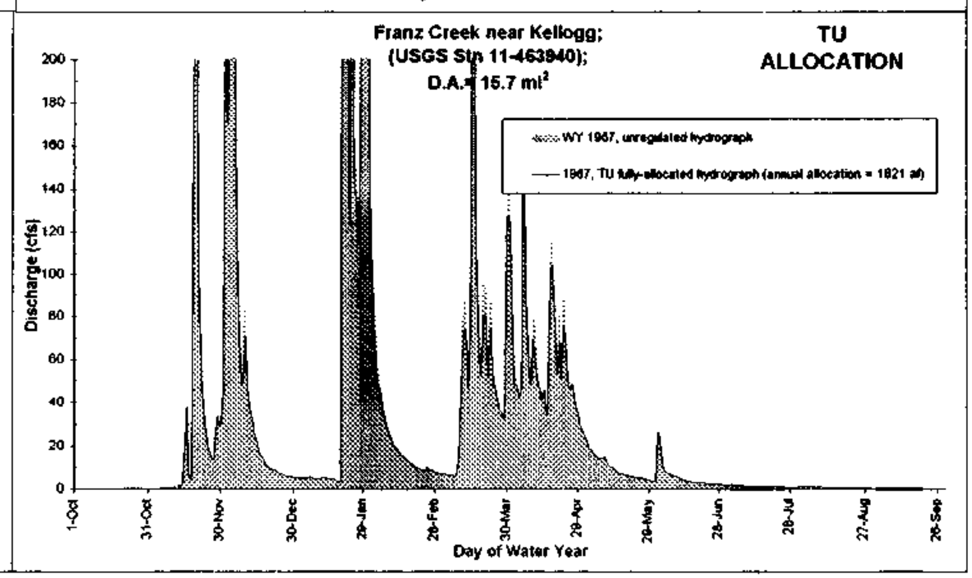




STREAM:	**FRANZ CREEK**	
BASIN:	**RUSSIAN RIVER BASIN**	
GAGING STATION:	Franz Creek nr Kellogg (11-463940)	
WATER YEAR	WY 1967	
DRAINAGE AREA	15.7 Mi2	
$Q_{AVG\ FOR\ YEAR}$ =	37.6 cfs	
60%Q_{AVG} =	14.1 cfs	
$Q_{MEDIANFEB}$ =	18.0 cfs	
$Q_{10\%Ex}$ =	48.0 cfs	
$Q_{20\%WINTER\ EX}$ =	67.0 cfs	
$Q_{20\%(Q20\%)}$ =	13.4 cfs	
$Q_{15\%(Q20\%)}$ =	10.0 cfs	
TU Rate =	15.0 cfs	
Unregulated Annual Yield =	15,249 af	% of Total
SWRCB Annual Allocation=	1,193 af	8%
NMFS Annual Allocation=	855 af	6%
TU Annual Allocation=	1,821 af	12%

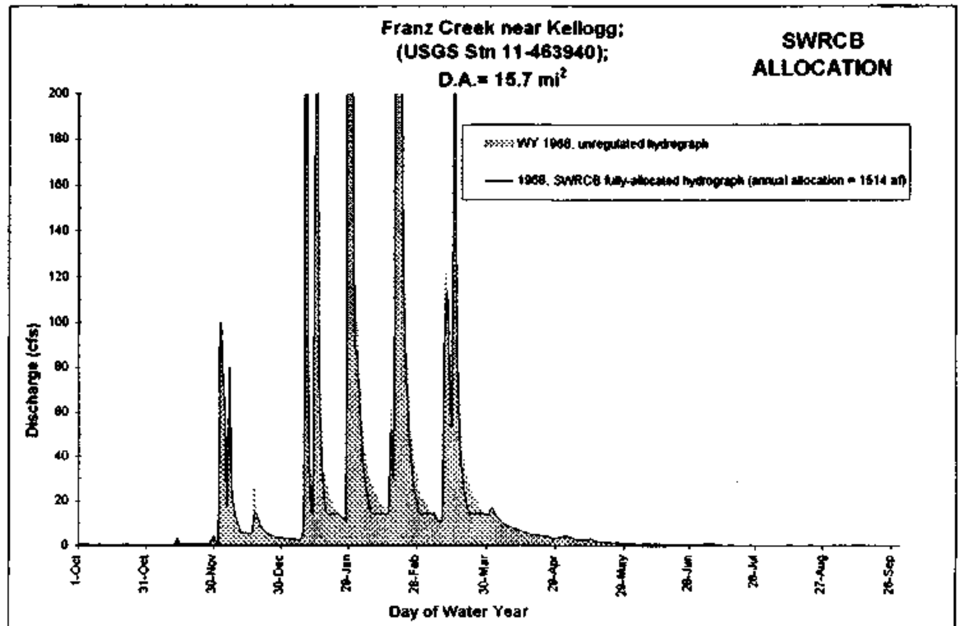


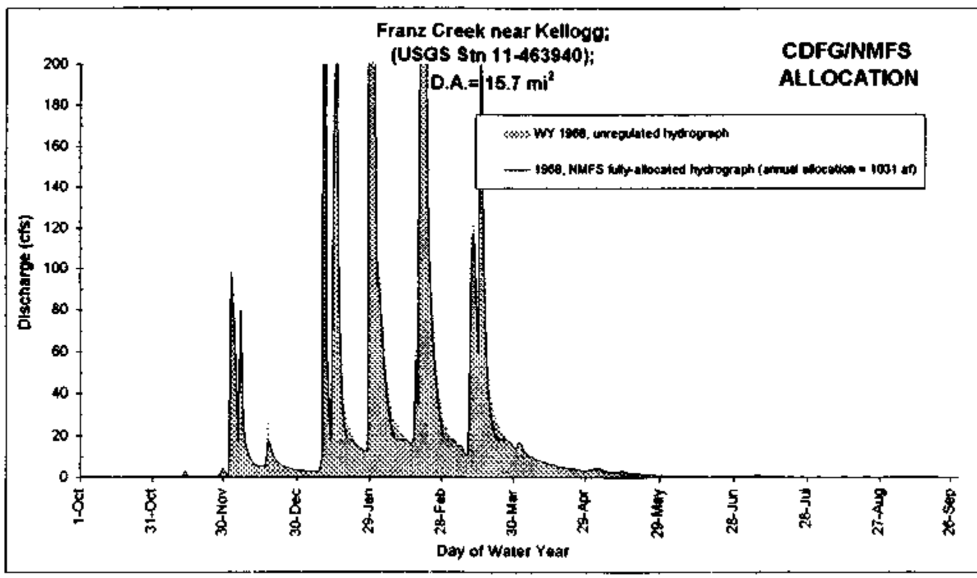


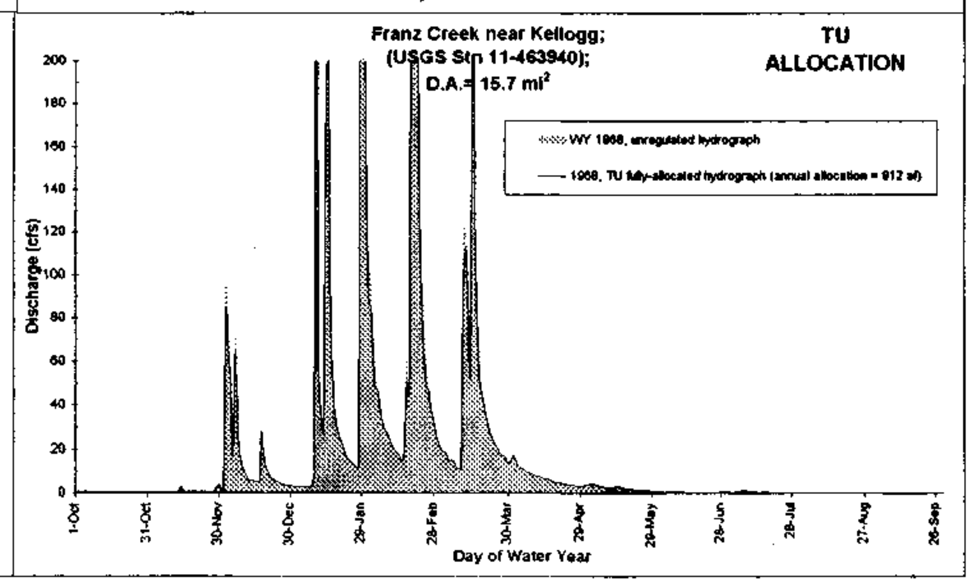


STREAM:	**FRANZ CREEK**
BASIN:	**RUSSIAN RIVER BASIN**
GAGING STATION:	Franz Creek nr Kellogg (11-463940)
WATER YEAR	WY 1968
DRAINAGE AREA	15.7 Mi2
$Q_{AVG\ FOR\ YEAR}$ =	16.7 cfs
$60\%Q_{AVG}$ =	14.1 cfs
$Q_{MEDIANFEB}$ =	18.0 cfs
$Q_{10\%Ex}$ =	48.0 cfs
$Q_{20\%WINTER\ EX}$ =	67.0 cfs
$Q_{20\%(Q20\%)}$ =	13.4 cfs
$Q_{15\%(Q20\%)}$ =	10.0 cfs
TU Rate =	15.0 cfs

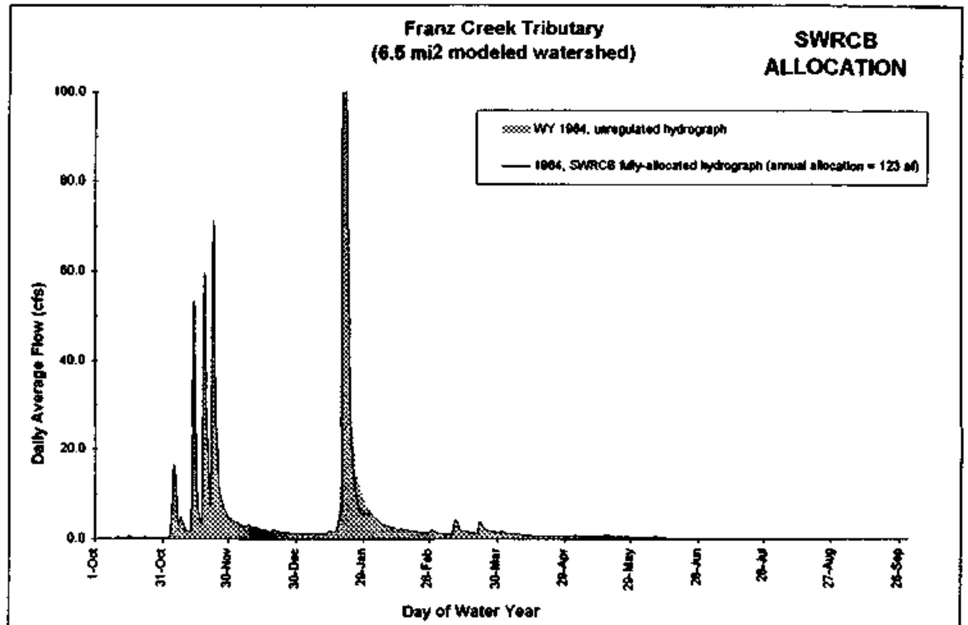
Unregulated Annual Yield =	12,050 af	% of Total
SWRCB Annual Allocation=	1,514 af	13%
NMFS Annual Allocation=	1,031 af	9%
TU Annual Allocation=	912 af	8%

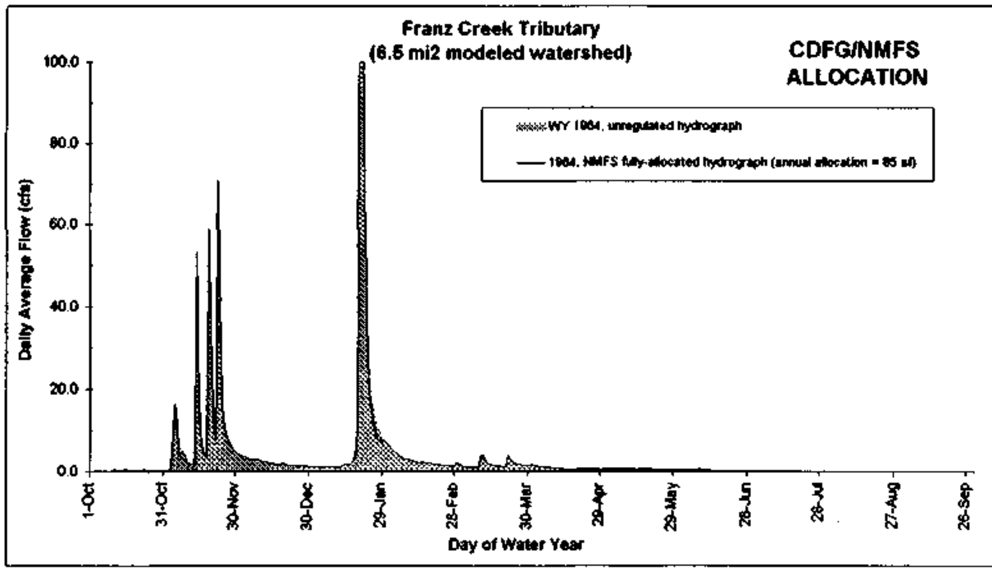


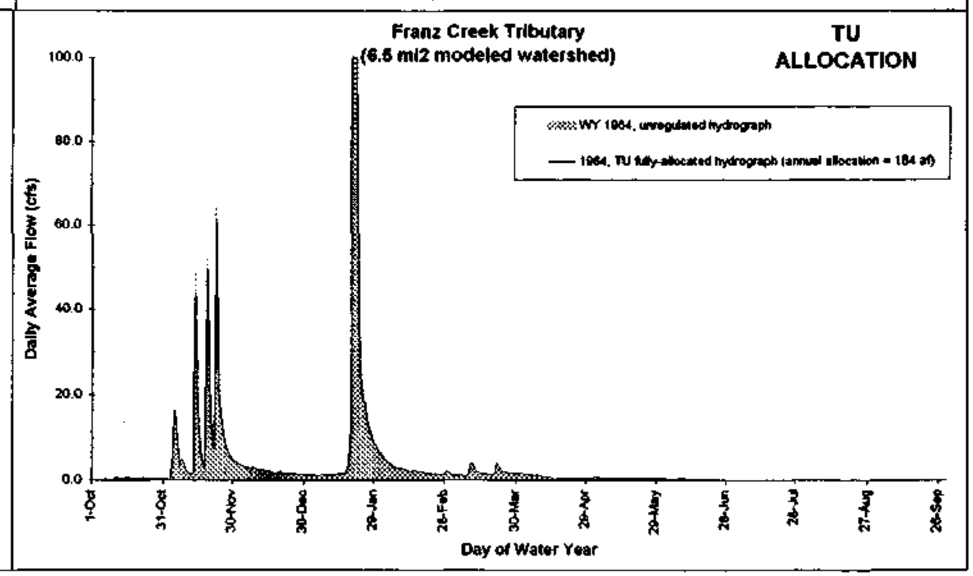




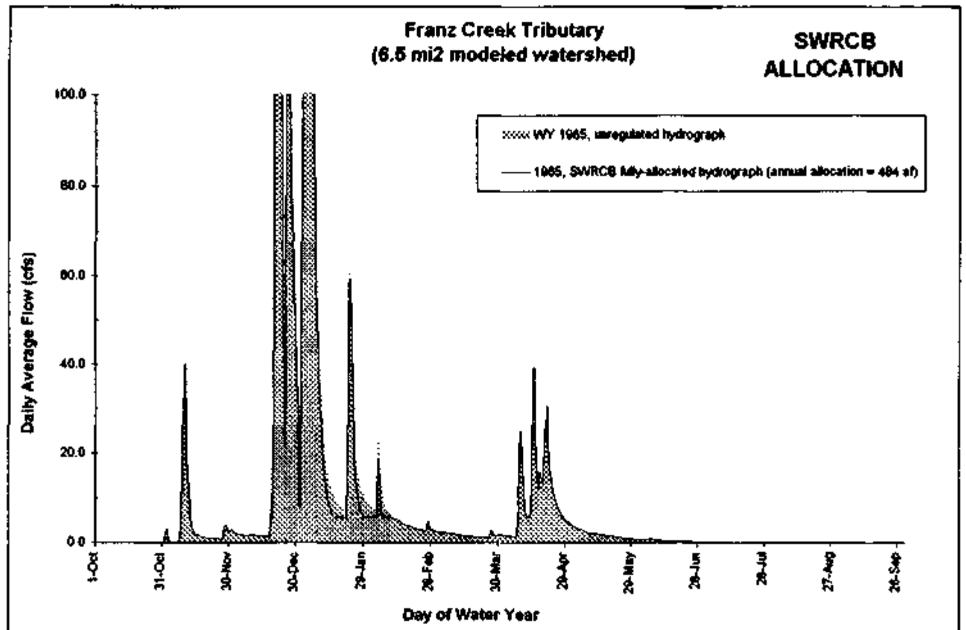
STREAM:	**FRANZ CREEK TRIBUTARY (modeled watershed)**	
BASIN:	**RUSSIAN RIVER BASIN**	
GAGING STATION.	Franz Creek nr Kellogg (11-463940)	
WATER YEAR	WY 1964	
DRAINAGE AREA	6.5 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	3.4 cfs	
$60\%Q_{AVG}$ =	5.8 cfs	
$Q_{MEDIANFEB}$ =	7.4 cfs	
$Q_{10\%EX}$ =	19.7 cfs	
$Q_{20\%WINTER\ EX}$ =	27.5 cfs	
$Q_{20\%(Q20\%)}$ =	5.5 cfs	
$Q_{15\%(Q20\%)}$ =	4.1 cfs	
TU Rate =	8.5 cfs	
Unregulated Annual Yield =	1,429 af	% of Total
SWRCB Annual Allocation=	123 af	9%
NMFS Annual Allocation=	65 af	6%
TU Annual Allocation=	184 af	13%

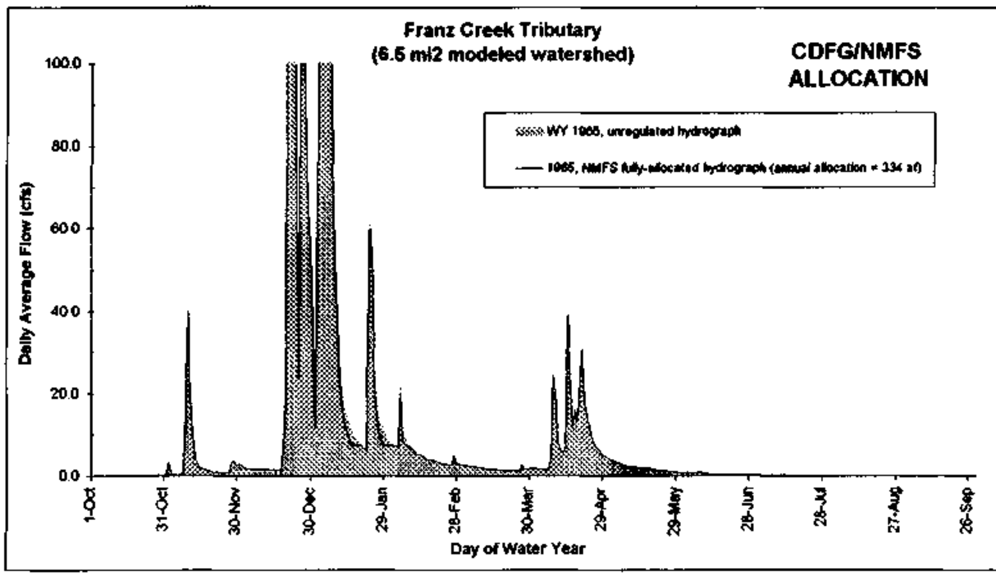


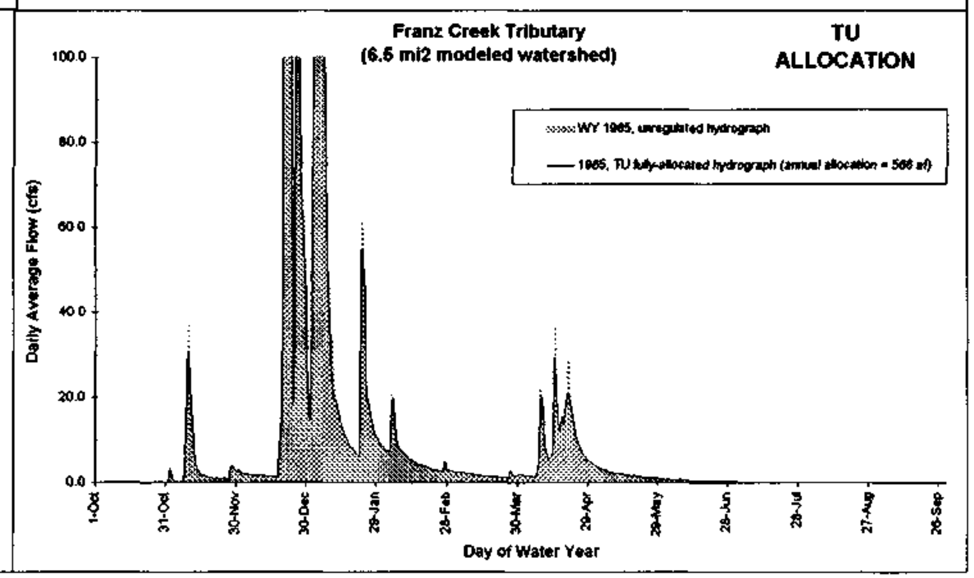




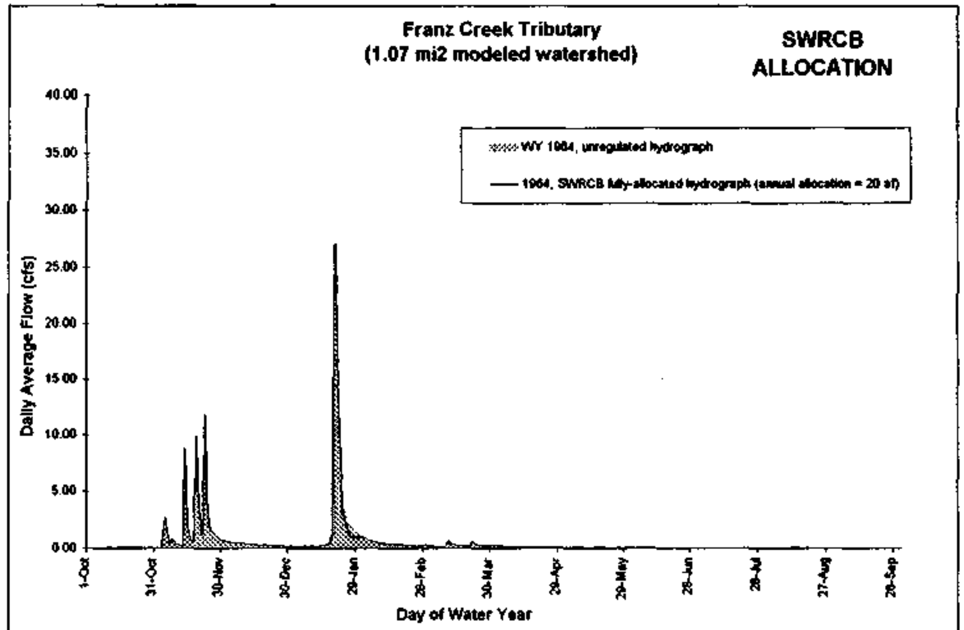
STREAM:	**FRANZ CREEK TRIBUTARY (modeled watershed)**	
BASIN:	**RUSSIAN RIVER BASIN**	
GAGING STATION:	Franz Creek nr Kellogg (11-463940)	
WATER YEAR	WY 1965	
DRAINAGE AREA	6.5 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	12.7 cfs	
$60\%Q_{AVG}$ =	5.8 cfs	
$Q_{MEDIANFEB}$ =	7.4 cfs	
$Q_{10\%EX}$ =	19.7 cfs	
$Q_{20\%WINTER\ EX}$ =	27.5 cfs	
$Q_{20\%(Q20\%)}$ =	5.5 cfs	
$Q_{15\%(Q20\%)}$ =	4.1 cfs	
TU Rate =	8.5 cfs	
Unregulated Annual Yield =	8,065 af	% of Total
SWRCB Annual Allocation=	484 af	6%
NMFS Annual Allocation=	334 af	4%
TU Annual Allocation=	566 af	7%

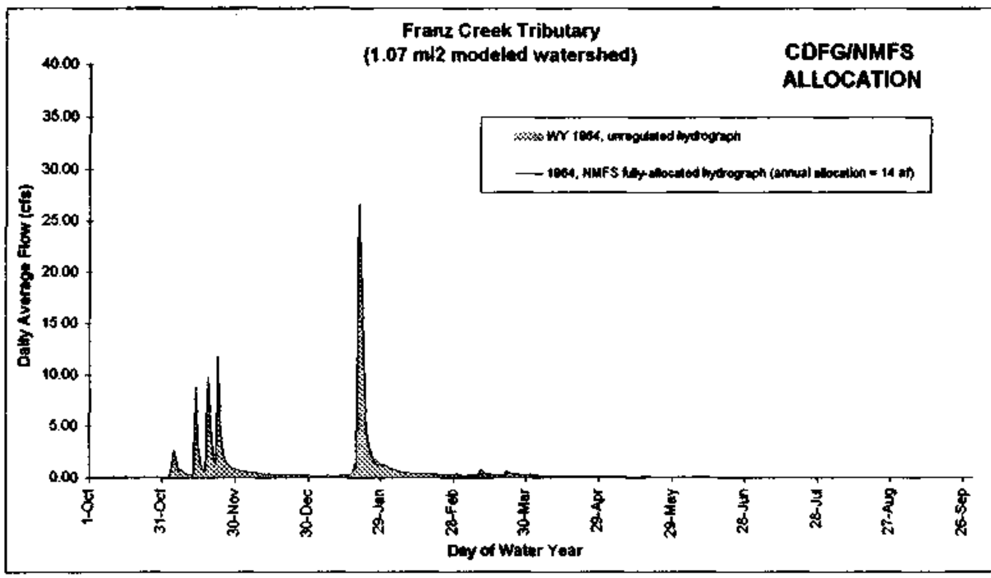


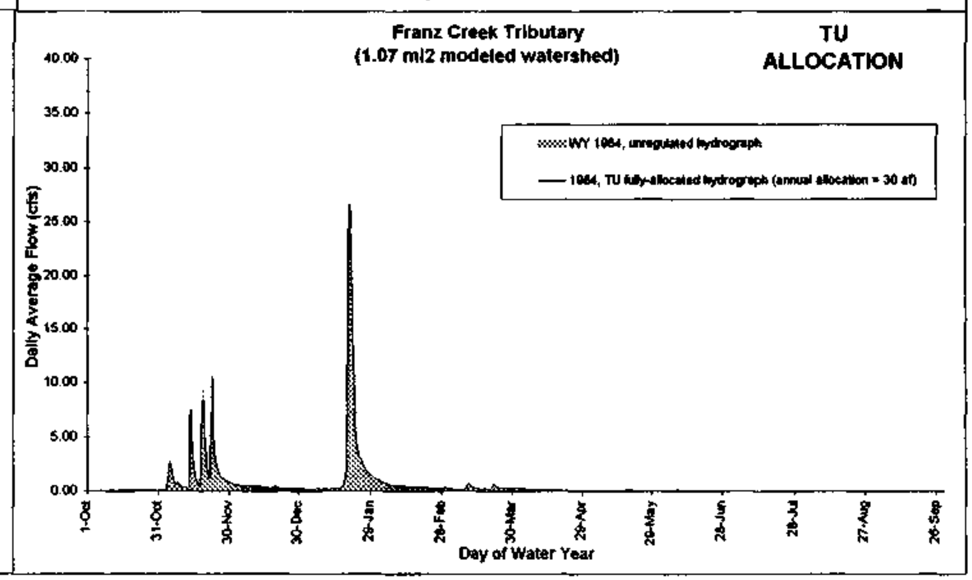




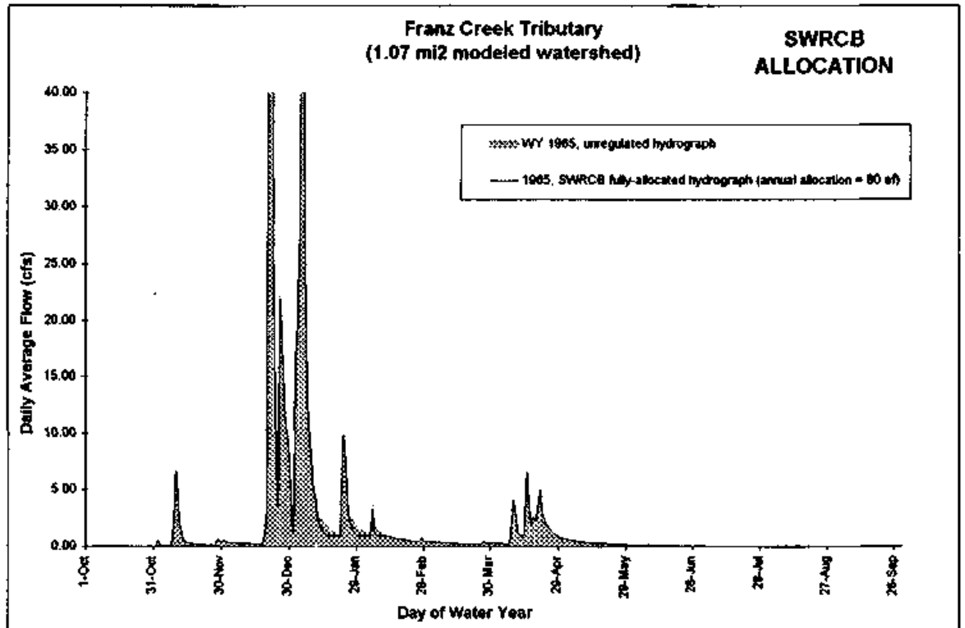
STREAM: **FRANZ CREEK TRIBUTARY (modeled watershed)**		
BASIN:	**RUSSIAN RIVER BASIN**	
GAGING STATION:	Franz Creek nr Kellogg (11-463940)	
WATER YEAR	WY 1964	
DRAINAGE AREA	1.07 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	0.6 cfs	
$80\%Q_{AVG}$ =	1.0 cfs	
$Q_{MEDIANFEB}$ =	1.2 cfs	
$Q_{10\%Ex}$ =	3.3 cfs	
$Q_{20\%WINTER\ EX}$ =	4.6 cfs	
$Q_{20\%(Q20\%)}$ =	0.9 cfs	
$Q_{15\%(Q20\%)}$ =	0.7 cfs	
TU Rate =	1.4 cfs	
Unregulated Annual Yield =	237 af	% of Total
SWRCB Annual Allocation=	*20 af*	9%
NMFS Annual Allocation=	14 af	6%
TU Annual Allocation=	26 af	11%

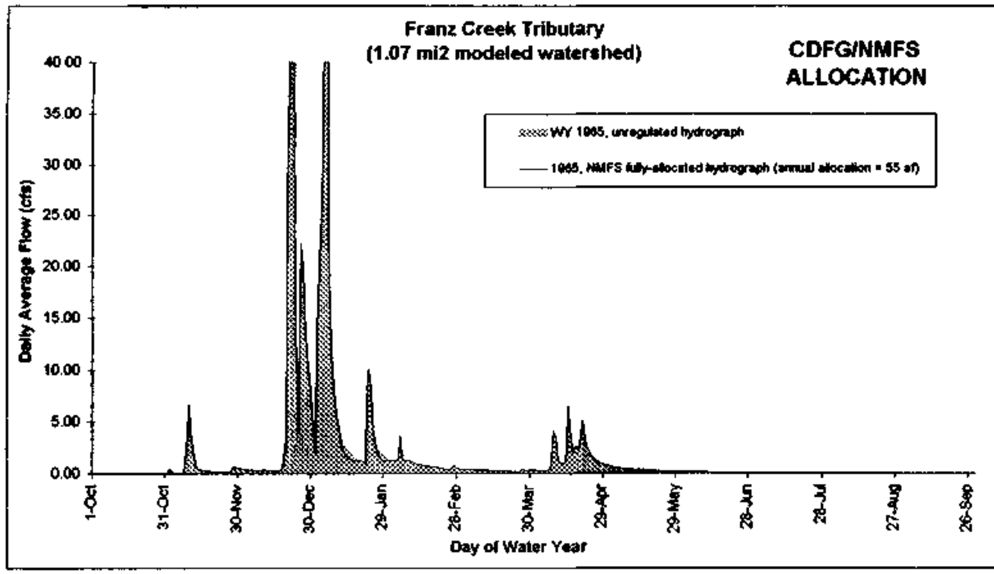


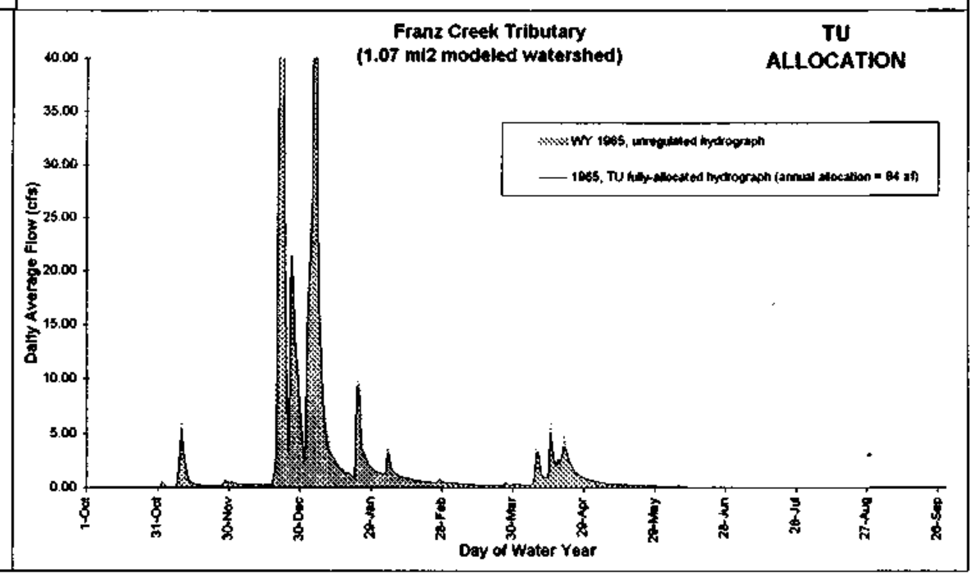




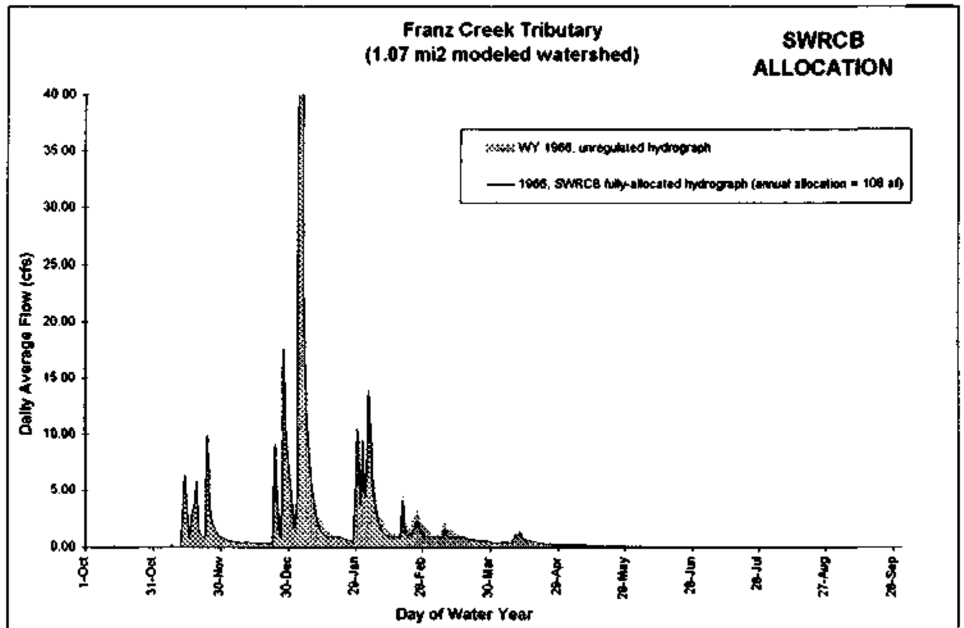
STREAM:	**FRANZ CREEK TRIBUTARY (modeled watershed)**		
BASIN:	**RUSSIAN RIVER BASIN**		
GAGING STATION:	Franz Creek nr Kellogg (11-463940)		
WATER YEAR	WY 1965		
DRAINAGE AREA	1.07 mi2		
$Q_{AVG\ FOR\ YEAR}$ =	2.1 cfs		
$60\%Q_{AVG}$ =	1.0 cfs		
$Q_{MEDIANFEB}$ =	1.2 cfs		
$Q_{10\%Ex}$ =	3.3 cfs		
$Q_{20\%WINTER\ EX}$ =	4.6 cfs		
$Q_{20\%(Q20\%)}$ =	0.9 cfs		
$Q_{15\%(Q20\%)}$ =	0.7 cfs		
TU Rate =	1.4 cfs		
Unregulated Annual Yield =	1,341 af	% of Total	
SWRCB Annual Allocation=	80 af	6%	
NMFS Annual Allocation=	55 af	4%	
TU Annual Allocation=	82 af	6%	

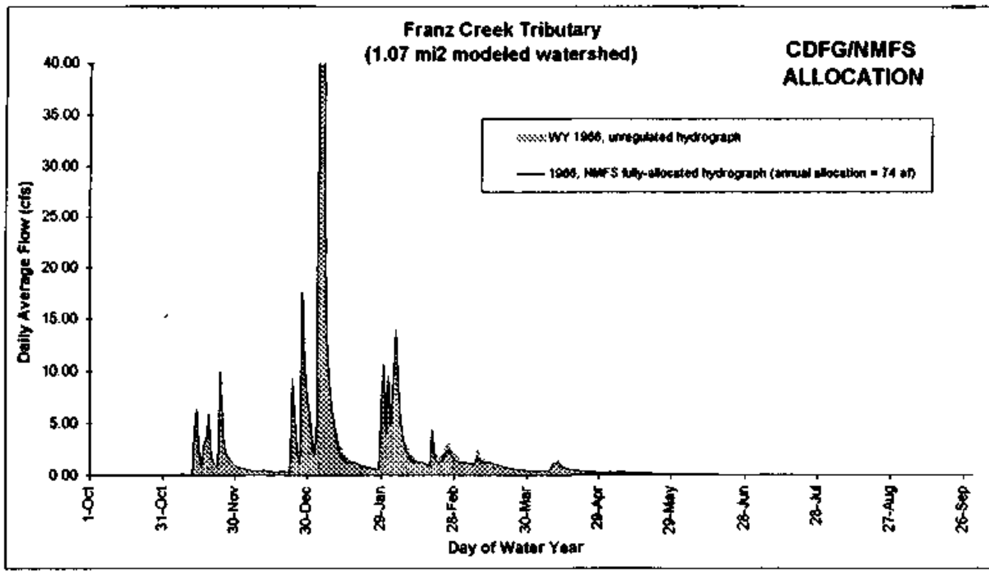


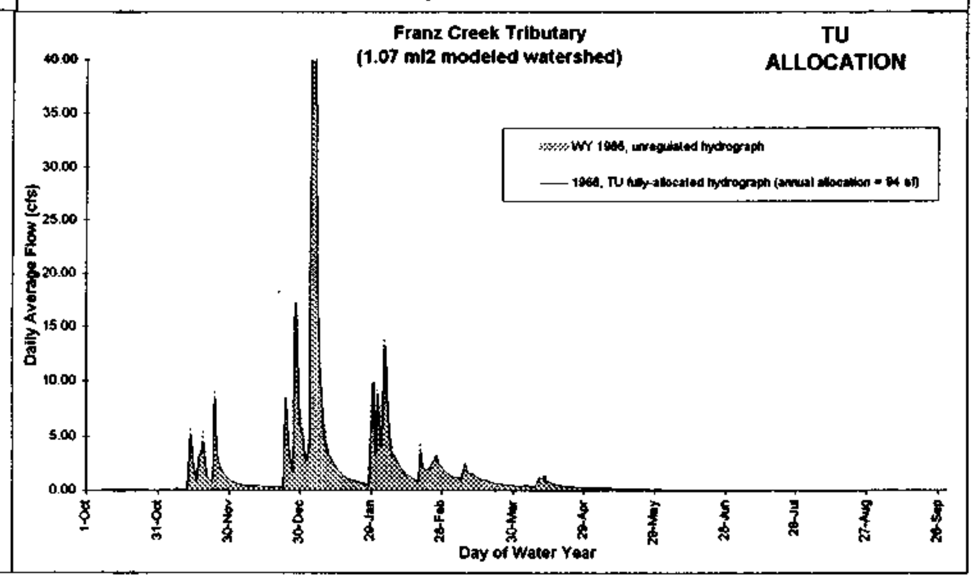




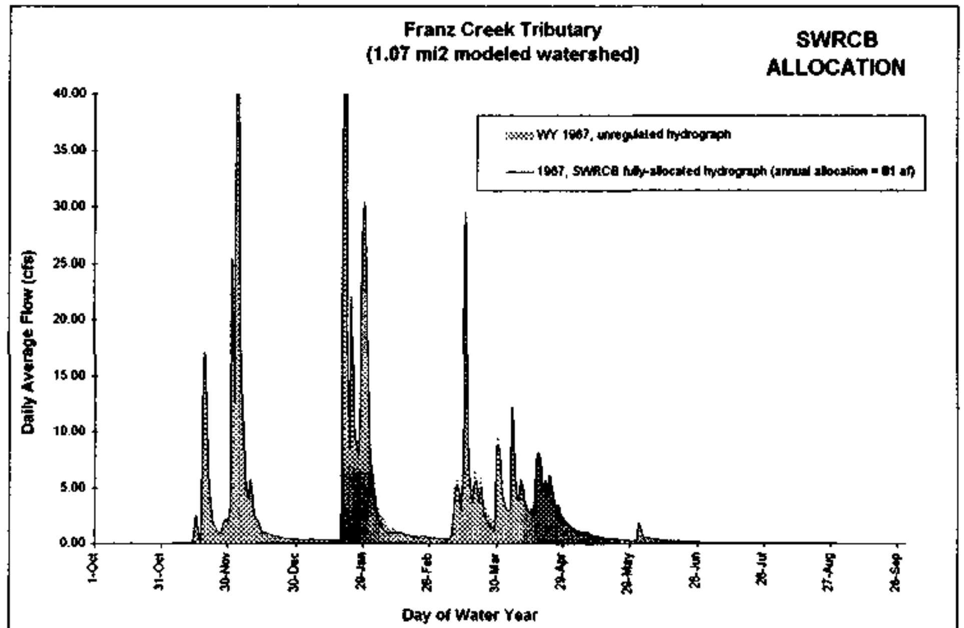
STREAM:	**FRANZ CREEK TRIBUTARY (modeled watershed)**	
BASIN:	**RUSSIAN RIVER BASIN**	
GAGING STATION:	Franz Creek nr Kellogg (11-463940)	
WATER YEAR	WY 1966	
DRAINAGE AREA	1.07 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	1.5 cfs	
$60\%Q_{AVG}$ =	1.0 cfs	
$Q_{MEDIANFEB}$ =	1.2 cfs	
$Q_{10\%EX}$ =	3.3 cfs	
$Q_{20\%WINTER\ EX}$ =	4.6 cfs	
$Q_{20\%(Q20\%)}$ =	0.9 cfs	
$Q_{15\%(Q20\%)}$ =	0.7 cfs	
TU Rate =	1.4 cfs	
Unregulated Annual Yield =	908 af	% of Total
SWRCB Annual Allocation=	108 af	12%
NMFS Annual Allocation=	74 af	8%
TU Annual Allocation=	81 af	9%

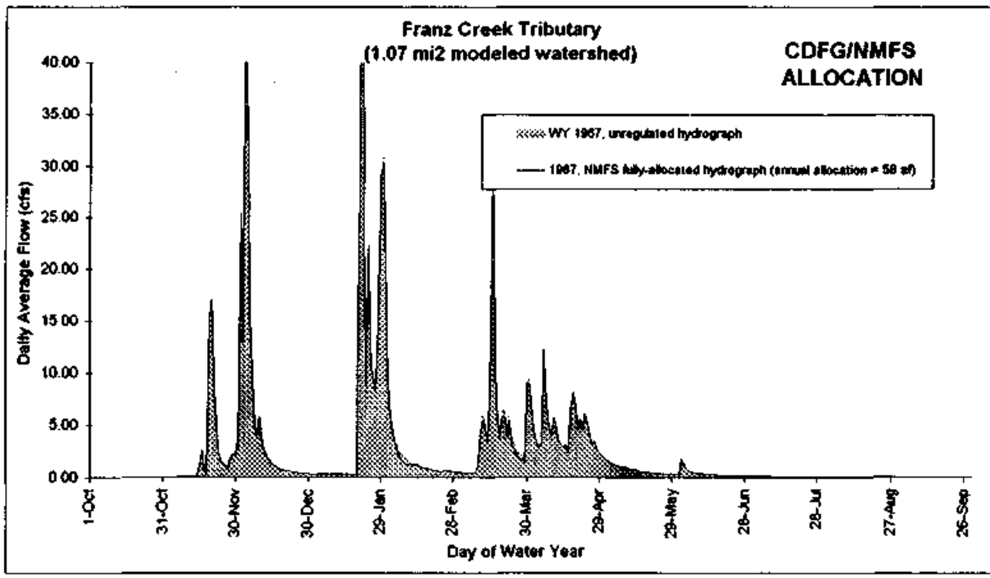


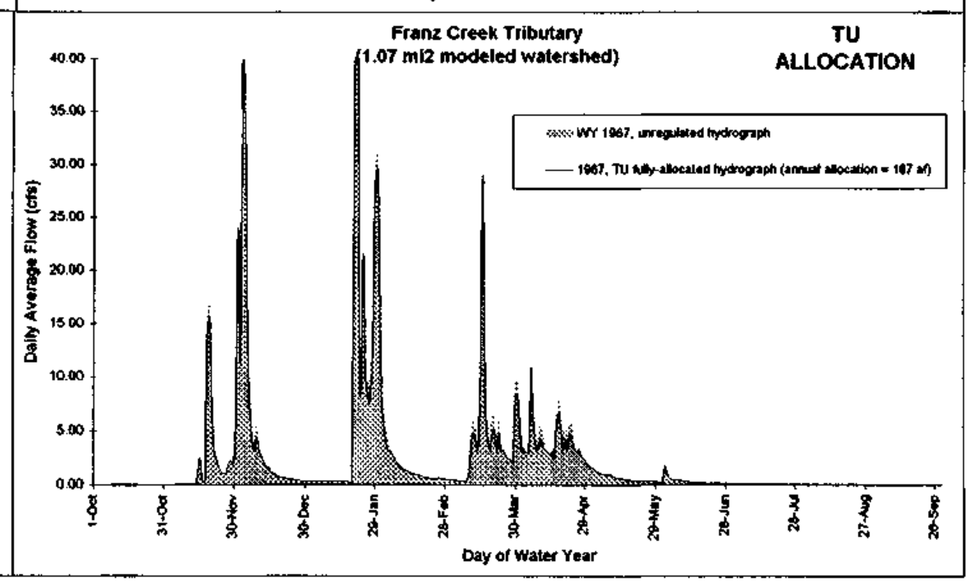




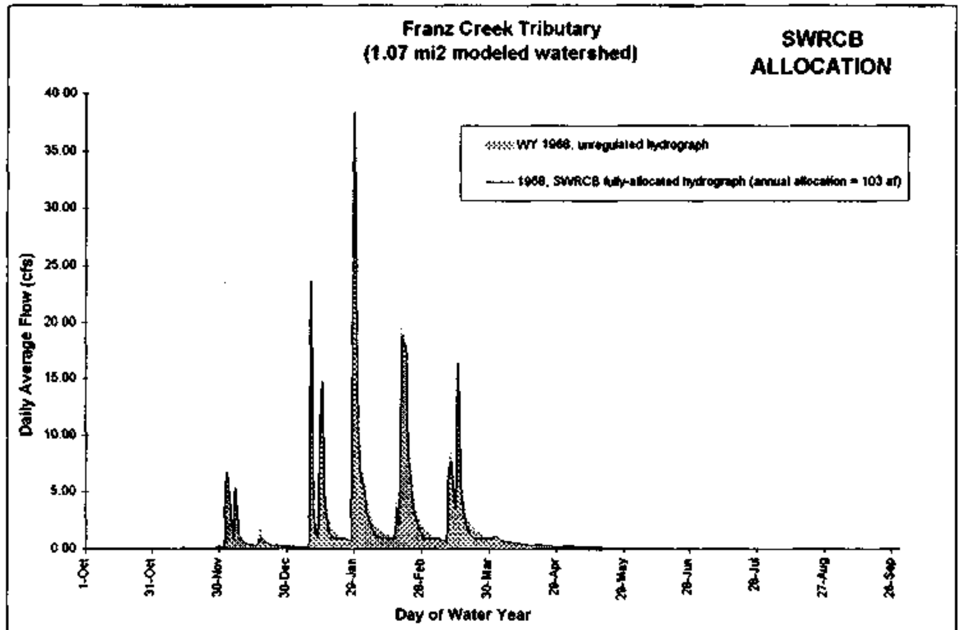
STREAM:	**FRANZ CREEK TRIBUTARY (modeled watershed)**	
BASIN:	**RUSSIAN RIVER BASIN**	
GAGING STATION:	Franz Creek nr Kellogg (11-463940)	
WATER YEAR	WY 1967	
DRAINAGE AREA	1.07 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	2.6 cfs	
$60\%Q_{AVG}$ =	1.0 cfs	
$Q_{MEDIANFEB}$ =	1.2 cfs	
$Q_{10\%Ex}$ =	3.3 cfs	
$Q_{20\%WINTER\ EX}$ =	4.6 cfs	
$Q_{20\%(Q20\%)}$ =	0.9 cfs	
$Q_{15\%(Q20\%)}$ =	0.7 cfs	
TU Rate =	1.4 cfs	
Unregulated Annual Yield =	1,037 af	% of Total
SWRCB Annual Allocation=	81 af	8%
NMFS Annual Allocation=	58 af	6%
TU Annual Allocation=	163 af	16%

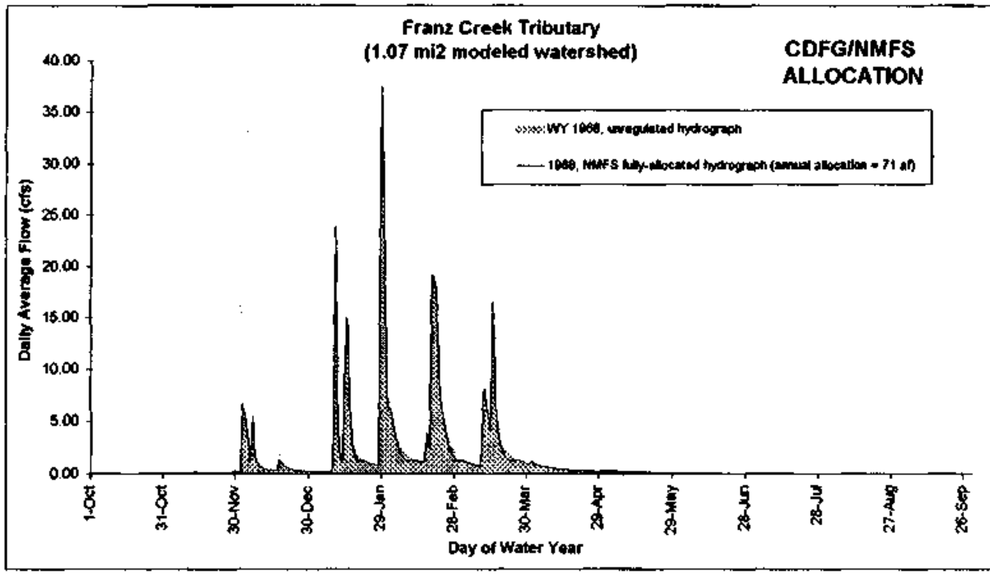


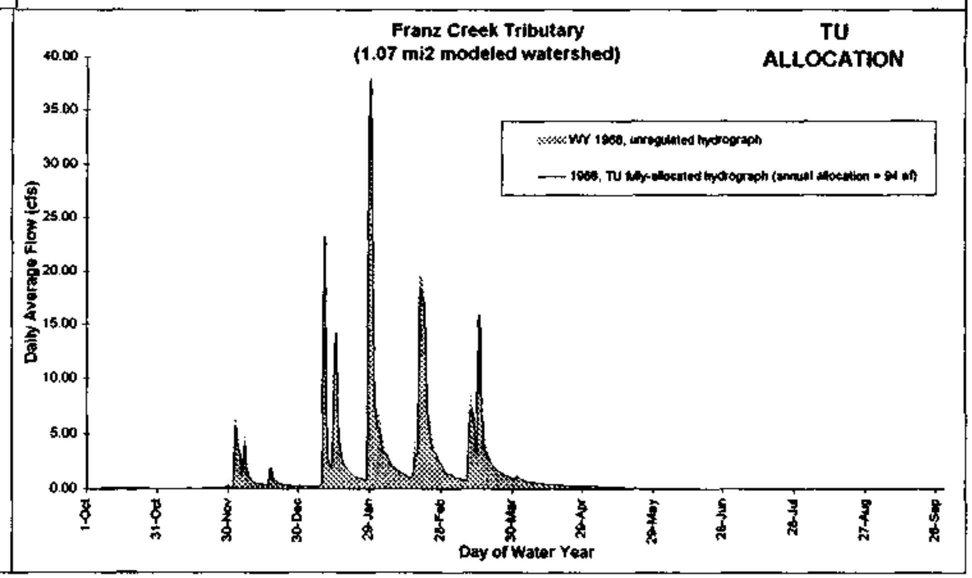




STREAM:	**FRANZ CREEK TRIBUTARY (modeled watershed)**		
BASIN:	**RUSSIAN RIVER BASIN**		
GAGING STATION:	Franz Creek nr Kellogg (11-463940)		
WATER YEAR	WY 1968		
DRAINAGE AREA	1.07 mi2		
$Q_{AVG\ FOR\ YEAR}$ =	1.3 cfs		
$60\%Q_{AVG}$ =	1.0 cfs		
$Q_{MEDIANFEB}$ =	1.2 cfs		
$Q_{10\%EX}$ =	3.3 cfs		
$Q_{20\%WINTER\ EX}$ =	4.6 cfs		
$Q_{20\%(Q20\%)}$ =	0.9 cfs		
$Q_{15\%(Q20\%)}$ =	0.7 cfs		
TU Rate =	1.4 cfs		
	Unregulated Annual Yield =	819 af	% of Total
	SWRCB Annual Allocation=	103 af	13%
	NMFS Annual Allocation=	71 af	9%
	TU Annual Allocation=	82 af	10%

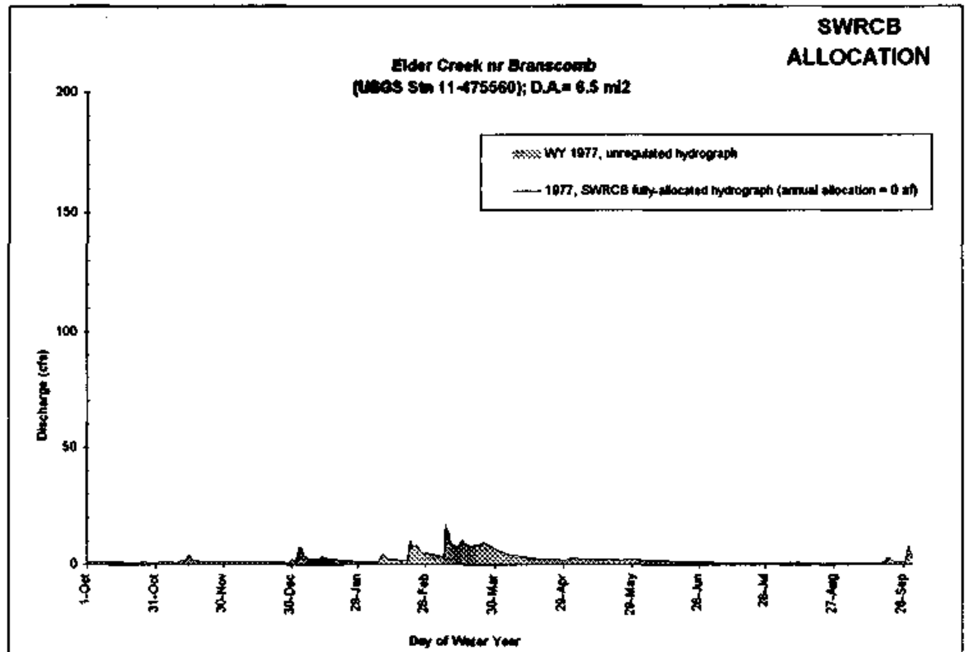


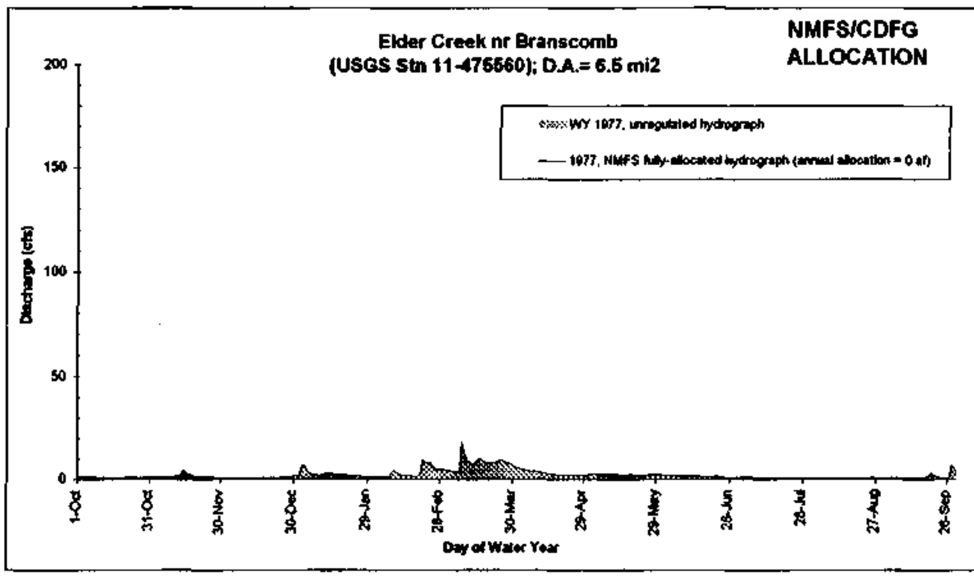


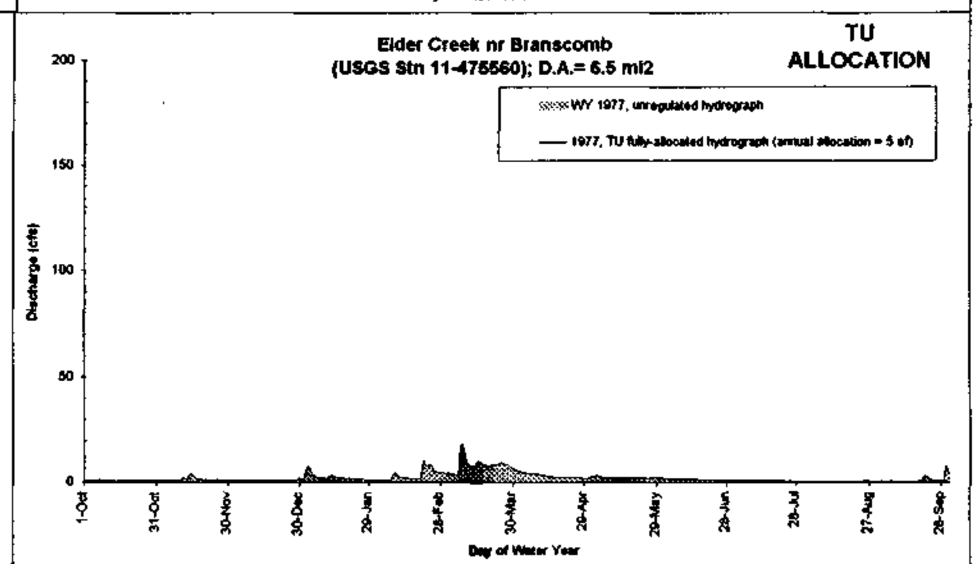


STREAM:	**Elder Creek**
BASIN:	**SF Eel River**
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**
WATER YEAR	WY 1977
DRAINAGE AREA	6.5 mi2
QAVG FOR YEAR =	2.1 cfs
60%QAVG =	15.4 cfs
QMEDIANFEB =	34.5 cfs
Q10%Ex =	67.0 cfs
Q20%WINTER EX =	87.0 cfs
Q20%(Q20%) =	17.4 cfs
Q15%(Q20%) =	13.0 cfs
TU Rate =	20.0 cfs

		% of Total
Unregulated Annual Yield =	832 af	
SWRCB Annual Allocation=	5 af	1%
NMFS Annual Allocation=	0 af	0%
TU Annual Allocation=	0 af	0%

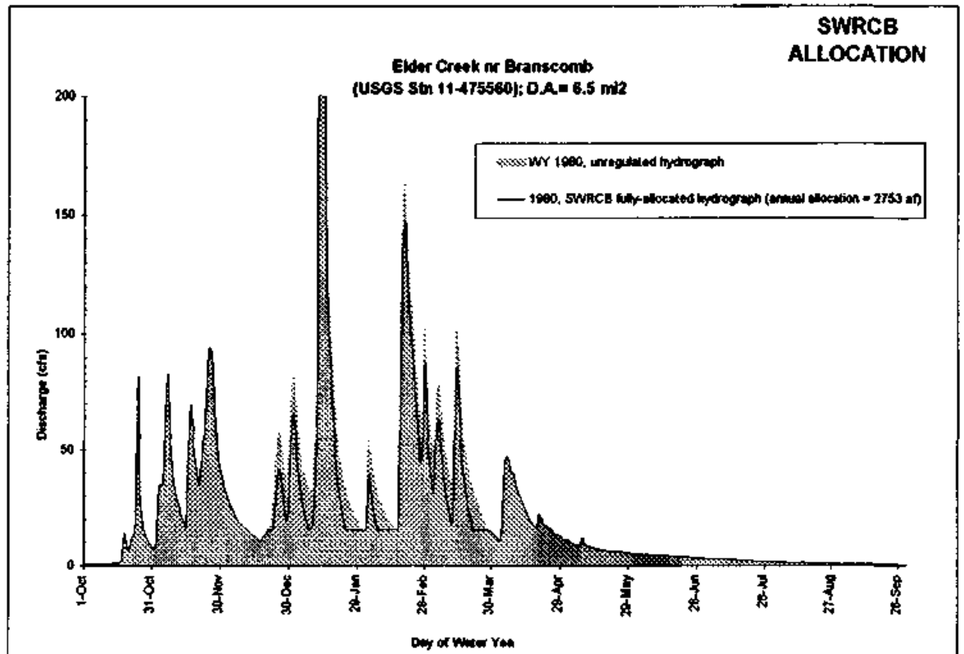


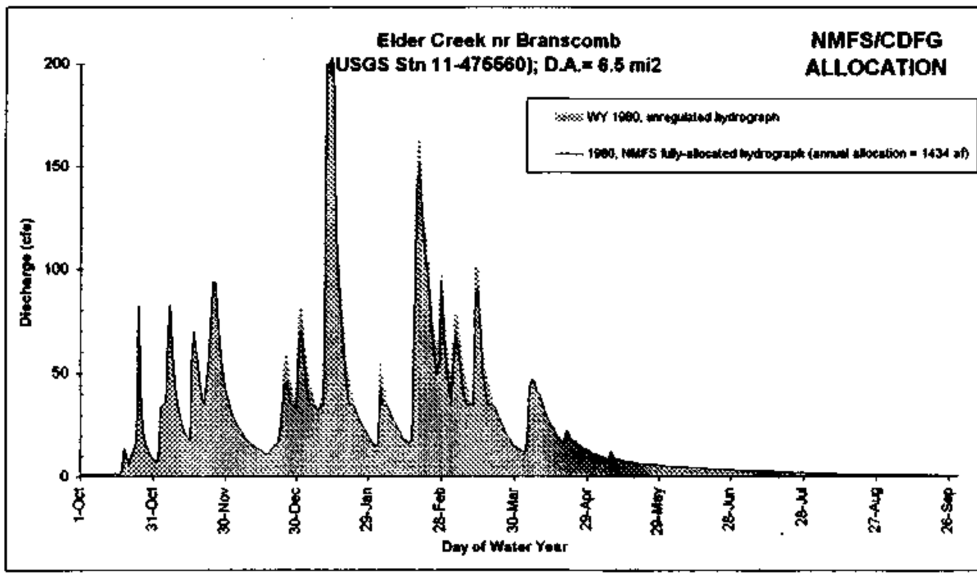


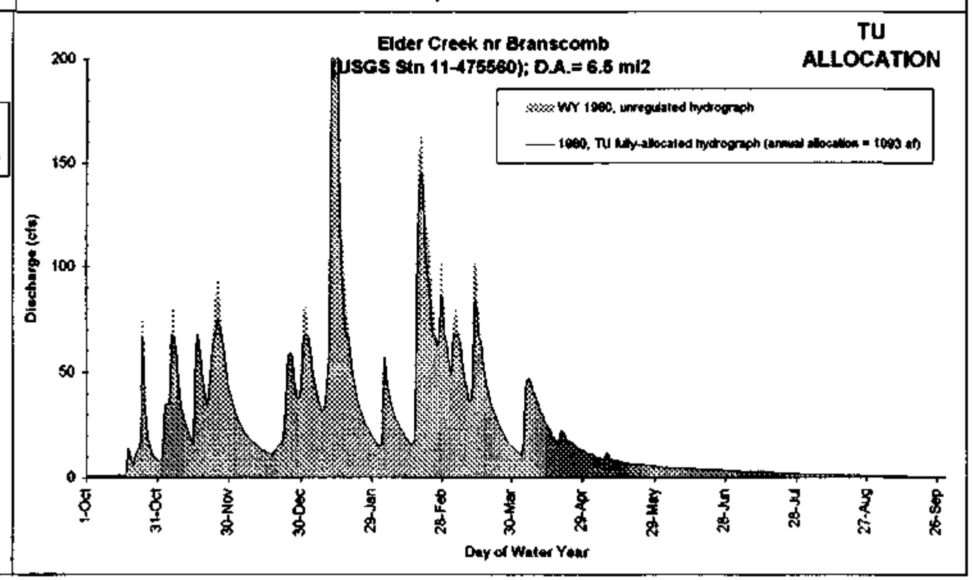


STREAM:	Elder Creek
BASIN:	SF Eel River
GAGING STATION:	Elder Creek nr Branscomb (Stn 11-475560)
WATER YEAR	WY 1980
DRAINAGE AREA	6.5 mi2
QAVG FOR YEAR =	25.6 cfs
60%QAVG =	15.4 cfs
QMEDIANFEB =	34.5 cfs
Q10%Ex =	67.0 cfs
Q20%WINTER EX =	87.0 cfs
Q20%(Q20%) =	17.4 cfs
Q15%(Q20%) =	13.0 cfs
TU Rate =	20.0 cfs

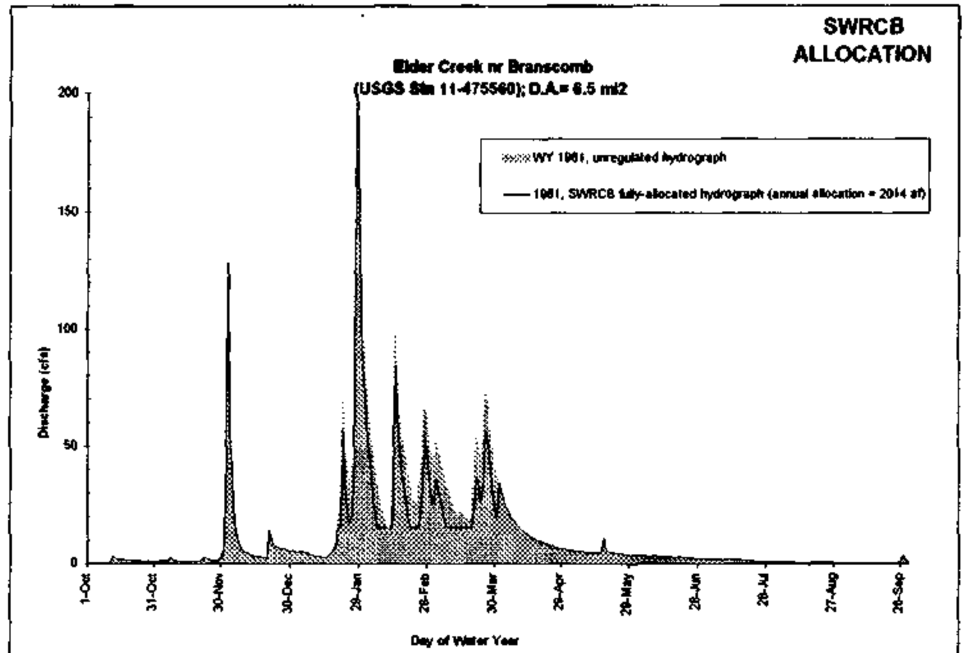
		% of Total
Unregulated Annual Yield =	12,184 af	
SWRCB Annual Allocation=	2,753 af	23%
NMFS Annual Allocation=	1,434 af	12%
TU Annual Allocation=	1,093 af	9%

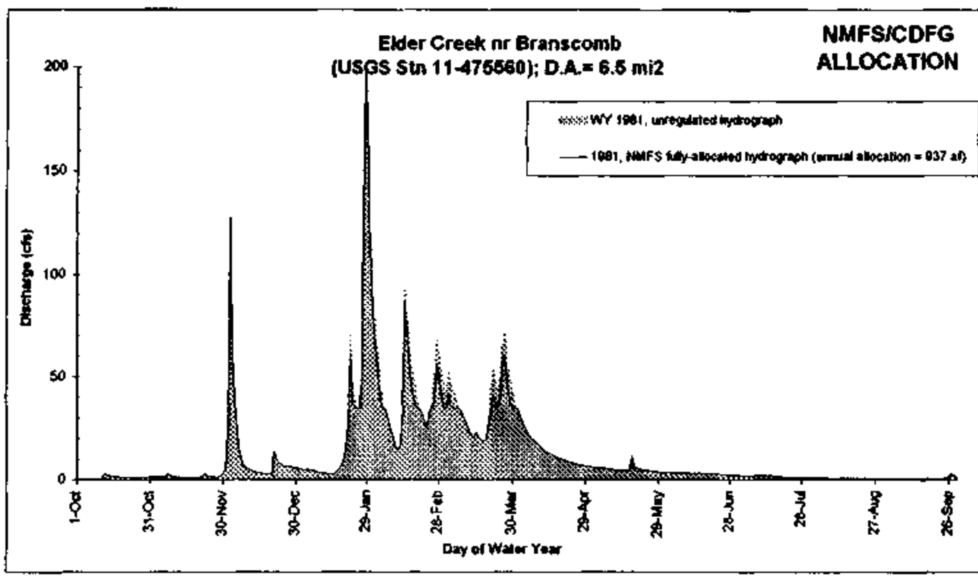


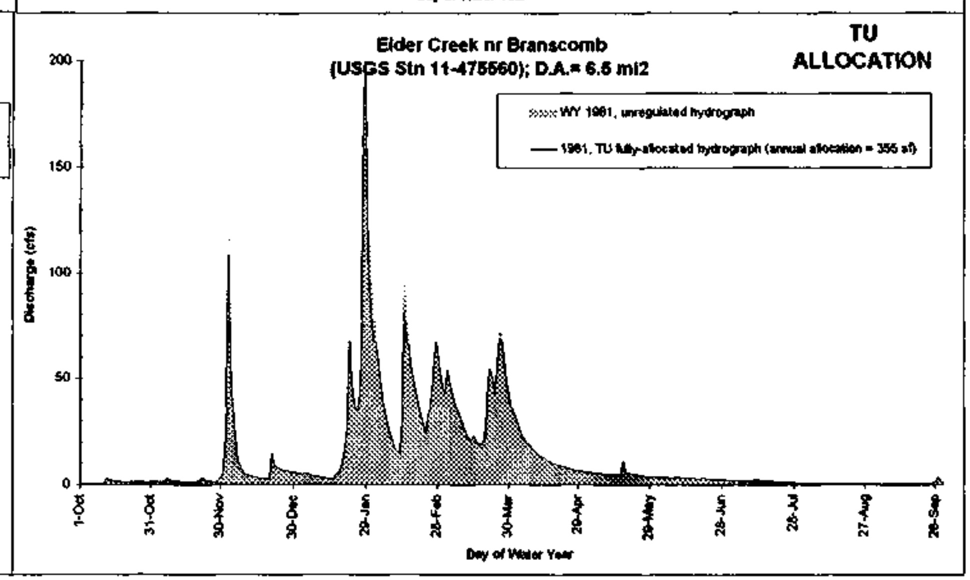




STREAM:	**Elder Creek**	
BASIN:	**SF Eel River**	
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**	
WATER YEAR	WY 1981	
DRAINAGE AREA	6.5 mi2	
QAVG FOR YEAR =	13.2 cfs	
60%QAVG =	15.4 cfs	
QMEDIANFEB =	34.5 cfs	
Q10%Ex =	67.0 cfs	
Q20%WINTER EX =	87.0 cfs	
Q20%(Q20%) =	17.4 cfs	
Q15%(Q20%) =	13.0 cfs	
TU Rate =	20.0 cfs	
Unregulated Annual Yield =	7,252 af	% of Total
SWRCB Annual Allocation=	2,014 af	28%
NMFS Annual Allocation=	937 af	13%
TU Annual Allocation=	355 af	5%

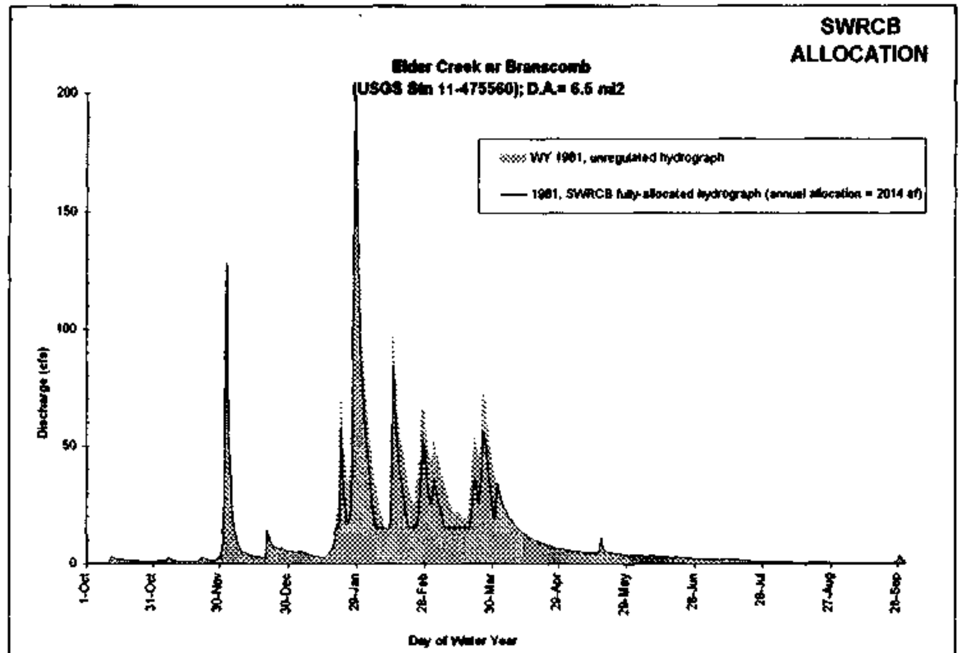


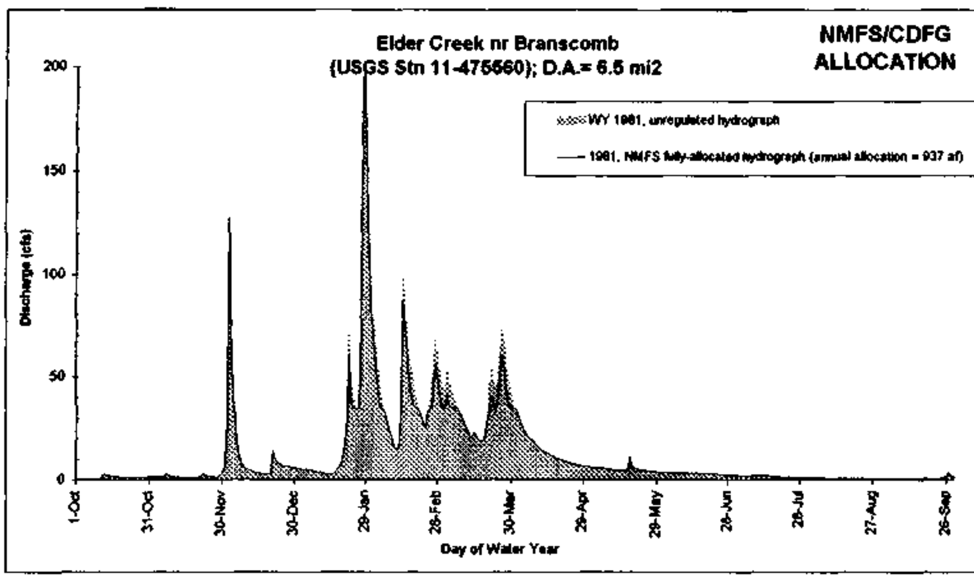


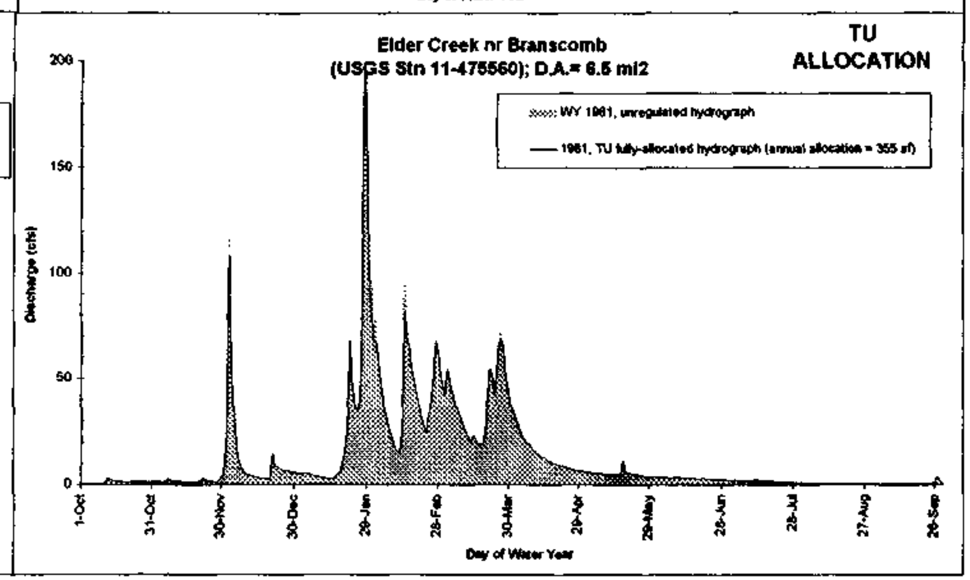


STREAM:	**Elder Creek**
BASIN:	**SF Eel River**
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**
WATER YEAR	WY 1981
DRAINAGE AREA	6.5 mi2
QAVG FOR YEAR =	13.2 cfs
60%QAVG =	15.4 cfs
QMEDIANFEB =	34.5 cfs
Q10%Ex =	67.0 cfs
Q20%WINTER EX =	87.0 cfs
Q20%(Q20%) =	17.4 cfs
Q15%(Q20%) =	13.0 cfs
TU Rate =	20.0 cfs

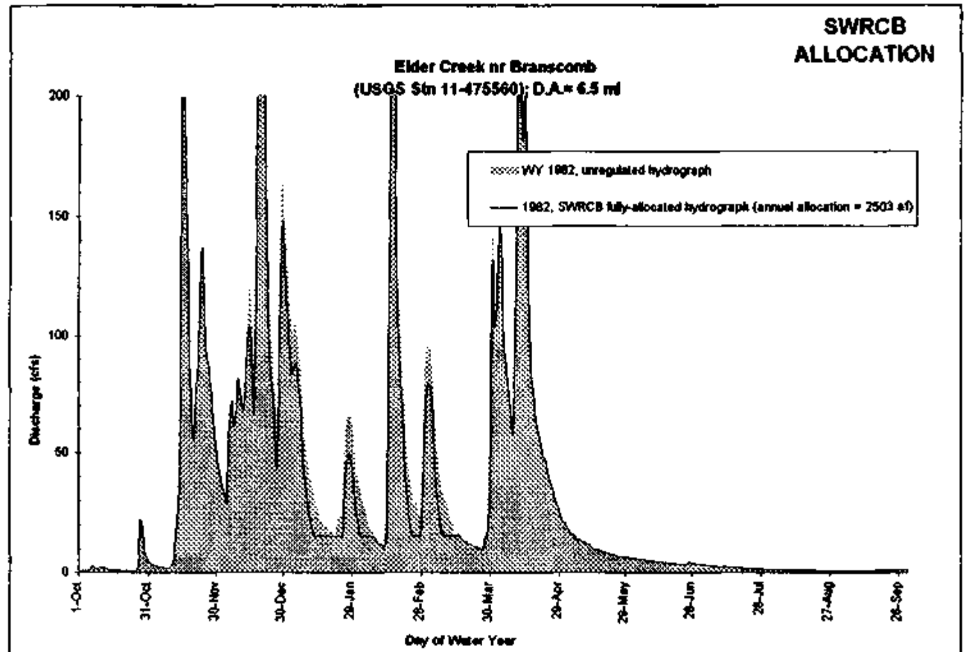
		% of Total
Unregulated Annual Yield =	7,252 af	
SWRCB Annual Allocation=	2,014 af	28%
NMFS Annual Allocation=	937 af	13%
TU Annual Allocation=	355 af	5%

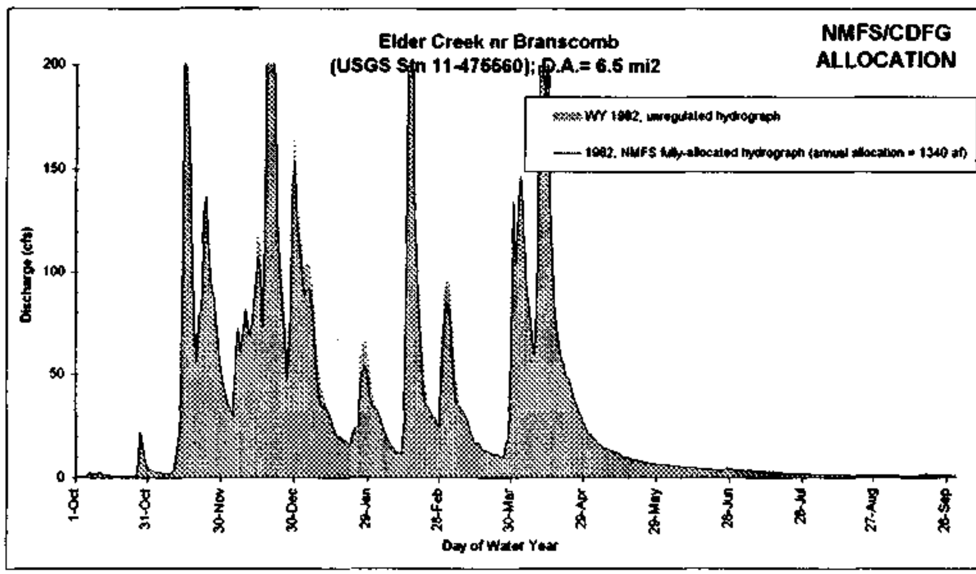


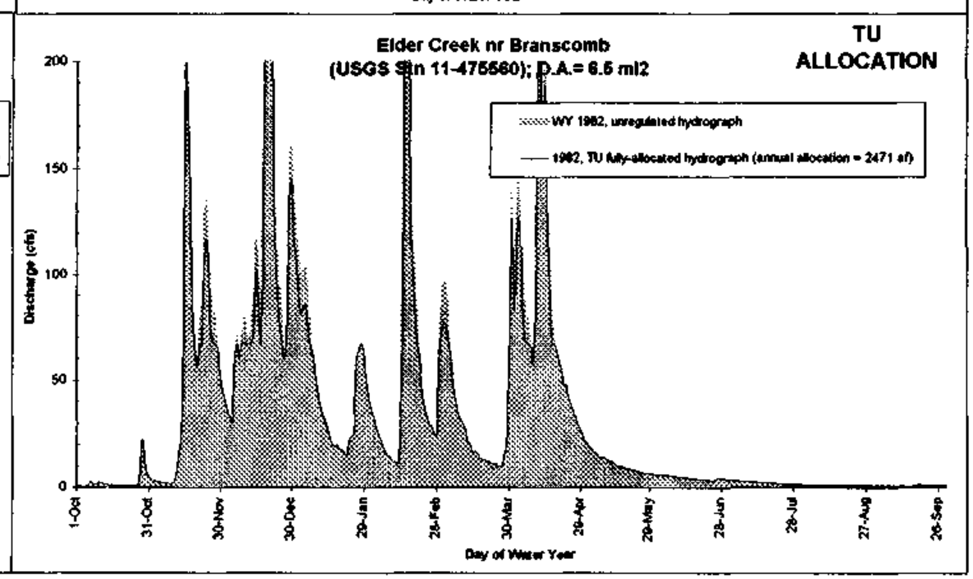




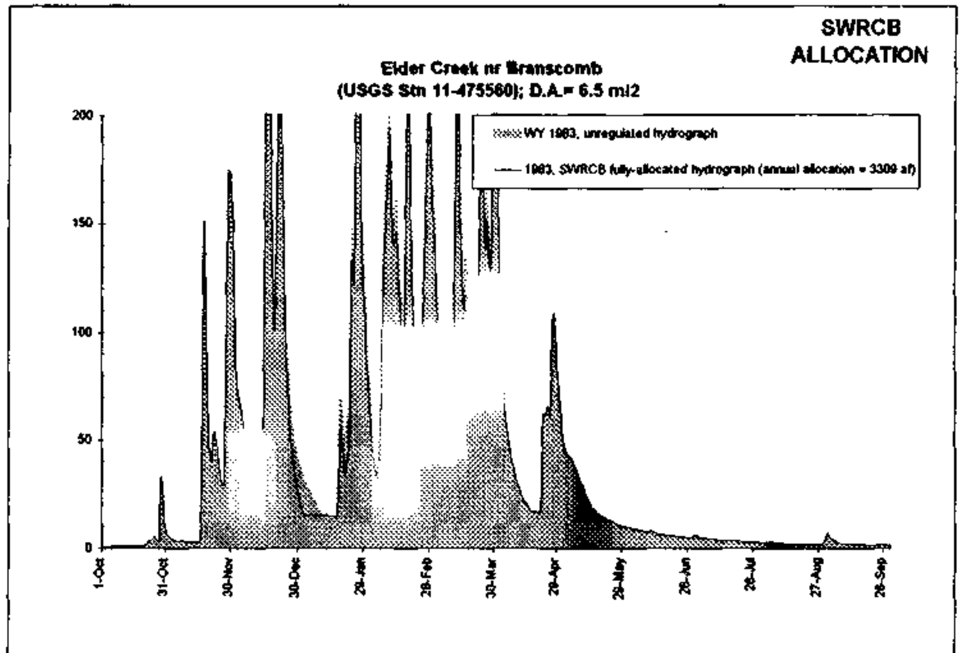
STREAM:	**Elder Creek**	
BASIN:	**SF Eel River**	
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**	
WATER YEAR	WY 1982	
DRAINAGE AREA	6.5 mi2	
QAVG FOR YEAR =	37.5 cfs	
60%QAVG =	15.4 cfs	
QMEDIANFEB =	34.5 cfs	
Q10%Ex =	67.0 cfs	
Q20%WINTER EX =	87.0 cfs	
Q20%(Q20%) =	17.4 cfs	
Q15%(Q20%) =	13.0 cfs	
TU Rate =	20.0 cfs	
Unregulated Annual Yield =	15,013 af	% of Total
SWRCB Annual Allocation=	2,503 af	17%
NMFS Annual Allocation=	1,340 af	9%
TU Annual Allocation=	2,471 af	16%

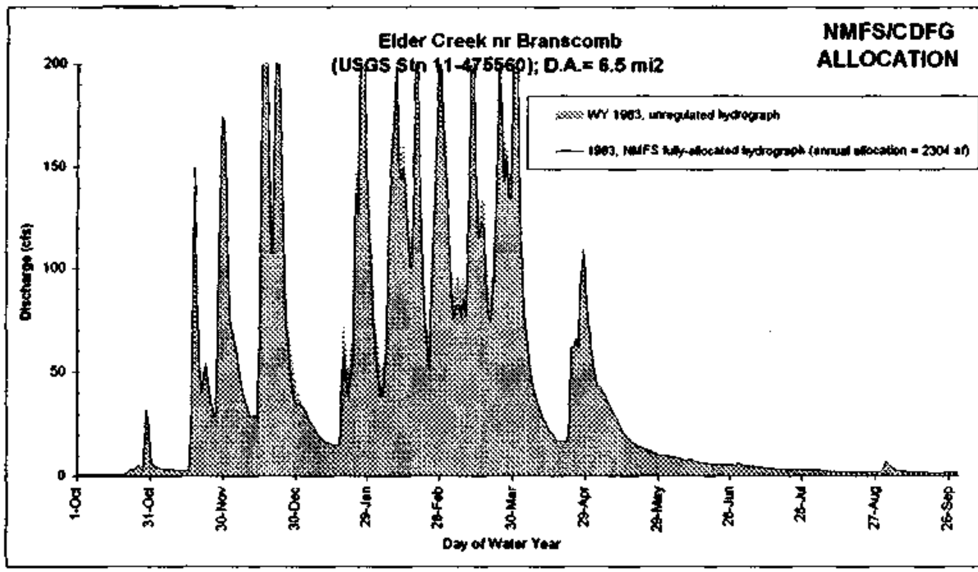


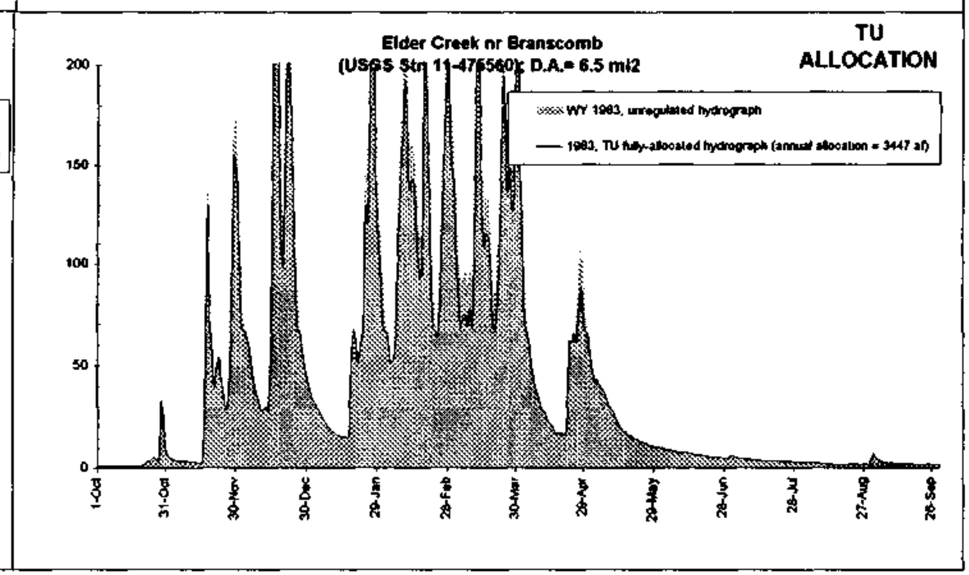




STREAM:	**Elder Creek**	
BASIN:	**SF Eel River**	
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**	
WATER YEAR	WY 1983	
DRAINAGE AREA	6.5 mi2	
QAVG FOR YEAR =	48.4 cfs	
60%QAVG =	15.4 cfs	
QMEDIANFEB =	34.5 cfs	
Q10%Ex =	67.0 cfs	
Q20%WINTER EX =	87.0 cfs	
Q20%(Q20%) =	17.4 cfs	
Q15%(Q20%) =	13.0 cfs	
TU Rate =	20.0 cfs	
Unregulated Annual Yield =	25,513 af	% of Total
SWRCB Annual Allocation=	3,309 af	13%
NMFS Annual Allocation=	2,304 af	9%
TU Annual Allocation=	3,447 af	14%

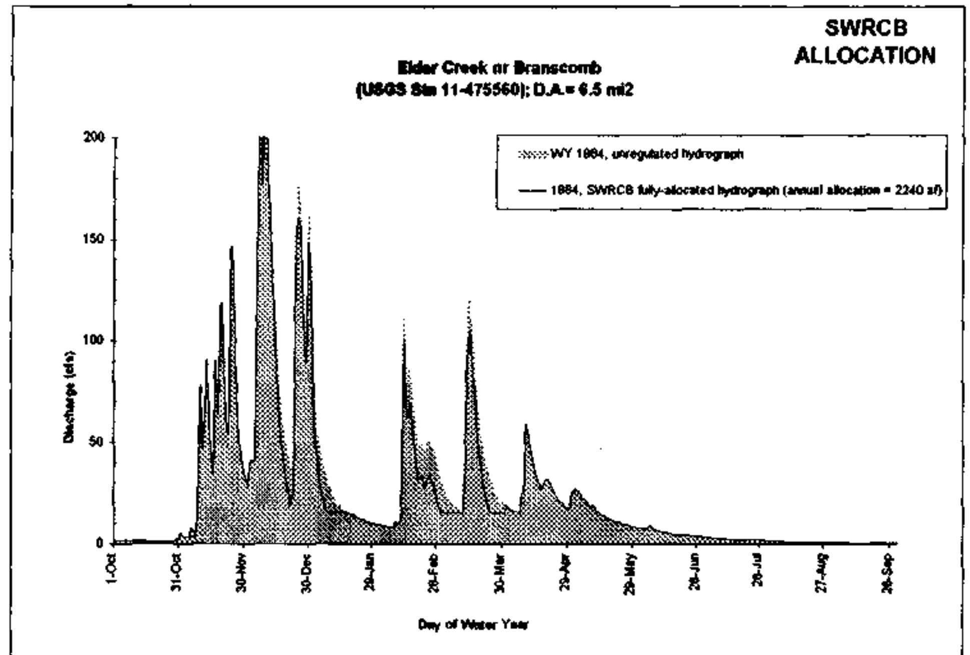


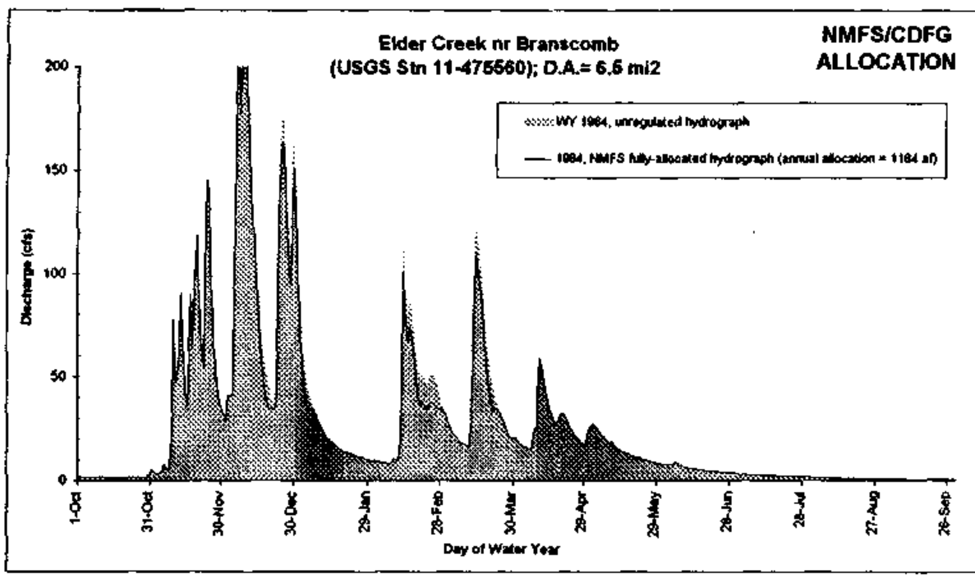


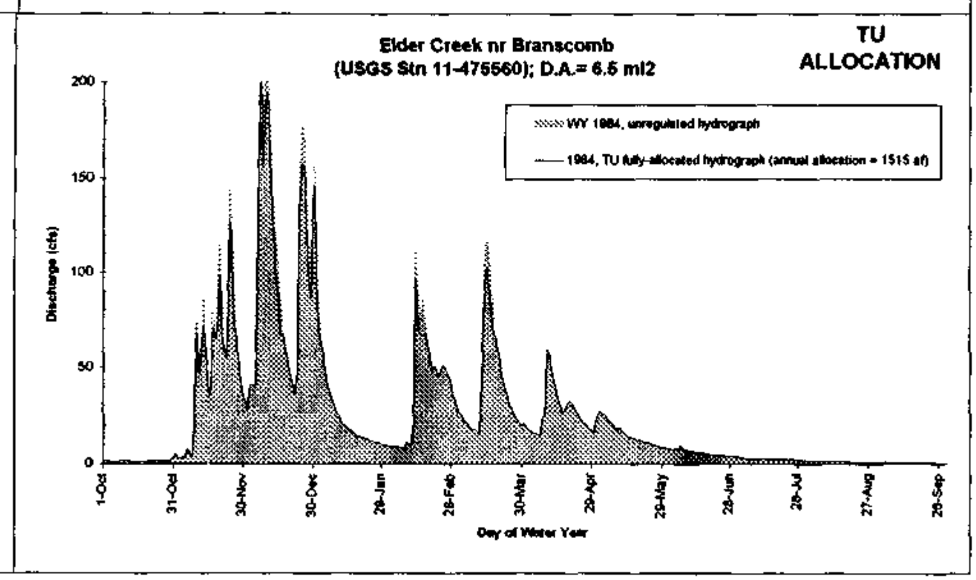


STREAM:	**Elder Creek**
BASIN:	**SF Eel River**
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**
WATER YEAR	WY 1984
DRAINAGE AREA	6.5 mi2
QAVG FOR YEAR =	27.3 cfs
60%QAVG =	15.4 cfs
QMEDIANFEB =	34.5 cfs
Q10%Ex =	67.0 cfs
Q20%WINTER EX =	87.0 cfs
Q20%(Q20%) =	17.4 cfs
Q15%(Q20%) =	13.0 cfs
TU Rate =	20.0 cfs

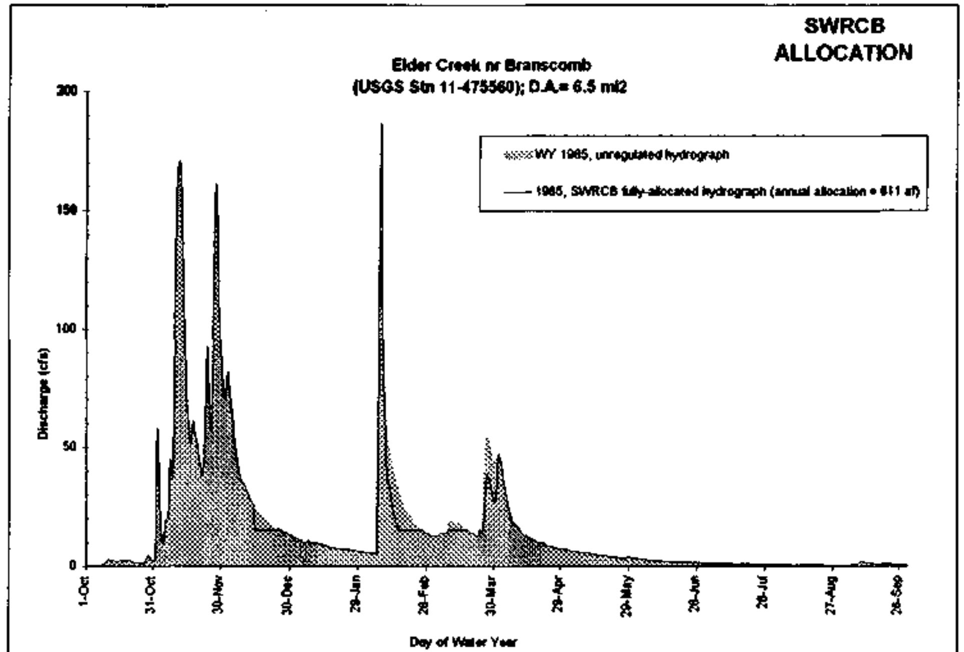
		% of Total
Unregulated Annual Yield =	9,813 af	
SWRCB Annual Allocation=	2,240 af	23%
NMFS Annual Allocation=	1,184 af	12%
TU Annual Allocation=	1,515 af	15%

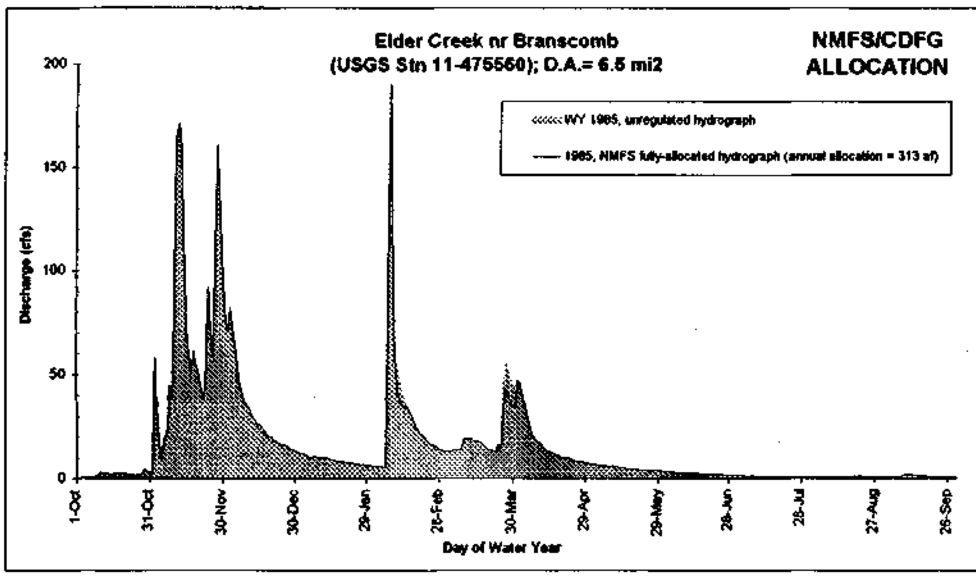


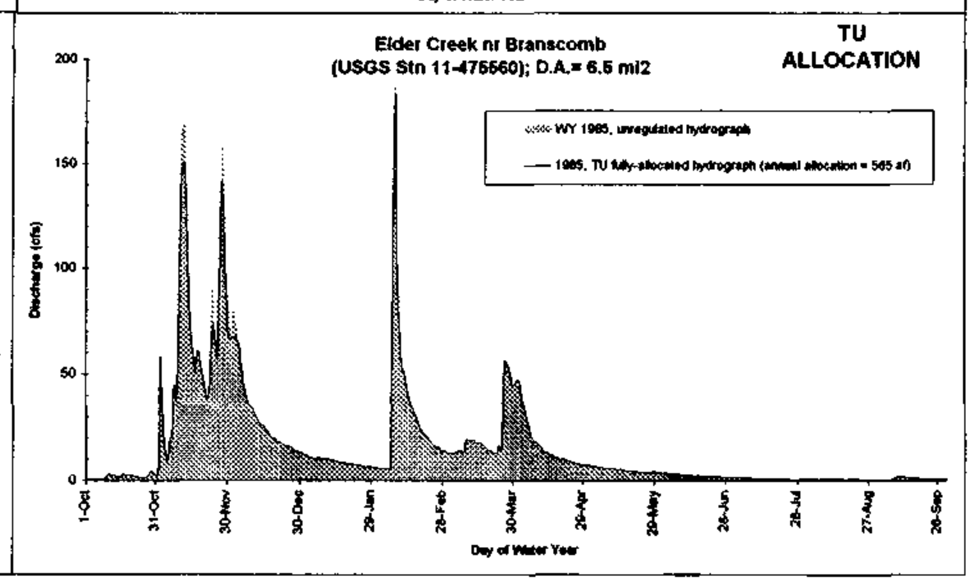




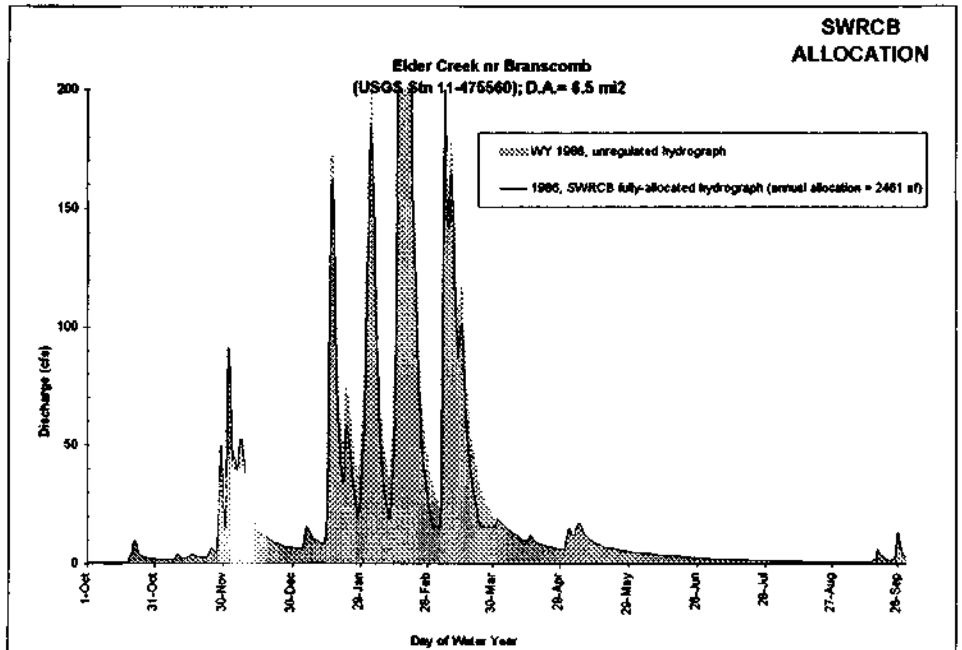
STREAM:	**Elder Creek**	
BASIN:	**SF Eel River**	
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**	
WATER YEAR	WY 1985	
DRAINAGE AREA	6.5 mi2	
QAVG FOR YEAR =	16.2 cfs	
60%QAVG =	15.4 cfs	
QMEDIANFEB =	34.5 cfs	
Q10%Ex =	67.0 cfs	
Q20%WINTER EX =	87.0 cfs	
Q20%(Q20%) =	17.4 cfs	
Q15%(Q20%) =	13.0 cfs	
TU Rate =	20.0 cfs	
Unregulated Annual Yield =	4,433 af	% of Total
SWRCB Annual Allocation=	811 af	18%
NMFS Annual Allocation=	313 af	7%
TU Annual Allocation=	565 af	13%

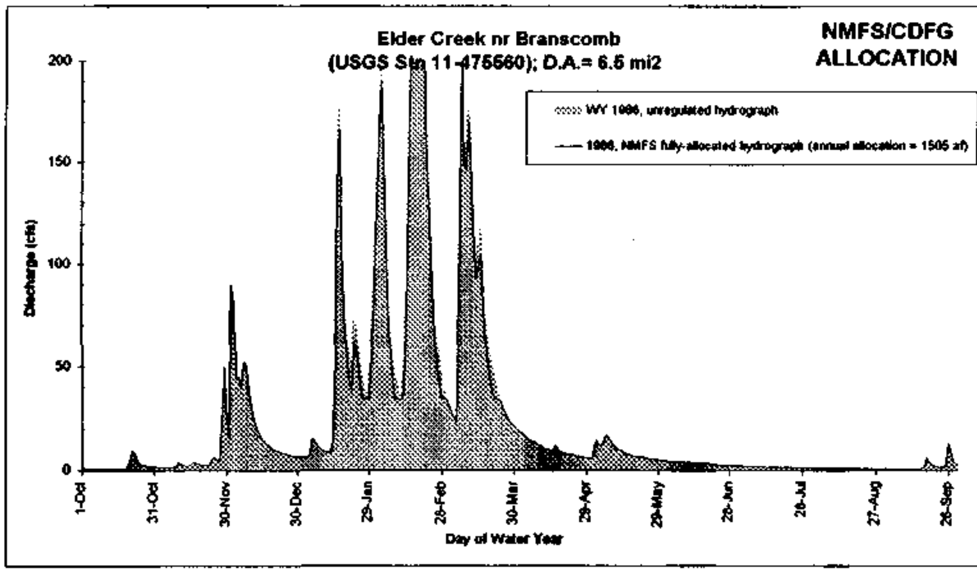


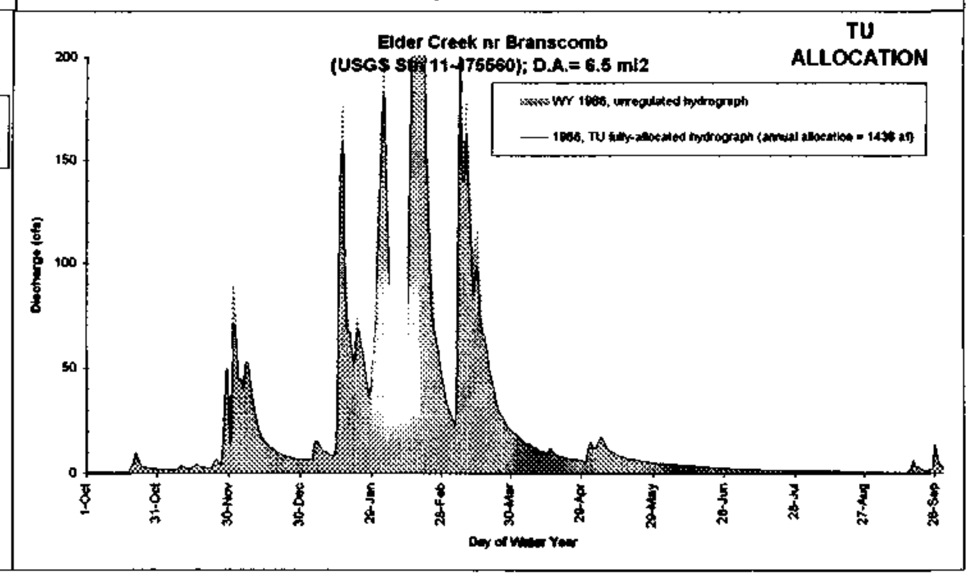




STREAM:	**Elder Creek**	
BASIN:	**SF Eel River**	
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**	
WATER YEAR	WY 1986	
DRAINAGE AREA	6.5 mi2	
QAVG FOR YEAR =	28.4 cfs	
60%QAVG =	15.4 cfs	
QMEDIANFEB =	34.5 cfs	
Q10%Ex =	67.0 cfs	
Q20%WINTER EX =	87.0 cfs	
Q20%(Q20%) =	17.4 cfs	
Q15%(Q20%) =	13.0 cfs	
TU Rate =	20.0 cfs	
Unregulated Annual Yield =	17,274 af	% of Total
SWRCB Annual Allocation=	2,461 af	14%
NMFS Annual Allocation=	1,505 af	9%
TU Annual Allocation=	1,438 af	8%

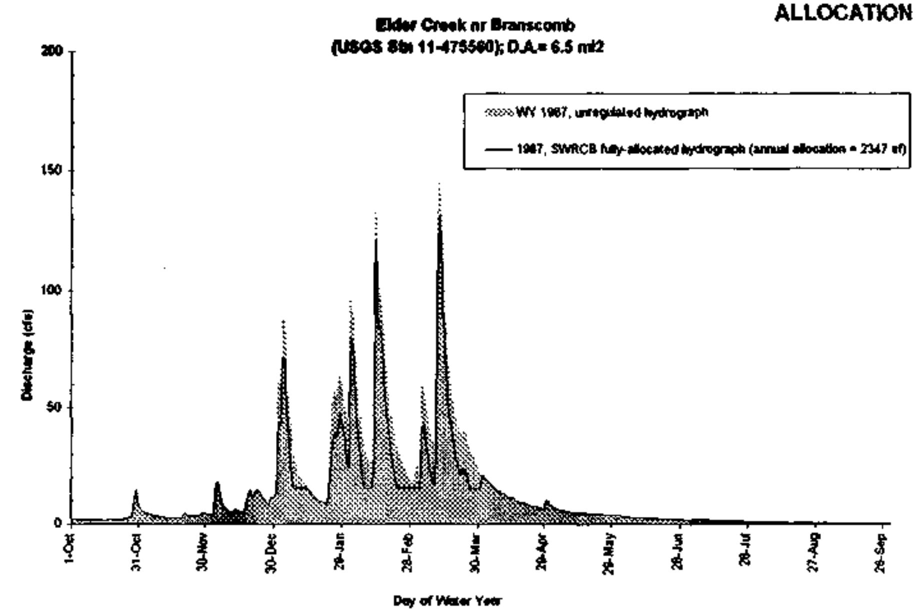




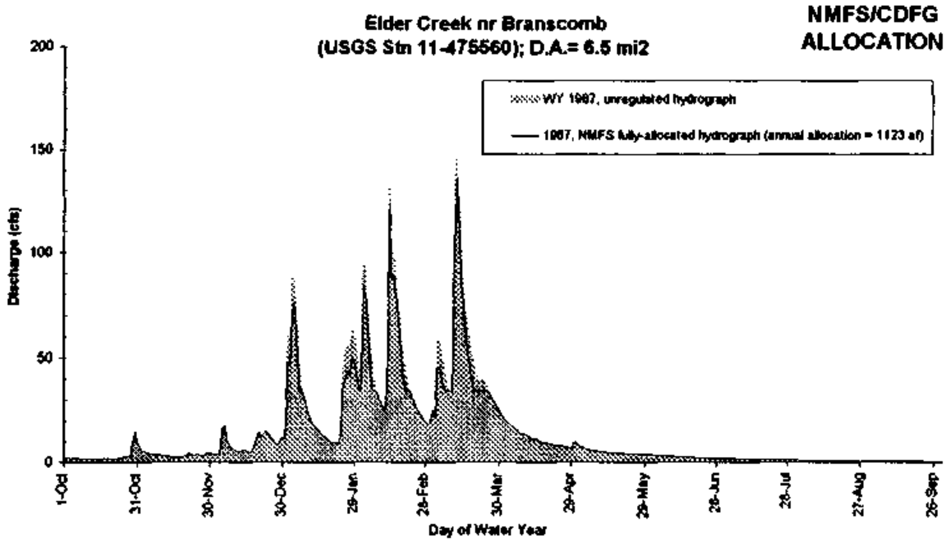


STREAM:	**Elder Creek**	
BASIN:	**SF Eel River**	
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**	
WATER YEAR	WY 1987	
DRAINAGE AREA	6.5 mi2	
QAVG FOR YEAR =	14.6 cfs	
60%QAVG =	15.4 cfs	
QMEDIANFEB =	34.5 cfs	
Q10%Ex =	67.0 cfs	
Q20%WINTER EX =	87.0 cfs	
Q20%(Q20%) =	17.4 cfs	
Q15%(Q20%) =	13.0 cfs	
TU Rate =	20.0 cfs	
Unregulated Annual Yield =	8,658 af	% of Total
SWRCB Annual Allocation=	2,347 af	27%
NMFS Annual Allocation=	1,123 af	13%
TU Annual Allocation=	530 af	6%

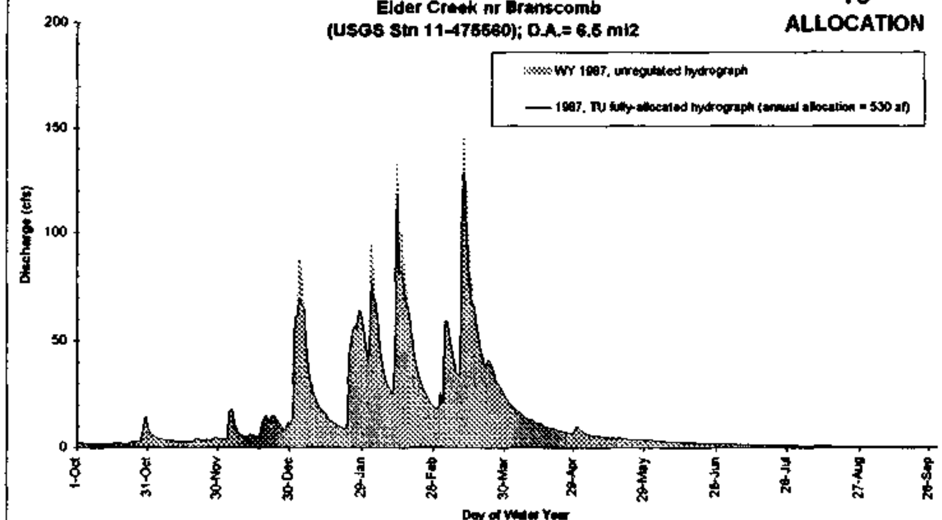
SWRCB ALLOCATION



NMFS/CDFG ALLOCATION

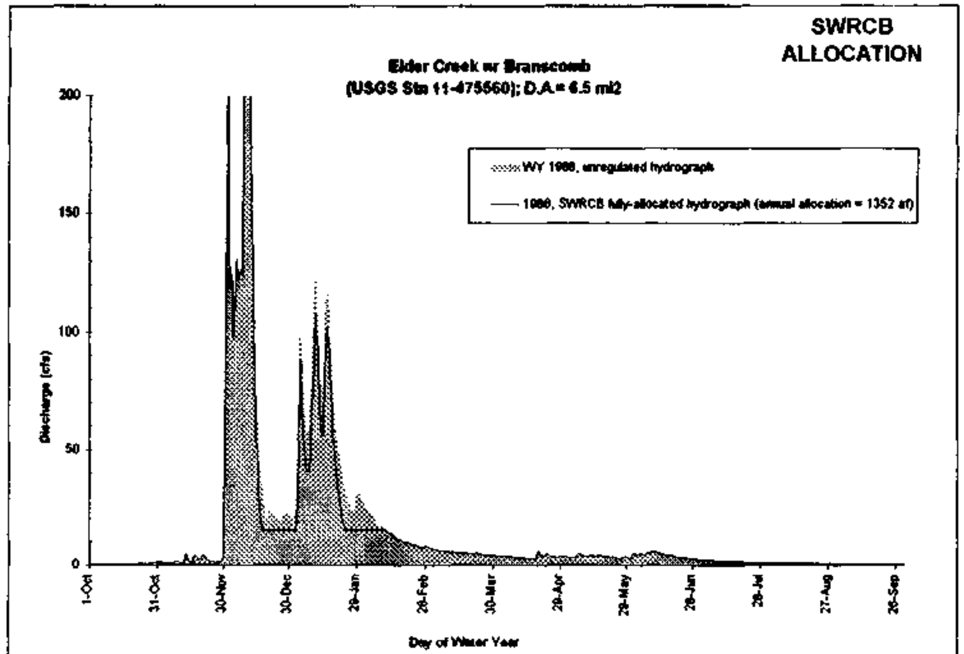


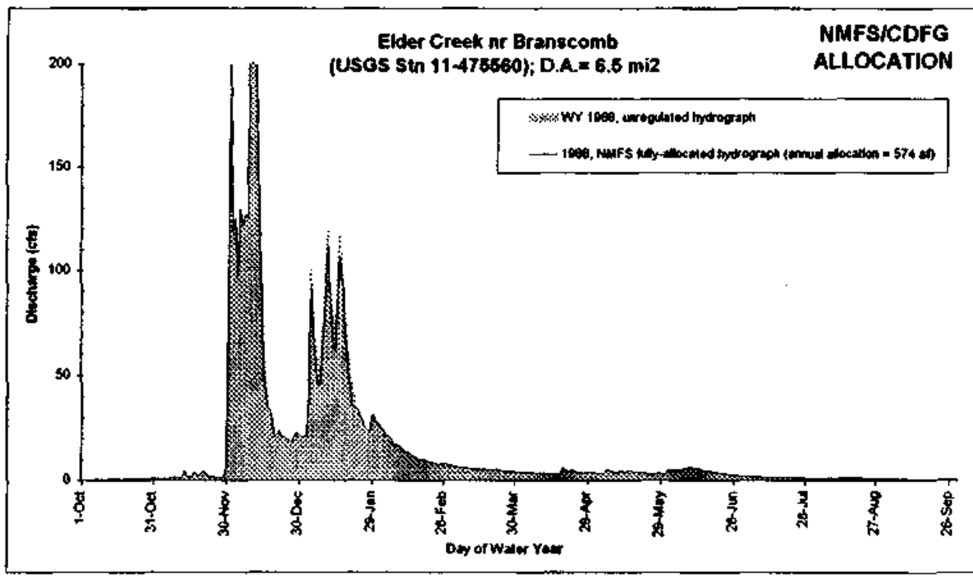
TU ALLOCATION

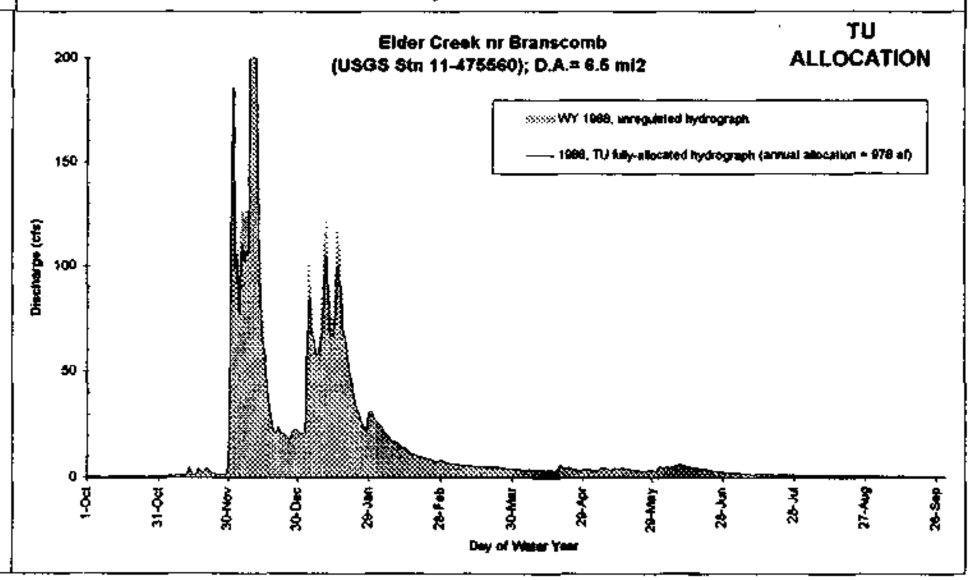


STREAM:	**Elder Creek**
BASIN:	**SF Eel River**
GAGING STATION:	**Elder Creek nr Branscomb (Stn 11-475560)**
WATER YEAR	WY 1988
DRAINAGE AREA	6.5 mi2
QAVG FOR YEAR =	18.0 cfs
60%QAVG =	15.4 cfs
QMEDIANFEB =	34.5 cfs
Q10%Ex =	67.0 cfs
Q20%WINTER EX =	87.0 cfs
Q20%(Q20%) =	17.4 cfs
Q15%(Q20%) =	13.0 cfs
TU Rate =	20.0 cfs

		% of Total
Unregulated Annual Yield =	5,906 af	
SWRCB Annual Allocation=	1,352 af	23%
NMFS Annual Allocation=	574 af	10%
TU Annual Allocation=	978 af	17%

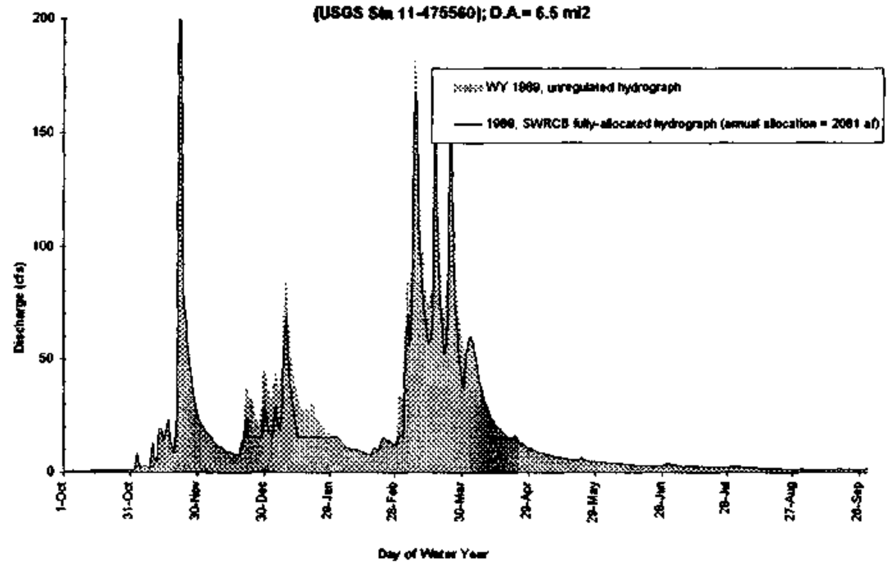




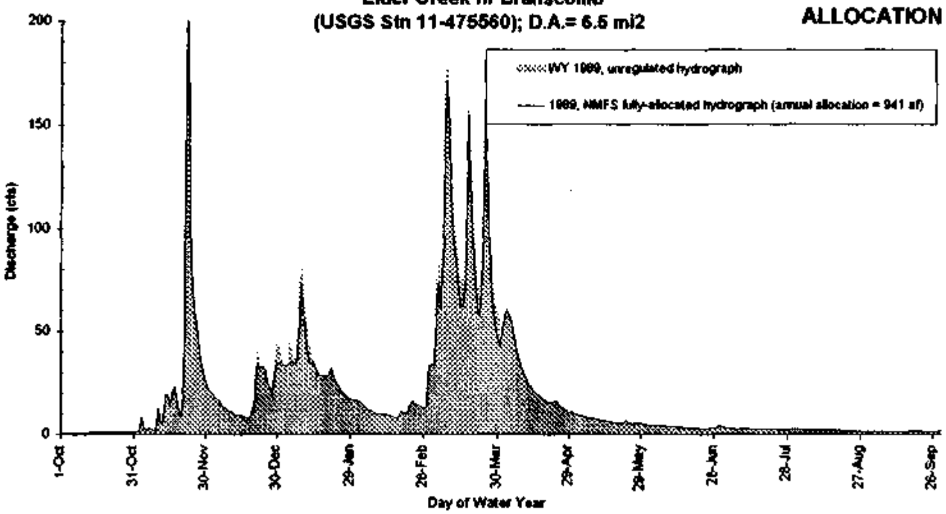


STREAM:	Elder Creek	
BASIN:	SF Eel River	
GAGING STATION:	Elder Creek nr Branscomb (Stn 11-475560)	
WATER YEAR	WY 1989	
DRAINAGE AREA	6.5 mi2	
QAVG FOR YEAR =	19.4 cfs	
60%QAVG =	15.4 cfs	
QMEDIANFEB =	34.5 cfs	
Q10%Ex =	67.0 cfs	
Q20%WINTER EX =	87.0 cfs	
Q20%(Q20%) =	17.4 cfs	
Q15%(Q20%) =	13.0 cfs	
TU Rate =	20.0 cfs	
Unregulated Annual Yield =	9,183 af	% of Total
SWRCB Annual Allocation=	2,081 af	23%
NMFS Annual Allocation=	941 af	10%
TU Annual Allocation=	904 af	10%

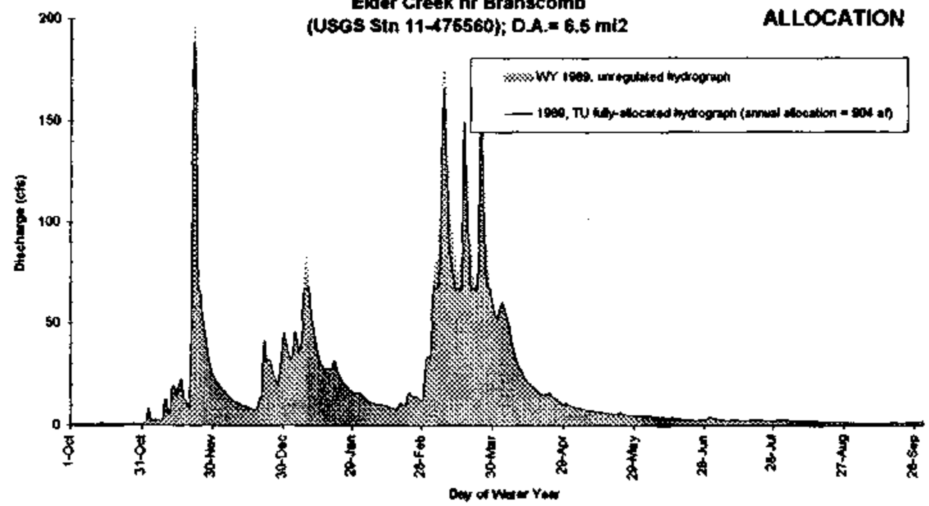
SWRCB ALLOCATION



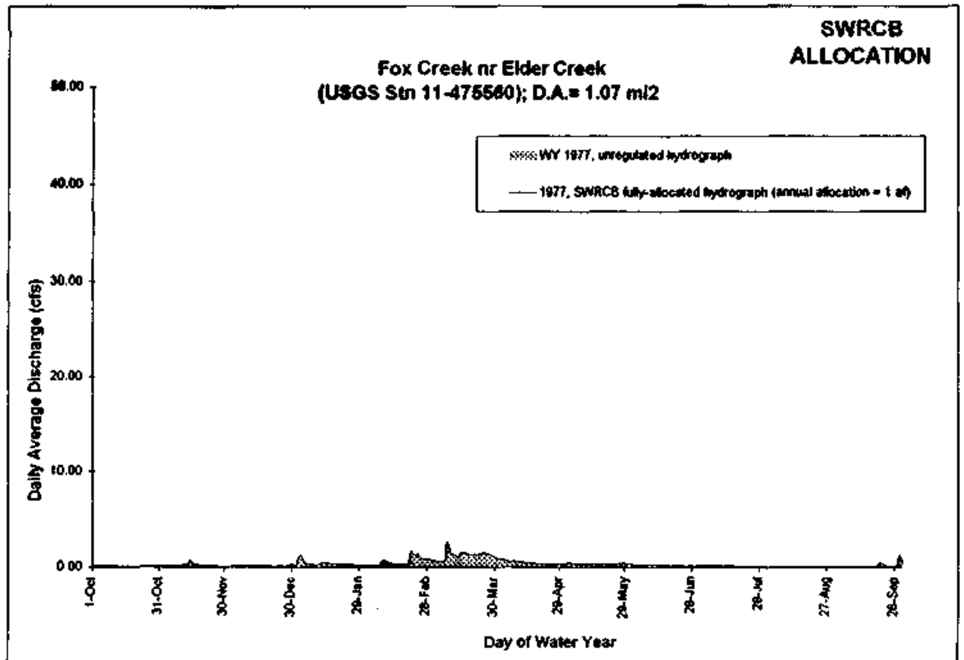
NMFS/CDFG ALLOCATION

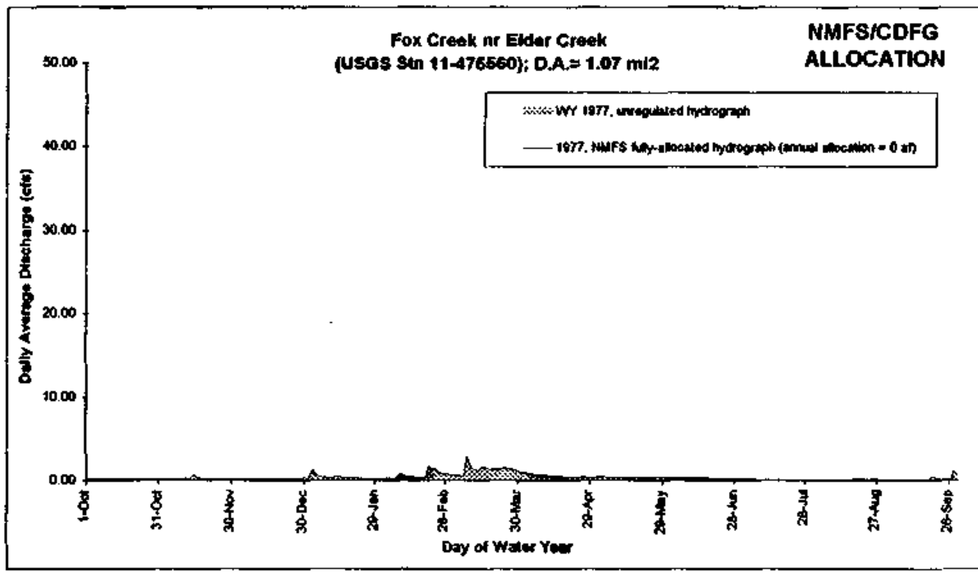


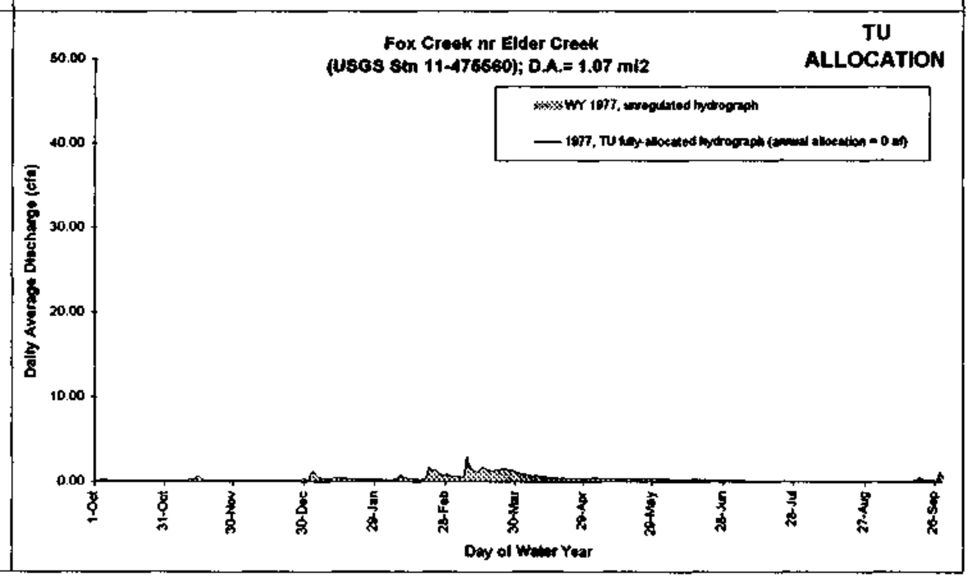
TU ALLOCATION



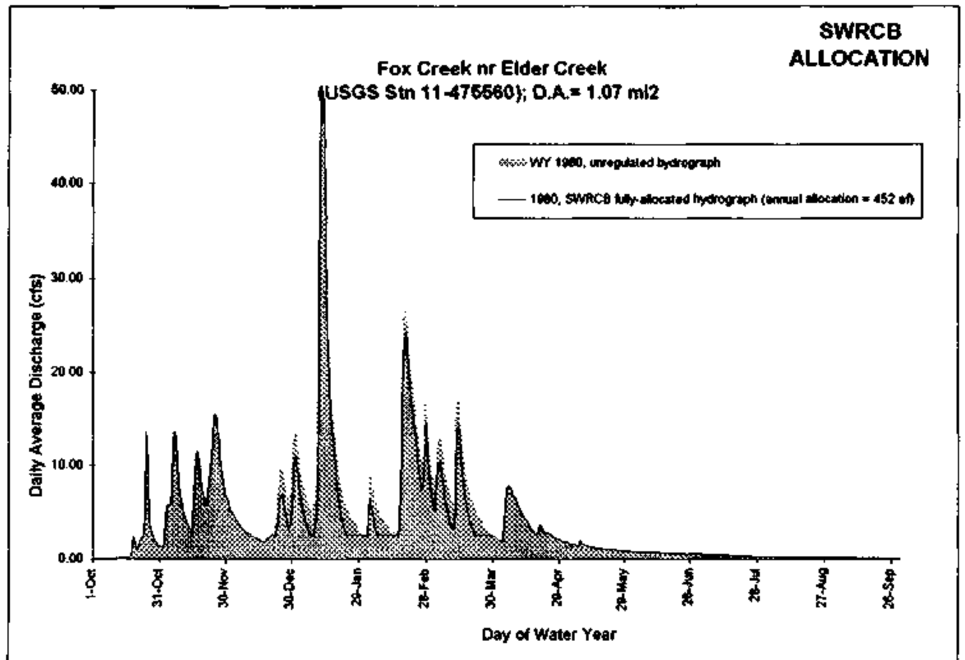
STREAM:	**Fox Creek**	
BASIN:	**SF Eel River Basin**	
GAGING STATION:	Elder Creek nr Branscomb (Stn 11-475560)	
WATER YEAR	WY 1977	
DRAINAGE AREA	1.1 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	0.3 cfs	
60%Q_{AVG} =	2.5 cfs	
$Q_{MEDIANFEB}$ =	5.7 cfs	
$Q_{10\%Ex}$ =	11.0 cfs	
$Q_{20\%WINTER\ EX}$ =	14.3 cfs	
$Q_{20\%(Q20\%)}$ =	2.9 cfs	
$Q_{15\%(Q20\%)}$ =	2.1 cfs	
TU Rate =	8.5 cfs	
Unregulated Annual Yield =	137 af	% of Total
SWRCB Annual Allocation=	1 af	1%
NMFS Annual Allocation=	0 af	0%
TU Annual Allocation=	0 af	0%

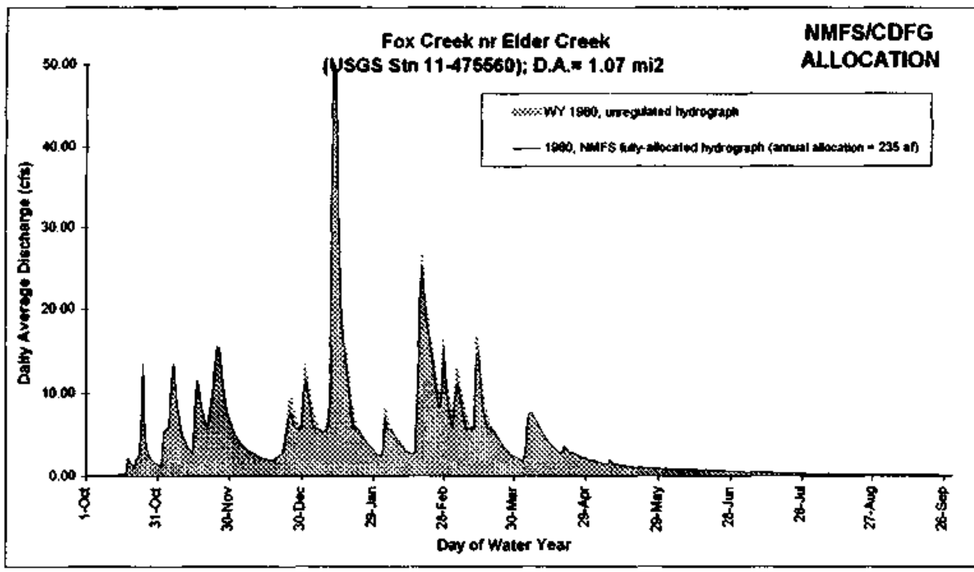


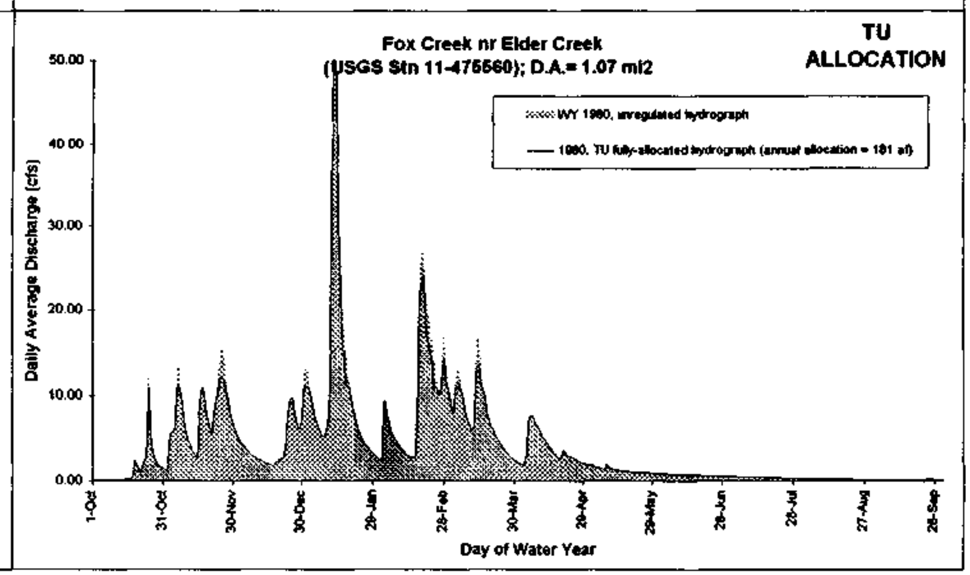




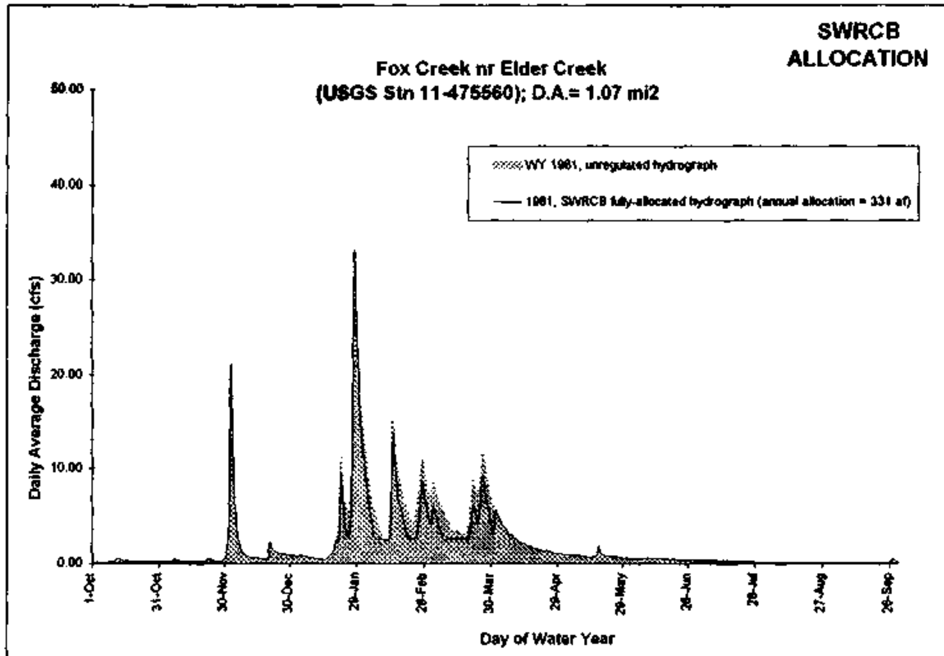
STREAM:	**Fox Creek**	
BASIN:	**SF Eel River Basin**	
GAGING STATION:	Elder Creek nr Branscomb (Stn 11-475560)	
WATER YEAR	WY 1980	
DRAINAGE AREA	1.1 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	4.2 cfs	
60%Q_{AVG} =	2.5 cfs	
$Q_{MEDIANFEB}$ =	5.7 cfs	
$Q_{10\%Ex}$ =	11.0 cfs	
$Q_{20\%WINTER\ EX}$ =	14.3 cfs	
$Q_{20\%(Q20\%)}$ =	2.9 cfs	
$Q_{15\%(Q20\%)}$ =	2.1 cfs	
TU Rate =	8.5 cfs	
Unregulated Annual Yield =	2,006 af	% of Total
SWRCB Annual Allocation=	452 af	23%
NMFS Annual Allocation=	235 af	12%
TU Annual Allocation=	181 af	9%

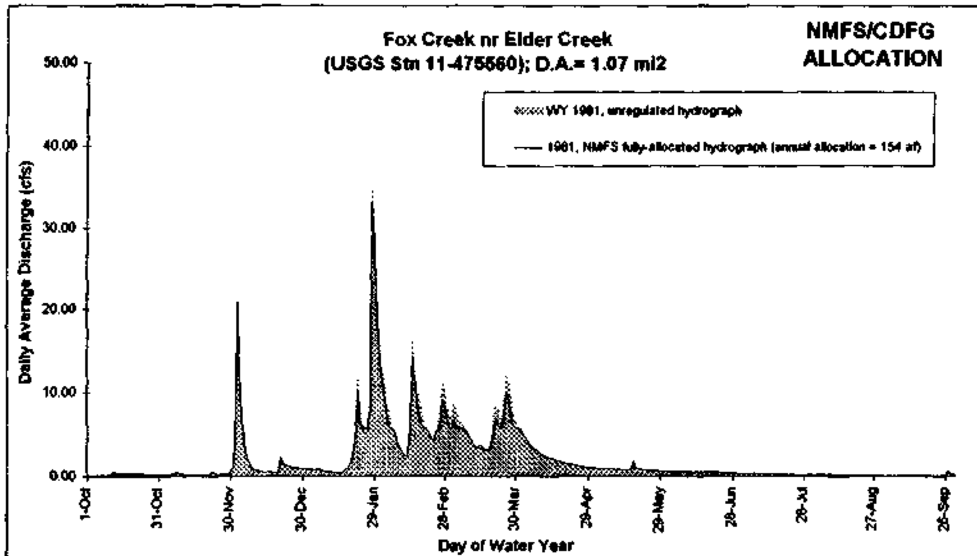


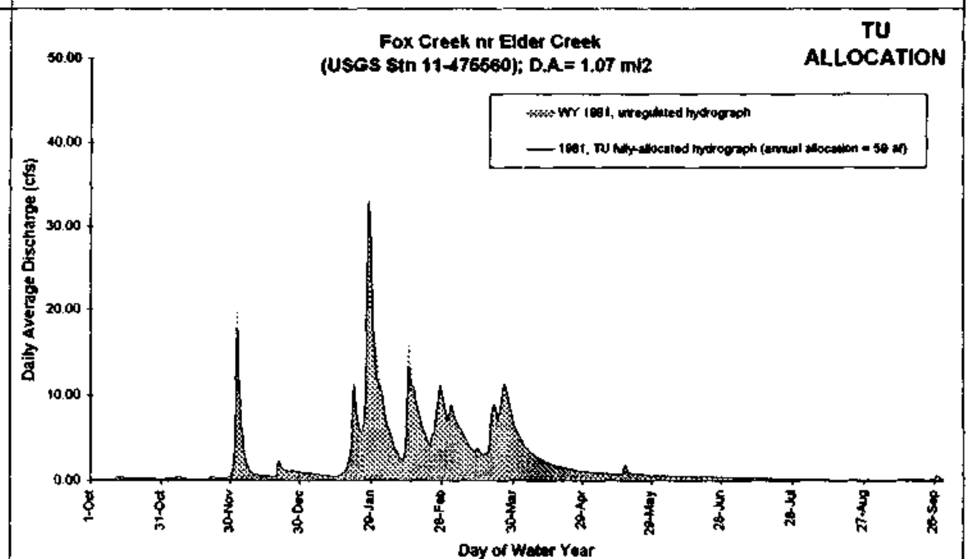




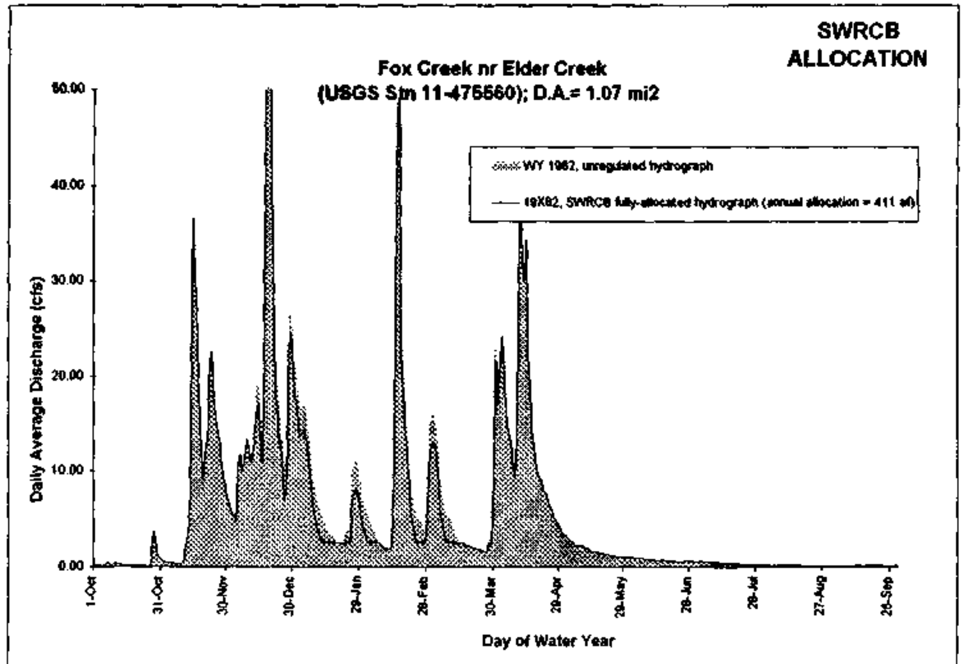
STREAM:	**Fox Creek**	
BASIN:	**SF Eel River Basin**	
GAGING STATION.	Elder Creek nr Branscomb (Stn 11-475560)	
WATER YEAR	WY 1981	
DRAINAGE AREA	1.1 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	2.2 cfs	
$60\%Q_{AVG}$ =	2.5 cfs	
$Q_{MEDIANFEB}$ =	5.7 cfs	
$Q_{10\%EX}$ =	11.0 cfs	
$Q_{20\%WINTER\ EX}$ =	14.3 cfs	
$Q_{20\%(Q20\%)}$ =	2.9 cfs	
$Q_{15\%(Q20\%)}$ =	2.1 cfs	
TU Rate =	8.5 cfs	
Unregulated Annual Yield =	1,194 af	% of Total
SWRCB Annual Allocation=	331 af	28%
NMFS Annual Allocation=	154 af	13%
TU Annual Allocation=	59 af	5%

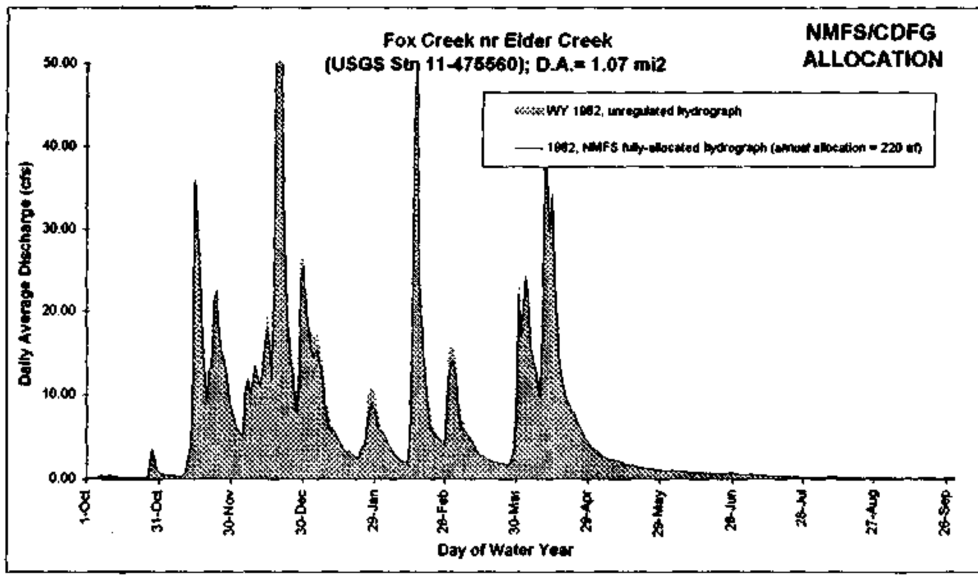


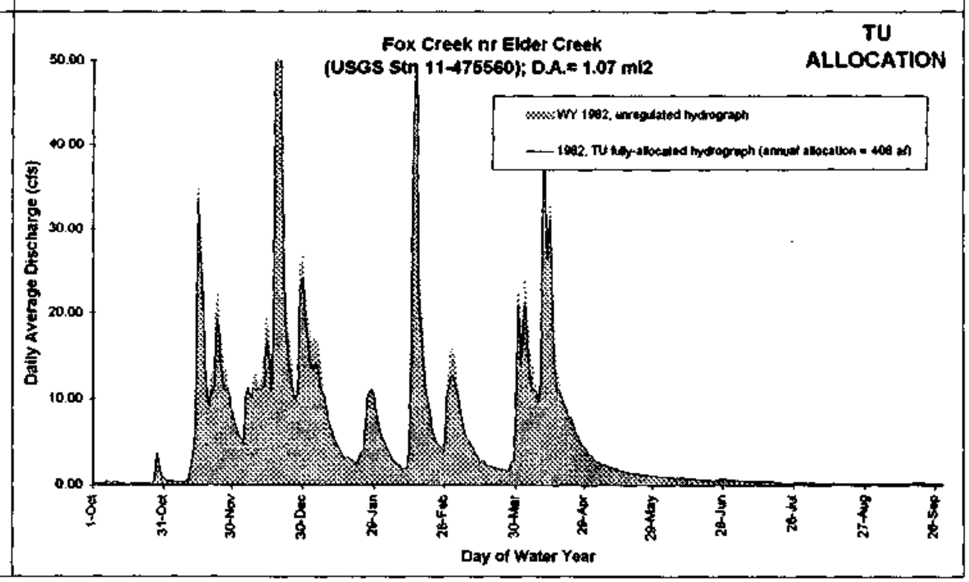




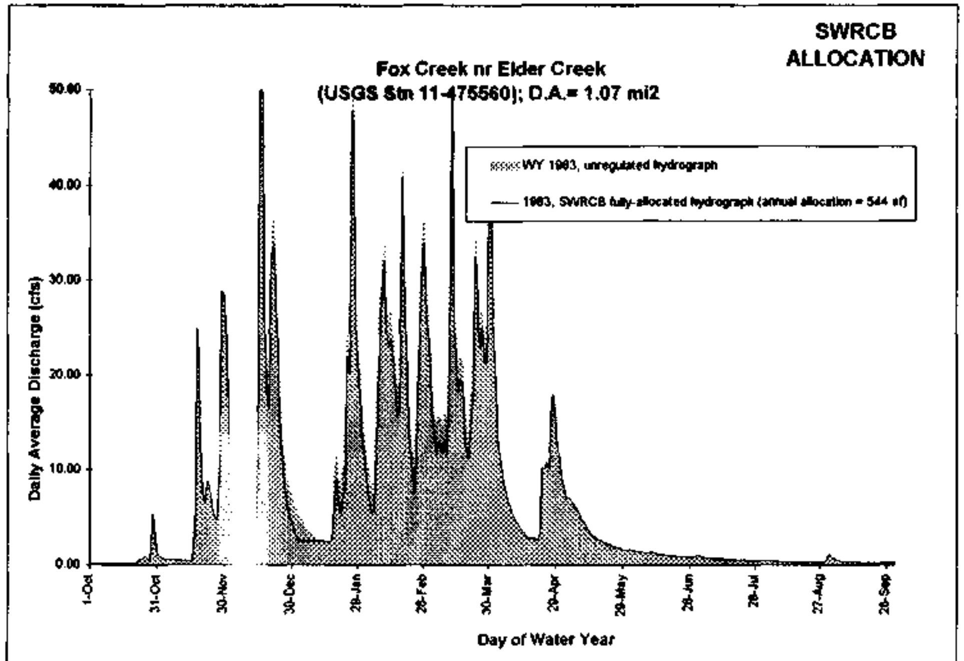
STREAM:	**Fox Creek**	
BASIN.	**SF Eel River Basin**	
GAGING STATION:	Elder Creek nr Branscomb (Stn 11-475560)	
WATER YEAR	WY 1982	
DRAINAGE AREA	1.1 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	6.2 cfs	
$60\%Q_{AVG}$ =	2.5 cfs	
$Q_{MEDIANFEB}$ =	5.7 cfs	
$Q_{10\%Ex}$ =	11.0 cfs	
$Q_{20\%WINTER\ EX}$ =	14.3 cfs	
$Q_{20\%(Q20\%)}$ =	2.9 cfs	
$Q_{15\%(Q20\%)}$ =	2 1 cfs	
TU Rate =	8 5 cfs	
Unregulated Annual Yield =	2,471 af	% of Total
SWRCB Annual Allocation=	411 af	17%
NMFS Annual Allocation=	220 af	9%
TU Annual Allocation=	408 af	16%

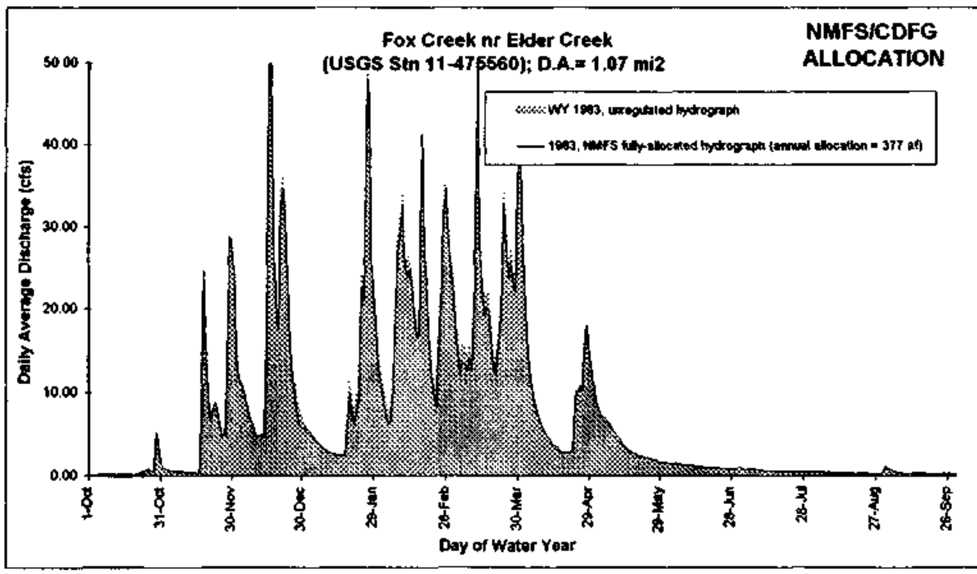


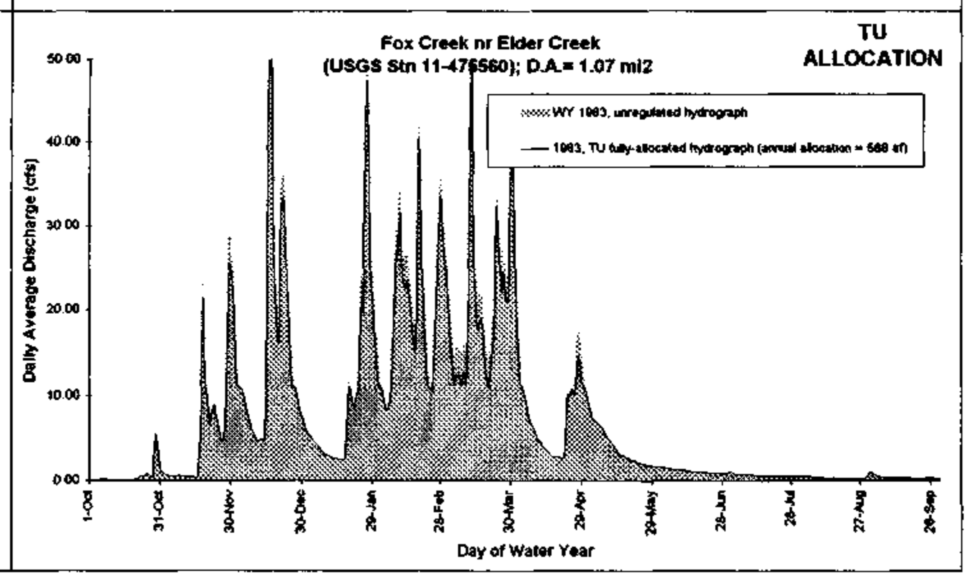




STREAM:	**Fox Creek**	
BASIN:	**SF Eel River Basin**	
GAGING STATION:	Elder Creek nr Branscomb (Stn 11-475560)	
WATER YEAR	WY 1983	
DRAINAGE AREA	1.1 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	8.0 cfs	
$60\%Q_{AVG}$ =	2.5 cfs	
$Q_{MEDIANFEB}$ =	5.7 cfs	
$Q_{10\%EX}$ =	11.0 cfs	
$Q_{20\%WINTER\ EX}$ =	14.3 cfs	
$Q_{20\%(Q20\%)}$ =	2.9 cfs	
$Q_{15\%(Q20\%)}$ =	2.1 cfs	
TU Rate =	8.5 cfs	
Unregulated Annual Yield =	4,200 af	% of Total
SWRCB Annual Allocation=	544 af	13%
NMFS Annual Allocation=	377 af	9%
TU Annual Allocation=	568 af	14%

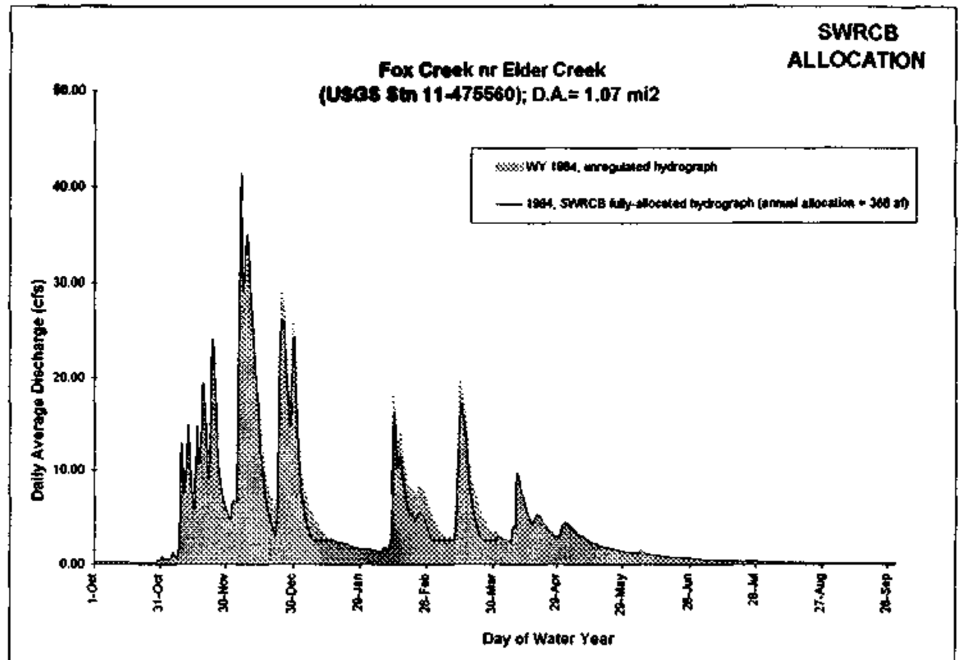


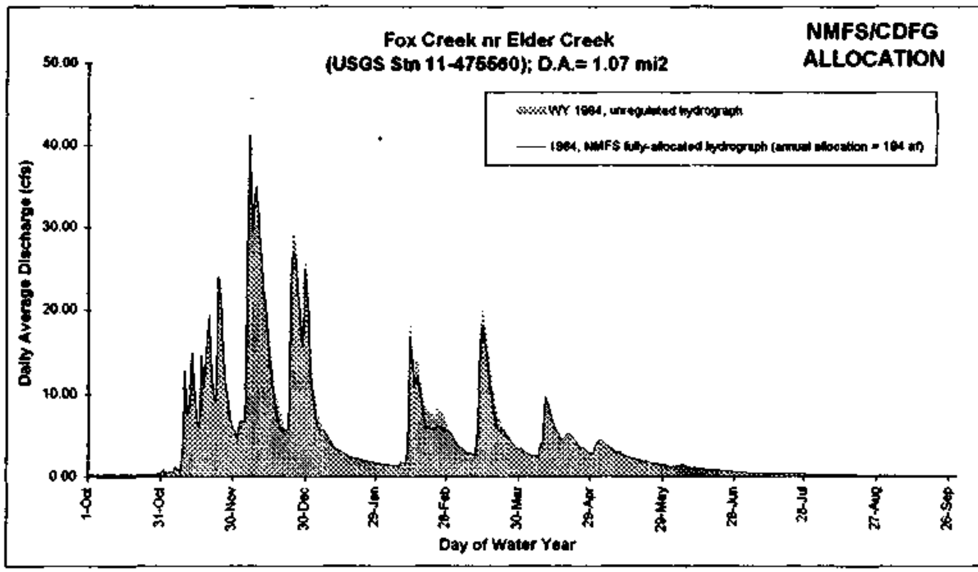


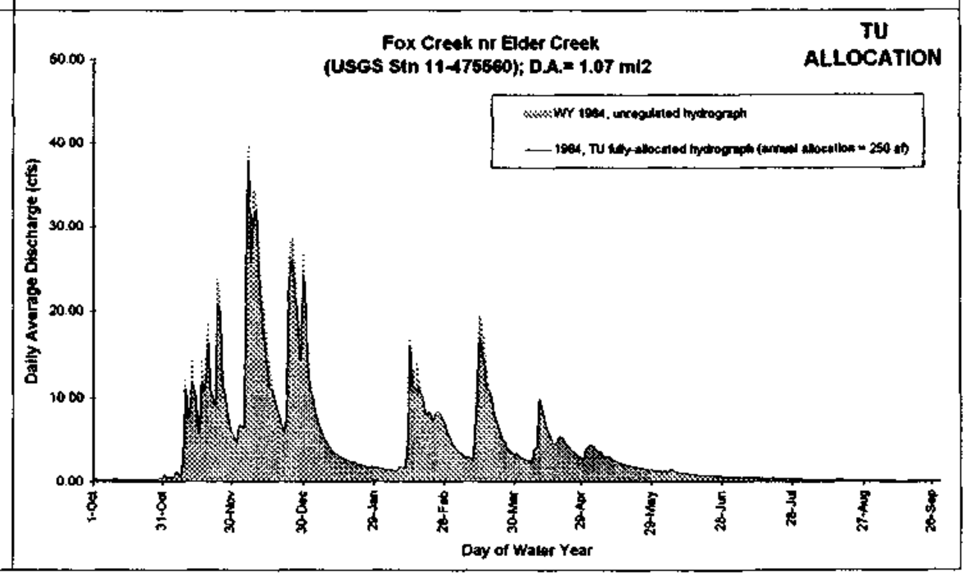


STREAM:	**Fox Creek**
BASIN:	**SF Eel River Basin**
GAGING STATION:	Elder Creek nr Branscomb (Stn 11-475560)
WATER YEAR	WY 1984
DRAINAGE AREA	1.1 mi2
$Q_{AVG\ FOR\ YEAR}$ =	4.5 cfs
60%Q_{AVG} =	2.5 cfs
$Q_{MEDIANFEB}$ =	5.7 cfs
$Q_{10\%EX}$ =	11.0 cfs
$Q_{20\%WINTER\ EX}$ =	14.3 cfs
$Q_{20\%(Q20\%)}$ =	2.9 cfs
$Q_{15\%(Q20\%)}$ =	2.1 cfs
TU Rate =	8.5 cfs

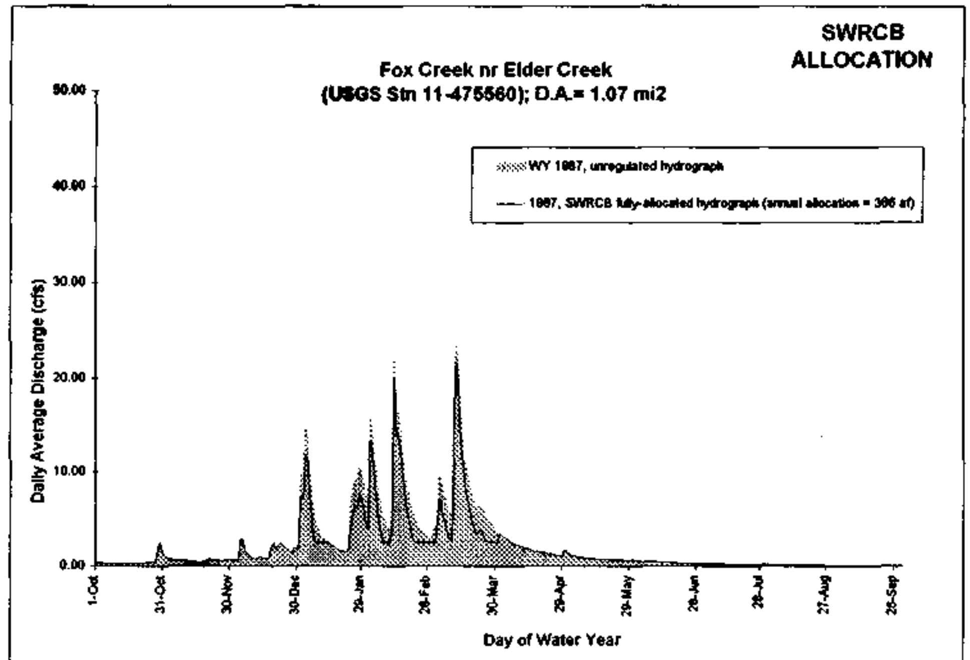
		% of Total
Unregulated Annual Yield =	1,615 af	
SWRCB Annual Allocation=	368 af	23%
NMFS Annual Allocation=	194 af	12%
TU Annual Allocation=	250 af	15%

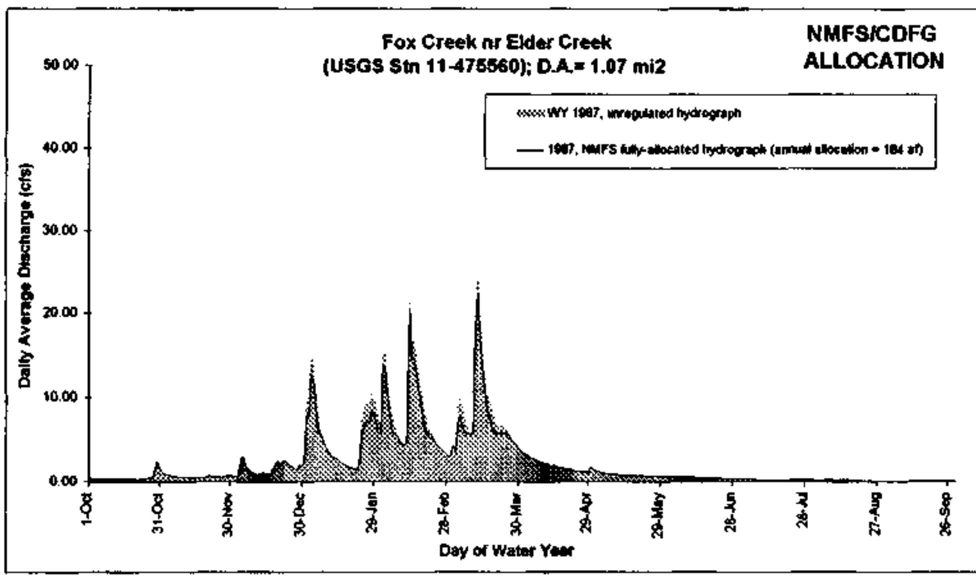


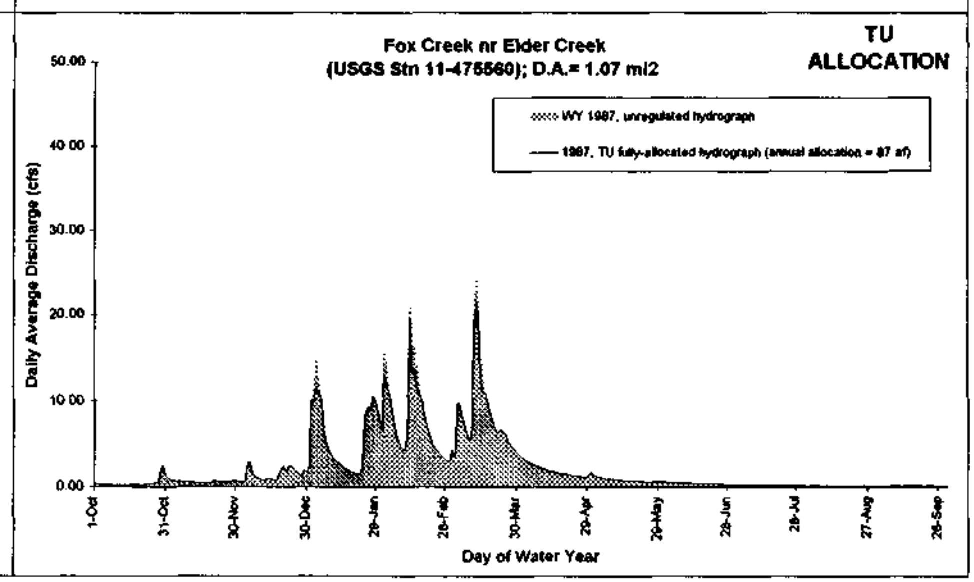




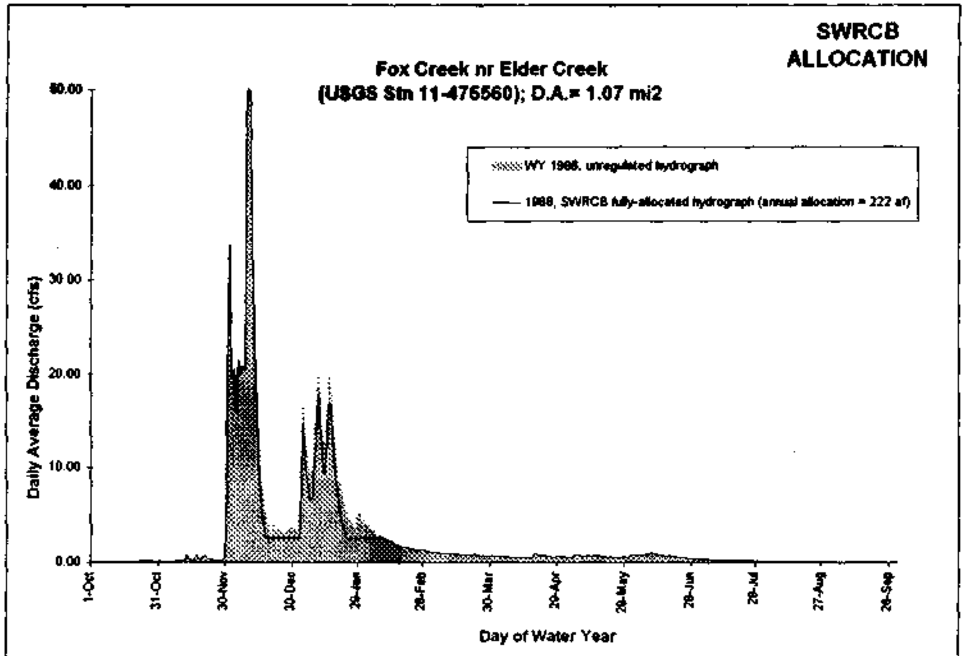
STREAM:	**Fox Creek**	
BASIN:	**SF Eel River Basin**	
GAGING STATION:	Elder Creek nr Branscomb (Stn 11-475560)	
WATER YEAR	WY 1987	
DRAINAGE AREA	1.1 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	2.4 cfs	
$60\%Q_{AVG}$ =	2.5 cfs	
$Q_{MEDIANFEB}$ =	5.7 cfs	
$Q_{10\%Ex}$ =	11.0 cfs	
$Q_{20\%WINTER\ EX}$ =	14.3 cfs	
$Q_{20\%(Q20\%)}$ =	2.9 cfs	
$Q_{15\%(Q20\%)}$ =	2.1 cfs	
TU Rate =	8.5 cfs	
Unregulated Annual Yield =	1,425 af	% of Total
SWRCB Annual Allocation=	386 af	27%
NMFS Annual Allocation=	184 af	13%
TU Annual Allocation=	87 af	6%

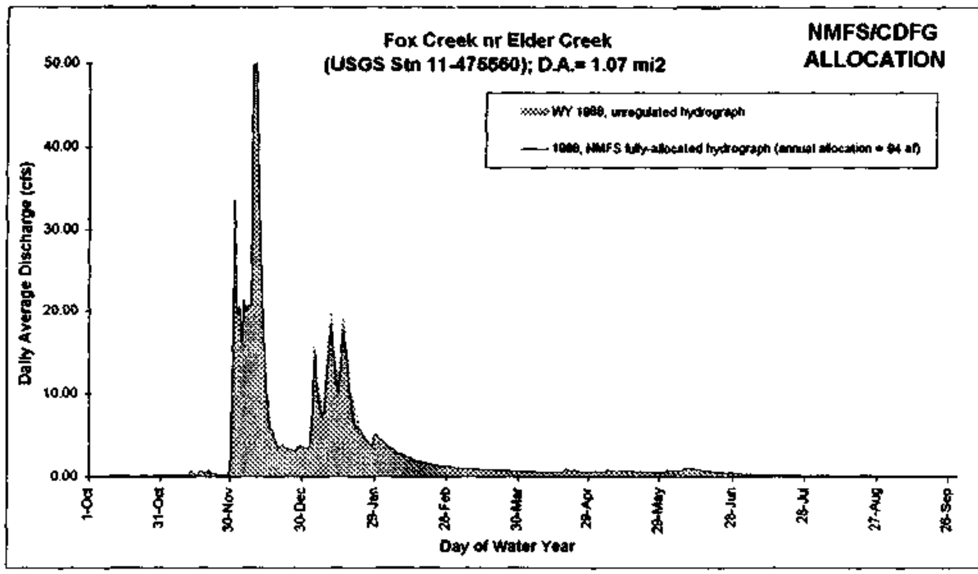


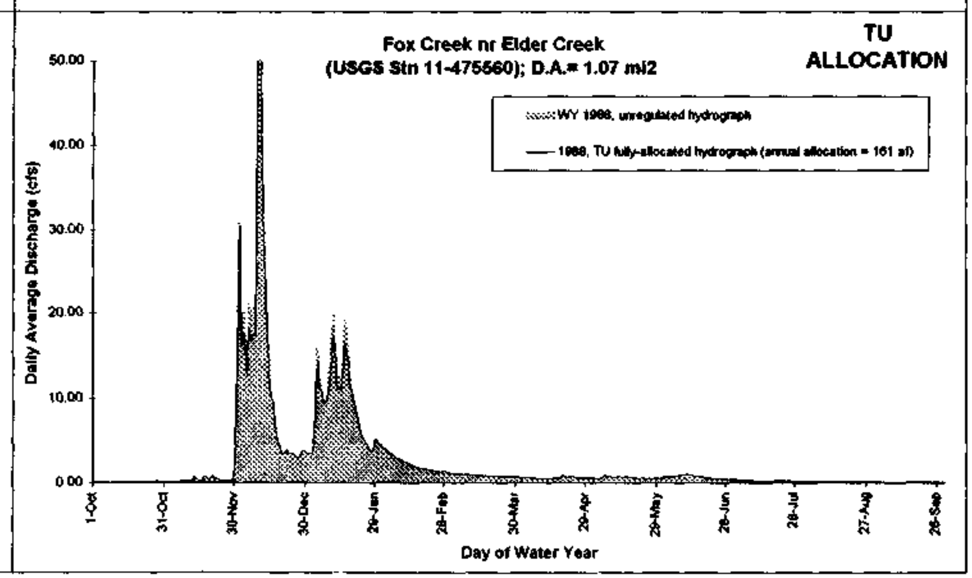




STREAM:	**Fox Creek**	
BASIN:	**SF Eel River Basin**	
GAGING STATION:	Elder Creek nr Branscomb (Stn 11-475560)	
WATER YEAR	WY 1988	
DRAINAGE AREA	1.1 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	2.6 cfs	
$60\%Q_{AVG}$ =	2.5 cfs	
$Q_{MEDIANFEB}$ =	5.7 cfs	
$Q_{10\%EX}$ =	11.0 cfs	
$Q_{20\%WINTER\ EX}$ =	14.3 cfs	
$Q_{20\%(Q20\%)}$ =	2.9 cfs	
$Q_{15\%(Q20\%)}$ =	2.1 cfs	
TU Rate =	8.5 cfs	
Unregulated Annual Yield =	972 af	% of Total
SWRCB Annual Allocation=	222 af	23%
NMFS Annual Allocation=	94 af	10%
TU Annual Allocation=	161 af	17%







STREAM:	**Fox Creek**	
BASIN:	**SF Eel River Basin**	
GAGING STATION:	Elder Creek nr Branscomb (Stn **11-475560**)	
WATER YEAR	WY 1989	
DRAINAGE AREA	1.1 mi2	
$Q_{AVG\ FOR\ YEAR}$ =	3.2 cfs	
60%Q_{AVG} =	2.5 cfs	
$Q_{MEDIANFEB}$ =	5.7 cfs	
$Q_{10\%Ex}$ =	11.0 cfs	
$Q_{20\%WINTER\ EX}$ =	14.3 cfs	
$Q_{20\%(Q20\%)}$ =	2.9 cfs	
$Q_{15\%(Q20\%)}$ =	2.1 cfs	
TU Rate =	8.5 cfs	
Unregulated Annual Yield =	1,512 af	% of Total
SWRCB Annual Allocation=	342 af	23%
NMFS Annual Allocation=	154 af	10%
TU Annual Allocation=	150 af	10%