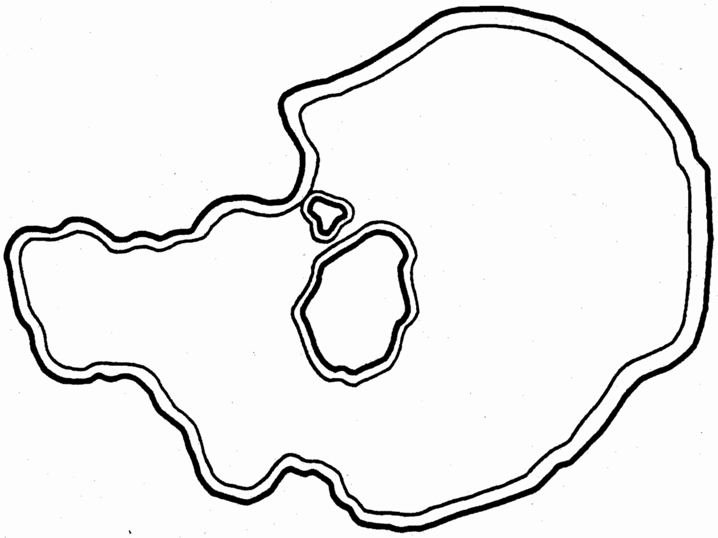
An Auxiliary Report
Prepared for the

# MONO BASIN WATER RIGHTS EIR

## Changes over Time in Geomorphic Conditions, Sediment Transport and Riparian Cover in the Owens River below Pleasant Valley Dam, Inyo County, California



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Mono Basin EIR Auxiliary Report No. 10

# An Auxiliary Report
# Prepared for the
# Mono Basin Water Rights EIR Project

This auxiliary report was prepared to support the environmental impact report (EIR) on the amendment of appropriative water rights for water diversions by the City of Los Angeles Department of Water and Power (LADWP) in the Mono Lake Basin. Jones & Stokes Associates is preparing the EIR under the technical direction of the California State Water Resources Control Board (SWRCB). EIR preparation is funded by LADWP.

SWRCB is considering revisions to LADWP's appropriative water rights on four streams tributary to Mono Lake, Lee Vining Creek, Rush Creek, Parker Creek, and Walker Creek. LADWP has diverted water from these creeks since 1941 for power generation and municipal water supply. Since the diversions began, the water level in Mono Lake has fallen by 40 feet.

The Mono Basin water rights EIR examines the environmental effects of maintaining Mono Lake at various elevations and the effects of possible reduced diversions of water from Mono Basin to Owens Valley and the City of Los Angeles. Flows in the four tributary creeks to Mono Lake and water levels in Mono Lake are interrelated. SWRCB's decision on amendments to LADWP's water rights will consider both minimum streamflows to maintain fish populations in good condition and minimum lake levels to protect public trust values.

This report is one of a series of auxiliary reports for the EIR prepared by subcontractors to Jones & Stokes Associates, the EIR consultant, and contractors to LADWP. Information and data presented in these auxiliary reports are used by Jones & Stokes Associates and SWRCB, the EIR lead agency, in describing environmental conditions and conducting the impact analyses for the EIR. Information from these reports used in the EIR is subject to interpretation and integration with other information by Jones & Stokes Associates and SWRCB in preparing the EIR.

The information and conclusions presented in this auxiliary report are solely the responsibility of the author.

Copies of this auxiliary report may be obtained at the cost of reproduction by writing to Jim Canaday, Environmental Specialist, State Water Resources Control Board, Division of Water Rights, P.O. Box 2000, Sacramento, CA 95810.

# CHANGES OVER TIME IN GEOMORPHIC CONDITIONS, SEDIMENT TRANSPORT AND RIPARIAN COVER IN THE OWENS RIVER BELOW PLEASANT VALLEY DAM, INYO COUNTY, CALIFORNIA

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May 1992

This study was conducted as part of the Mono Basin Water Rights EIR under the direction of the California State Water Resources Control Board.

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# 1. ABSTRACT

Annual flows in the Owens River below Pleasant Valley Dam have increased approximately 30 percent since gaging commenced in 1935, largely as a result of diversions from the Mono Lake basin. This technical report, prepared as a component of the Middle Owens River Instream Flow Incremental Methodology Study conducted by Jones & Stokes Associates, describes and interprets changes in channel morphology, bank vegetation, and sediment transport primarily within a 15-mile reach of the Owens River extending for six miles below Pleasant Valley Dam. This reach comprises the Wild Trout Reach and is an important trout sport fishery (Figure 1). The Wild Trout Reach comprises segments 1 and 2 of the Middle Owens River IFIM Study.

We have used a combination of historical aerial photography (1944, 1967 and 1990) and field analyses during November 1990 and May 1991 to examine changes in channel morphology and riparian vegetation density since the early 1940s. Results from a 1972 U. S. Geological Survey study performed on the Wild Trout Reach (Williams 1975) also have been evaluated to establish whether geomorphic or riparian habitat changes have occurred from the opening of the second Mono aqueduct in 1970 or from other land/water use practices.

Our findings indicate that:

1. The hydraulic geometry of six representative sites in the Wild Trout Reach have not changed appreciably since 1972, and it is likely that the assumption of dynamic equilibrium is met sufficiently to support the validity of using the IFIM study results into the foreseeable future; longer-term observations of channel hydraulic geometry and longitudinal channel characteristics are required to conclusively demonstrate channel stability into the foreseeable future.

2. The density of riparian vegetation has changed significantly, with a 47 percent increase in dense riparian vegetation between 1967 and 1990, mostly occurring in the lower half of the six-mile study reach.

3. Average downcutting of 0.4 and 0.2 feet was computed for 2 of 6 sections established by USGS staff in 1972, but little or no changes in width or velocity were discernible at these sections.

4. Channel length and sinuosity (meandering) have changed less than 1 percent overall, but changes have been more significant within specific reaches.

5. The banks and bed of the channel are the primary source of both coarse and fine inorganic sediment in all portions of the Wild Trout Reach, with bluff cutting at one location acting as a secondary contributor. Horton Creek and other tributaries are at present minor contributors to both coarse and fine loads.

6. Short portions of the bed are distinctly armored in the lower portions of the reach, but considerable sediment is available for transport and there appears to be relatively high availability of detachable substrate suitable for trout spawning.

7. The number of deep undercut banks has diminished markedly over the past two or three decades, most likely because of a loss of bank strength associated with the sharp decrease in wooded riparian banks during the 1950s and 1960s (since partially reversed), and rapid changes in streamflow associated with Pleasant Valley Dam operations that drop water levels rapidly and accelerate collapse of suddenly unsupported saturated banks.

8. Sediment transport rates appear to increase sharply above a range of about 600-800 cfs, based on measurements made in 1972. The 1991 measurements suggest that the same sediment-transport relationships still apply at lower flows, but measurements at 600 to

800 cfs could not be made since such discharges did not occur in 1991.

## 2. INTRODUCTION

### Scope of Study

Biologists and long-time observers familiar with the Owens River below Pleasant Valley Dam consistently voice concerns over ongoing changes in the channel and the possible effects of these changes on trout production or age distribution. Informed observers report that the deep undercut banks of a generation ago are absent, and that the river is faster and perhaps more turbid than in the past. Data to support or refute these impressions of knowledgeable observers are largely lacking. The need for such data, or an expert geomorphic description of the channel, is sufficiently clear that the California Department of Fish and Game prepared a scope of work (subsequently not issued) seeking professional geoscience assistance in evaluating what these changes have been.

Jones & Stokes Associates is conducting an instream flow study on the Middle Owens River using the Instream Flow Incremental Methodology (IFIM). Recognizing the local value of applying geomorphic reasoning in planning the IFIM study and in interpreting its results, Jones & Stokes Associates requested that we ". . . conduct qualitative analyses of geomorphic conditions, such as channel downcutting and widening, fine sand and clay accumulations, and gravel recruitment and sedimentation." Within this framework, we were asked to conduct five specific tasks:

- Participate in channel-segment and site selection for the IFIM
- Obtain and interpret existing aerial photographs to delineate changes in channel pattern
- Describe events associated with channel changes
- Evaluate channel geometry relationships
- Qualitatively summarize bed and bank conditions, and their effects on the validity of the instream flow study and aquatic habitats.

The first task was accomplished largely in the field during November 1990 and May 1991. This report describes the results of our analyses, plus additional observations and analyses which we found warranted to meet the range of qualitative descriptions sought.

The level of funding provided for this study allowed for a total of approximately 30 staff days, of which about half were to be in the field over a brief period in May and June, 1991.

The study was originally conceived to be based upon repeated measurements at flows of approximately 150, 225 and 450 cfs, to be released by LADWP over a period of two weeks in late May and early June 1991. LADWP was unable to make these releases due to damage to a penstock. We modified the work program in the field to focus upon changes at six sites within the Wild Trout Reach (formally known as the Wild Trout Management Area) where USGS staff had described sediment-transport and bed conditions over a broad range of flows in 1972 (Williams, 1975). The Wild Trout Reach comprises segments 1 and 2 of the Jones & Stokes Associates' Middle Owens River IFIM Study. These sites and the prior work, which became central to our study, are described in detail below.

Our analyses were directed toward developing geomorphic data subsequently to be used in assessing potential effects of alternate flow regimes resulting from varying levels of diversions from the Mono Basin. Many local observers believe that a management plan is needed for the Owens River below Pleasant Valley Dam, and particularly for the Wild Trout Reach. We have tried to provide as much information and analysis to evaluate local management concerns as is possible consistent with our specific assignment. We make no recommendations, however, for management of the Wild Trout Reach, because that is not our charge.

## Summary of approaches and methods

One goal of this study was to evaluate whether changes in flow regime or other alterations of the floodplain have affected riparian habitat and channel morphology in the Wild Trout Reach of the Owens River. Our approach to evaluating potential changes used four major, independent lines of inquiry:

1. Historical aerial photographic analysis. We used photography from 1944, 1967 and 1990 to examine and quantify historical changes in riparian vegetation density and channel morphology variables (i.e. meander geometry, width, etc. ).

2. Bed sedimentology analysis. We re-visited the sites of a 1972 study (Williams, 1975) on the Wild Trout Reach to acquire data on the particle-size and rock-type composition of the bed. The particle-size information could be compared with the earlier study to examine changes in bed texture since 1967. Rock-type censuses of the bed allowed us to examine the source of bed sediments, in an effort to clarify the sources of the bed-forming cobbles and pebbles.

3. Hydraulic geometry analysis. Williams (1975) established at-a-station relationships for stream width and average depth based on discharge. Such relationships are known as 'hydraulic geometry' (Leopold and Maddock, 1953). We have generated similar relationships for the revisited sections in an effort to determine if deepening or widening are actively occurring.

4. Interviews and reviews. We interviewed biologists familiar with the river and reviewed past channel conditions.

## Previous work

The Owens River has experienced a net increase in flows as a result of the Mono diversions into the Owens basin. Williams (1975) presents the only organized and published data on the Middle Owens River; he found that no significant changes had occurred in the channel as of 1972 and made no recommendations for future flow release patterns. His data provide a basis for comparisons with future studies. In a more recent re-analysis of the 1972 data (Williams, 1987) he seemed to indicate that some subreaches of the stream had readjusted to the higher flows associated with the diversions, while others were undergoing readjustment. These data, however, were based on at-a-station observations at seven cross sections and may not present a complete picture of dynamic channel adjustments to changes in flow regime. To our knowledge, no other geomorphic studies have been performed on the Wild Trout Reach. An exhaustive search of state agency records (California Department of Fish and Game, U.S. Geological Survey, LADWP, etc.) turned up no additional data on cross sections, bed elevations, or other aspects of channel morphology. There is an extensive record of historical aerial photographs for the Owens River Valley, from 1942 to 1990, some of which is at sufficiently large scale to perform accurate measurement of channel form and morphology. We made use of photography from 1944, 1967 and 1990 in this study.

Few studies address the geomorphic effects of increased discharge and changes in flow regime associated with such changes in river hydrology. The Owens River, then, presents an interesting problem in assessment of downstream effects. Unfortunately, few existing theoretical or general studies are available to help guide this analysis.

## Acknowledgements

This study was under the direction of Phil Dunn, fisheries biologist with Jones & Stokes Associates. It benefits from intense field discussions with Bill Mitchell and Jeff Koslowski (JSA), and with Alan Pickard and Gary Smith (DFG). John Dienstadt and Darryl Wong (DFG) freely offered their thoughts and observations developed after many years of working on the Wild Trout Reach. John Dienstadt loaned the 1967 aerial photographs which made the historical analysis possible. Randy Neudeck (LADWP) assisted with historical flow records and assisted in obtaining the 1944 aerial photographs.

## 3. HISTORICAL BACKGROUND

Flows in the Owens River below Pleasant Valley Dam were initially augmented in 1941 by diversions from the Mono Basin. For the next 30 years, these diversions averaged 257178 acre-feet annually. A second barrel of the Mono Tunnel was completed in 1970, and an additional average 58292 acre feet per year have been conveyed through it. Annual flows in the Owens River watershed, originally 217419 acre-feet/year, have been increased by an average of 31 percent, and by 15 percent in the wettest years. Storage has been increased above the Wild Trout Reach with the completion of Crowley Lake (183,500 acre feet capacity) in 1941, and Pleasant Valley Reservoir (16,500 acre feet capacity) in 1954. No coarse sediment presently enters the study reach from above Pleasant Valley Dam.

The late nineteenth and twentieth centuries have witnessed changes in land use practices on the Owens River, resulting from increased water needs in the arid southwest. Hydrologic diversions mark the past 80 years of the Owens drainage, with intensification of ground-water withdrawal and new aqueduct construction playing the greatest role. Land use is mostly restricted to agricultural, mining, quarrying, and ranching operations. We summarize some of the important characteristics of land and water use in the following sections.

### Hydrology

The earliest large diversions affecting the study reach began in 1941 when the Los Angeles Department of Water and Power (LADWP) constructed the first Mono aqueduct. This aqueduct took water from the Mono basin and fed it into the Owens drainage, thereby increasing the flow in the Owens River. Earlier, wells were also constructed throughout the basin to augment flow through ground-water sources (Sorenson, et al., 1989). Crowley Dam was constructed as a storage reservoir in 1941, followed by completion of the smaller Pleasant Valley Reservoir in 1954. Finally, in 1970, the second Mono aqueduct was opened, diverting further flows into the Owens River system.

Williams (1975:12) provides a summary of the flow history for the study reach. Based on gauge records from the LADWP streamflow station, located 1.4 miles (2.2 km.) downstream of Pleasant Valley Dam, his data show a pre-dam regime with higher peak flows and higher base flow than after dam closure in 1954, in spite of the higher mean flows of recent years. Pre-dam flows range from maxima of more than 1100 cfs to minima just less than 200 cfs. Post dam flows range between about 750 and 50 cfs. Another consequence of dam construction is the regulation of frequency of flows. Prior to dam construction the flow record is marked by several high flood peaks, between which there is little variation in discharge. After dam closure and with the onset of regulation, the flow regime is marked by many sharp peaks and troughs in the flow record. This change in flood frequency, as well as the shift toward lower baseflows and overall flood peaks, suggests that regulation has pushed the Owens River toward a less regular flow regime, with a higher frequency of generally lower peak flows.

Although peak flows may be lower, the total water conveyed through the system below Pleasant Valley Dam has increased, due to the higher frequency of flows of 400 to 700 cfs. Total discharge at Pleasant Valley has risen by 30 percent since 1935. Plots of total discharge on a yearly basis show a steady increase (Figure 2). This increase in total conveyance implies an overall increase in stream energy applied to the channel, and could potentially destabilize the channel and alter riparian habitat. Potential geomorphic changes might theoretically include increases in meander size, downcutting, aggradation, widening or local narrowing. Geomorphic response to changes in flow regime is often complex and unpredictable over timescales of several years to tens of years (Schumm, 1977) and precise prediction is generally not possible. However, it is safe to conclude that an increase in stream power beyond a critical threshold may force the stream toward geomorphic instability. Changes in riparian habitat might include an alteration of texture of bed sediments, a decrease in the number of slackwater pools, and increases in turbidity.

The seasonal distribution of flows has also changed since construction of impoundments and diversions upstream of the Wild Trout Reach. Prior to the construction of the first Mono tunnel in 1941, winter (October through March) flows were greater than summer flows (April through September)(Figure 3). After the construction of Crowley Dam and the completion of the first Mono tunnel, there was a large variation in the seasonal difference in total flows, fluctuating between net negative and net positive values. This pattern continued until 1970 when the second Mono tunnel was installed. From 1970 to the present, summer flows have exceeded winter flows, with net negative values in the seasonal difference of flows. The winter-dominated regime has changed to summer-dominated flows. Superimposed on the increase in total flows, these changes could possibly have significant impacts on channel form and riparian habitat.

Monthly data, however, do not completely or adequately describe the flow conditions on the Owens Wild Trout Reach. A closer inspection of a single year's records reveals a square curve, where peak flows are sustained for long periods; for example, sustained flows greater than 500 cfs have been recorded for up to three months (Williams, 1975:14). Flows are sometimes then rapidly decreased. In an effort to characterize changes in flow regime resulting from diversions and impoundments on the Wild Trout Reach, we chose to examine two years of daily flow data from pre- and post-dam and aqueduct time periods. Data from 1938 and 1982 were chosen because precipitation values were very similar for those years of record (1938=24.76" and 1982=24.98" at Bishop Creek Intake) (R. Neudeck, personal communication, 1991).

Pre-dam (1938) average daily flows at the Pleasant Valley gauge are distinctive of snowmelt-fed streams (Figure 4). Snowmelt streams like the Owens (with spring-fed baseflow-sustaining flows) show a sharp rise in the hydrograph as snowmelt begins in earnest, with the maximum flows in May or June. Other, smaller peaks may be associated with early periods of melt, summer thunderstorms or winter cyclonic storms. Post-dam daily flows are far from these "natural" conditions. Data from 1982, a comparable precipitation year to 1938, show a very different pattern of flows (Figure 4).

Several major differences are apparent in flow regime between pre- and post-dam periods. First, both rising and falling hydrograph limbs are far steeper, indicating more rapid increases and declines in discharge associated with changing releases from the dam. Second, flood peaks have been attenuated by as much as 500 cfs for the largest events. Third, there are more yearly fluctuations in flow; pre-dam data show one large peak with a gradual decline to base flow over several months time, while post-dam data show several large peaks with shorter overall duration associated with each peak. Fourth, wet-year baseflow has increased substantially from a range of 200 to 300 cfs in 1938 to approximately 400 cfs after impoundments and diversions are in place in 1984.

Other diversions reduce discharge in a downstream direction through the study reach. The diversion for the Bishop Canal is located 4200 feet downstream of the boundary between subreaches C and D (Figure 1) on subreach D, and reduces discharge in part of reach D and all of reaches E and F. A smaller diversion, the McNally Ditch, which has diverted flow since at least 1944, is located 400 feet downstream from the boundary between reaches E and F. The McNally Ditch only operates during high-flow periods, to recharge ground water in areas north of the study reach, and remains dry for most of the year (R. Neudeck, personal communication, 1991). The reduced discharge resulting from these diversions is considered negligible compared to the larger-scale changes resulting from regulation of the Owens River and imports from the Mono Lake basin.

Williams (1975:9) suggests that, based on observations of mean streambed elevation at the gauge site, the streambed has lowered at this location by about 0.75 feet. His streambed data certainly seem to reflect this. However, the relatively small average lowering Williams observed could be explained, at least in part, by the passage of migrating bedforms. We observed, in May 1991, several gravel bars with at least 0.7 feet of relief (measured from lee-face base to crest). Local residents also report an observable degree of channel incision over the upper portions of the study reach. It is one of the objectives of this study to corroborate or deny the existence of such incision on the Wild Trout Reach.

Ground water has been withdrawn from the Owens River alluvial aquifer since at least the 1930s. Large ground-water diversions may have the effect of decreasing flow within the channel or accelerating channel erosion as a result of the depletion of floodplain vegetation sustained by ground-water reserves. We are not aware of any studies that specifically address ground-water withdrawal from the Owens River and its effects on the Wild Trout Reach.

## Land use

The 1944, 1967 and 1990 aerial photographs show the evolution of several major land uses in or near the Wild Trout Reach. These include aggregate production, livestock, recreational facilities, dams and roads. The upper portions of the study reach show the most visible effects of these practices, but the entire floodplain has been subject to one or another throughout its recent history.

Subreach A (Figure 1) lies immediately downstream of Pleasant Valley Dam and is most disturbed by impoundments and construction associated with the dam. Service roads leading to the dam cross the channel, where flow is constricted through sub-road culverts. A large parking area borders the channel immediately downstream of the dam, lying approximately thirty feet above the channel. The channel margins have been rip-rapped with large blocks of Bishop Tuff to stabilize the stream side of this parking area. A large mound of fill dirt (30 to 40 feet in height), probably remnant from dam construction, lies above and adjacent to the left bank of the channel. This fill may contribute small amounts of sediment to the channel when the material slides or is eroded. A discontinuous strip of campsites extends from the parking area to the downstream end of reach A. The extent of these campsites and the intensity of their use have expanded greatly since 1967, and were evident in 1944. Some portions of stream bank have been cleared, particularly within the B.L.M. campground at the easternmost end of the reach, to accommodate more campers. The banks of the channel have been stabilized with riprap at locations throughout the camping area, probably contributing coarse sediment to the stream.

The floodplain adjacent to reaches B and C, just downstream from the camping area, is crisscrossed with jeep trails and paths. The north side of the channel is particularly impacted since most of these trails originate from Chalk Bluffs Road, which runs along the north side of the valley. These trails provide access to the stream for fishing. Not surprisingly, the density of these roads decreases with distance downstream from the camping area. Reaches D and E have fewer access roads on the north side of the channel, while reach F has fewer still. Roads leading to these lower reaches approach from the south across rangeland and were probably associated with grazing operations. Most of these trails show little recent use, indicating that they do not play as important a role in fishing access.

A bridge crosses the stream at Five Bridges Road, that forms the downstream end of subreach F. This bridge, constructed with cement abutments and supports, has been present since at least 1967; the 1944 aerial photography shows a low water crossing located about a half mile upstream of the present bridge, prior to the construction of Five Bridges Road.

Aggregate operations can be found in the study area but they are limited to higher terraces and do not directly affect the stream or floodplain. Reaches B, E and F all have quarries associated with them; however, those associated with reaches B and E are no longer operational. A large plant north of reach F, that began after 1967, is a major regional supplier. Given their presence on terraces and off the immediate floodplain, quarries probably have a negligible impact on stream behavior and/or morphology.

It is unknown to us precisely when intensive grazing began in the study area. Ranching definitely pre-dates the construction of all major water projects (pre-1913). The 1944 photos show fencelines that have been maintained and persist to the present, suggesting continuing ranching operations. As late as the early to mid-1960s the northern portion of the floodplain (north of the channel) was sprayed with the herbicide 2, 4-D, burned and drag-chained to clear land for further grazing (D. Wong, personal communication, 1991). The 1967 photographs show disturbed hummocky ground with exposed soil that differs greatly from the more densely vegetated floodplain that lies to the south of the channel. Clearing at that time was far more extensive north of the river than to the south; this is still evidenced by the significantly higher vegetation density on the south bank in the 1990 photography.

In summary, the construction of the dam, road construction for dam access, and camping facilities dominate the land use of the upstream portion of the study reach. The central portions show a great deal of evidence of trampling and erosion from the encroachment of roads and trails for fishing access, as well as significant clearing on the north bank for increasing grazing potential. The lower portions of the study reach, particularly subreaches E and F are least disturbed, but show evidence of intensive grazing.

## 4. APPROACHES AND METHODS

### Study area

The Wild Trout Reach of the Owens River lies just downstream of Pleasant Valley Dam. The stream follows a straight course for approximately one mile below the dam, where it is still confined within the Owens River gorge. After this point, the valley widens and the river meanders over a broader floodplain. Ubiquitous meander scrolls on the floodplain attest to the river's shifting course through recent time. We have confined our quantitative evaluation to a portion of the river that runs from the dam to a point approximately six miles downstream, at a site known as Five Bridges. We chose to work on this segment because of the particularly high value assigned to the fishery, and also because it corresponds to that studied by Williams (1975) which allows us to make effective comparisons with his results.

We focused our analyses of riparian vegetation communities and channel morphology on five reaches of the Owens River, immediately downstream of Pleasant Valley Dam. These reaches correspond to California Department of Fish and Game study reaches B, C, D, E, and F; we have maintained the same labels for our study reaches (Figure 1). Each reach extends approximately one mile downvalley (2 to 3 river miles). Reach "A" was not analyzed because it lies almost completely within the Owens River gorge and is highly channelized. It differs substantially from the meandering portions of the stream in that it (1) is fundamentally straight-channeled and extensively modified by engineering works, (2) is developed on or near bedrock rather than alluvium, and (3) has a bed composed principally of material which has entered the channel from the immediately adjacent cliffs of Bishop Tuff. Changes in this reach would not be representative either of the Wild Trout Reach or of the Middle Owens River as a whole.

### Multiple-date aerial photographic analysis

In an effort to examine changes in channel morphology and riparian vegetation density through time, we undertook an analysis of aerial photographs from 1944, 1967 and 1990. This time frame allowed us to examine the channel prior to and after construction of the second Mono aqueduct diversion in 1970 and closure of Pleasant Valley Dam in 1954. The 1944 photography is representative of the period when the first Mono aqueduct and Crowley Dam came on line in 1941. The scale of the photography was as follows:

1. October 15, 1944: 1" = 1200' (black and white) 220 cfs

2. November 29, 1967: 1" = 300' (black and white) 686 cfs

3. September 14, 1990: 1" = 200' (color) 144 cfs

The large scale of the 1967 and 1990 photography allowed us to make detailed measurements of several variables. Similar analyses were not possible on the smaller scale 1944 photographs. The 1944 photos, however, provided quantitative data on stream length and meander geometry, as well as qualitative information on riparian vegetation density. Two aspects of the stream were examined on the photography: geomorphic variables and densities of riparian vegetation along the banks of the main channels.

### Geomorphic variables

Changes in flow regime and/or land use may have an effect on overall channel geometry and morphology. For each reach, we chose to measure several aspects of channel geometry from the aerial photographs in an effort to ascertain whether the channel was geomorphically stable or unstable during the period 1944 to 1990. The following geomorphic variables were measured:

1. Channel area. The total surface area of the stream. In combination with overall channel length, this variable allowed us to compute an aggregate average width for each reach. Channel area depends in part on the flow, so areas at different flows cannot easily be compared.

2. Channel length. The length of the stream along the principal channel.

3. Reach length. The straight-line distance from beginning to end of each reach. This number was essentially constant for each reach and acted as a surrogate for valley length in determinations of channel sinuosity (channel length/valley length).

4. Number of meander apices. Inflection points on the channel were examined to determine the number of meanders or bends in the stream by reach (Figure 5). Choosing inflection points, rather than attempting to choose meander apices directly, increases the accuracy and replicability of meander measurements since inflections are more easily identifiable on maps and photographs.

5. Meander wavelength. The linear distance between two consecutive inflection points provided a measure of meander wavelength.

6. Meander amplitude. The amplitude of meanders was determined by drawing a line connecting consecutive inflection points, then dropping a perpendicular to this line from the maximum point of deflection of the stream (Figure 5).

### Woody vegetation density on the banks of the main channel

An important component of riparian habitat is the density of bank riparian vegetation. This also an important consideration in the stability of river channels. If bank vegetation densities are high, banks are not as easily eroded and bank stability is enhanced, perhaps with an associated increase in channel depth (incision or downcutting). Banks, barren of woody vegetation, are generally more susceptible to erosion, unless the bank is underlain by bedrock. Woody vegetation also significantly contributes to trout habitat.

After close inspection of the aerial photography, we determined that it would not be possible to delineate vegetation class areas on the floodplain, since the pattern of vegetation on the floodplain was so complex. However, it was possible to examine the density of vegetation immediately adjacent to the channel banks. We defined four generalized classes of vegetation density for our analyses:

1. Dense: continuous woody vegetation (tree or large shrub), more than a single row of individuals in width.

2. Sparse: Discontinuous woody vegetation, less than a single row of individuals wide, or a continuous cover of low, grassy vegetation.

3. Barren or very sparse sagebrush: No vegetation or very widely-spaced sagebrush with vegetation-free ground between individual plants.

4. Bars: Emergent, pre- or incipient vegetation on bars (such as point bars) with very low vegetation density. This category is highly dependent on stage/discharge and should not be used in comparisons between years where discharge is significantly different.

### Bed sedimentology

We looked at two aspects of bed sedimentology, particle sizes and rock type, to further characterize riparian habitats and to determine if significant changes had occurred in the channel since 1972, when Williams described conditions using similar methods. We attempted to relocate the six cross sections used in this previous study and performed similar particle-size analyses for comparative purposes. We found two of the galvanized steel monument posts set by Williams, and were thus able to precisely relocate two of these sections (Sections 2 and 5). The remaining four cross sections were located as accurately as possible based on mapped locations and descriptions from the report (Williams, 1975) (Figure 1). Where precise relocation was not possible, we based the location of our cross sections on that portion of the channel that would have the most stable cross sectional geometry, assuming that Williams had made a similar choice. Therefore we located our sections near riffles and at crossovers.

The size distribution of bed sediments was measured by the particle-count method of Wolman. Size classes used varied by the square root of 2 (i.e., 32-45 mm., 45-64 mm., 64-90 mm.). The size of the intermediate or 'b' axis was measured. After locating the cross section, we sampled between 75 and 100 clasts over a roughly 30' x 40' area encompassing both up- and downstream portions of the section (whole bed counts). Separate counts were also performed on nearby bars (bar counts) to examine the textural differences between bars and the entire bed, since material in the bars tends to be sediment transported at routine high flows, with other portions of the bed less likely to move under such conditions. A bar count was not performed at Section 1 due to the absence of a discrete bar. The rock-type composition of each clast was determined at the same time as the particles were measured for size.

### Hydraulic geometry

Leopold and Maddock (1953) related channel form in western U.S. streams to the concept of hydraulic geometry, where parameters of stream morphology and hydrology, such as width, depth, velocity and sediment transport rates, are related by power expressions to discharge. Williams (1975, 1987) formulated hydraulic geometry relations for each of the cross sections he examined and for the gauge site (Figure 1). These relationships establish a 1972 set of hydraulic relationships that can then be compared with existing conditions. We re-surveyed channel cross sections at or near Williams' original locations to compute average depth and channel width at a known discharge, as well as estimated bankfull width and depth. Two of these cross sections were precisely re-located, while the remaining four were located as accurately as possible based on published maps by Williams (1975:10) (Figure 1). Our results were compared with the established hydraulic geometries to determine if significant changes in width or depth have occurred since 1972 and to examine the overall stability of the stream.

### Bedload and suspended-sediment transport measurements

We sampled bedload and suspended-sediment in transport at each site, and computed transport rates, to compare these data with similar measurements made by Williams (1975). Our sampling was conducted at 225 cfs, as measured below Pleasant Valley Dam. The data were mainly used for comparison with the conditions sampled by Williams in 1972, so that trends in transport at a given flow might be noted.

Bedload was sampled with a hand-held 3-inch Helley-Smith bedload sampler fitted with a 0.250 mm mesh bag. Sampling techniques are those of Emmett (1980), which were also used by Williams with similar equipment and bag mesh (pers. comm., 1991). These methods, with only very minor modifications, are those used most widely at present, as well. Therefore, results may be compared not only for the Owens River on the two dates, but also with those reported on other streams.

At each site, the active bed was sampled at one-foot intervals for standard times, either 30 or 60 seconds. Bedload-transport rates were computed from the weight of the material sampled, active bed width, sampler width, and sampling duration. All reported values were as actual (not immersed) weights and were not corrected for fine organic matter concurrently sampled.

Suspended-sediment load was sampled using a hand-held DH48 sampler using the equal-transit rate (ETR) method. Sediment and water were collected in clean sampling containers. One sample (# 4910524155; see Appendix G), however, yielded results 50 times greater than others collected on the same day; we believe this to be an anomalous outlier, which was not considered in further analysis. Samples were preserved with 3 ml. of bleach and were transported to the laboratory in an opaque container. Analyses of suspended-sediment concentrations were performed by Soil Control Laboratory (Watsonville, California) using the whole-sample method and pre-washed glass-fiber filters provided by Balance Hydrologics.

Results of both bedload and suspended-sediment sampling are summarized in Appendix G.

## 5. RESULTS

### Validity of dynamic equilibrium and segment boundaries

The analysis of channel pattern, hydraulic geometry, and geomorphic variables support an assumption of dynamic equilibrium, as the concept is used in the design and application of the IFIM. We have also worked with Jones & Stokes Associates in, first, establishing geomorphically-reasonable segment boundaries, and, subsequently, reviewing the channel geometry data at IFIM transects and find these segments to usefully describe the geomorphic segments (or "main reaches") found in the middle Owens River.

### Changes in riparian vegetation density

We were able to measure the lengths of our four classes of riparian vegetative cover along both banks for reaches B, C, D, E and F for the years 1967 and 1990. A small portion of reach C was not covered by the 1967 photography; therefore, we omitted this uncovered length of channel from our 1990 measurements. The scale of the 1944 photography was too small to delineate riparian vegetation densities, and we were only able to make qualitative assessments for the earliest photography available for our use.

Changes in the riparian class "bars" should not be regarded as meaningful since the presence or absence of exposed, lightly-vegetated bars is highly discharge dependent. There is a dramatic 74 percent increase in this riparian class between 1967 and 1990, most or all of which can be explained by the 540 cfs difference in discharges between these two photography dates. Discharge was at 686 cfs on the date of the 1967 photography (5/8/67); many lateral and point bars would be submerged at this very high stage. On the other hand, the flow on September 14, 1990 (the date of the 1990 photography) was 144 cfs, significantly less than bankfull and leaving many bars exposed.

Comparisons between the other three classes are more meaningful, however, since all extend into the overbank environment and are not directly tied to discharge. The most notable and significant changes occur within the dense and sparse classes (Tables 1 and 2). As of 1967, dense riparian vegetation lined between 10 and 30 percent of each reach (Figure 6). Sparse riparian cover made up the majority of the channel margin. Visual comparisons with 1944 photographs indicate a significant reduction in dense cover between 1944 and 1967, with most losses occurring in downstream reaches D, E, and F. This reduction corresponds to the period when vegetation was cleared from the floodplain to increase range area for cattle. The 1990 photography shows a marked increase in dense riparian vegetation in reaches D, E, and F (Figure 6). Reach F experienced the greatest 1967 to 1990 change with a 71 percent increase in dense cover and a 102 percent decrease in sparse cover (Table 2). Interestingly, reaches B and C remained fairly constant, experiencing less than 5 percent change in both dense and sparse classes.

As might be expected with increasing vegetation density, reaches D and E experienced large declines in barren or lightly-vegetated banks. However, reach F experienced a 31 percent increase in barren cover; this represents, however, only about 300 linear feet of change.

### Changes in geomorphic variables

Most measures of planform channel morphology are relatively insensitive to anything other than the largest changes in flow regime. We have made measurements of these variables in an attempt to discern any large-scale systematic changes and to set a baseline for future studies. Generally, higher bankfull discharge is associated with larger meander amplitudes and wavelengths, while higher sinuosities may be related to an overall reduction in channel gradient. The total number of meander apices is a gross surrogate measure of sinuosity and planform geometry, and large changes in this variable might suggest an unstable or dynamically adjusting channel.

Table 2 summarizes the percent change in geomorphic variables for the study area on a reach by reach basis. Aside from those variables that are not dependent on discharge (i.e. channel area and average width), there appear to be no large or systematic changes in planform geometry between 1944 and 1990. Most increases in variables between 1944 and 1967 are offset in part by decreases of the same variables between 1967 and 1990. In the period 1967-1990, the total number of meander apices increased 9 percent with all reaches except Reach D, which experienced a net increase in this variable. This may imply an instability in the channel morphology, resulting from increased lateral migration, but, again, this is a relatively insensitive measure of channel stability.

One can discern qualitative changes in channel planform position through time (Figure 7), indicating that the channel is quite actively laterally migrating through normal processes of meander migration and cutoff. There do not appear to be significant differences in migration behavior in a downstream direction, but this cannot be confirmed without more precise measurements of channel geometry on rectified aerial photographs. The actual shape or style of meandering does not appear to have changed substantially, except for possibly an enhancement of meander curvature. Again, this would be expected for an ordinary meandering channel.

More important are absolute changes in geomorphic variables within a single year in a downstream direction (Table 1). On both the 1967 and 1990 photography, average stream width is reduced on the more densely vegetated D, E, and F reaches. Part of this reduced width might be ascribed to overhanging riparian vegetation, which would narrow the apparent width of the channel on aerial photography, but this would not explain why we see similar decreases for 1967, when dense riparian cover is very low on these reaches. This suggests that an increased riparian cover leads to a narrower channel, since the lower reaches have had a longer-term dense cover than reaches B and C, which were sparsely vegetated as far back as the 1944 photography.

Similarly, meander geometries also reduce in a downstream direction (Table 1), with both meander amplitude and wavelength declining by 39 and 28 percent, respectively, for the 1990 data. This overall downstream reduction in meander geometry and stream width may be a function of a downstream decrease in discharge from channel losses or diversions; however, changes in bank sediment characteristics may also be responsible for changes in channel geometry.

## Representativeness of cross sections

Many of the following results depend largely on field measurements taken at channel cross sections in 1972, 1990 and 1991. This section discusses the representativeness of these sections as surrogates for average overall channel behavior.

The six cross sections selected by Williams in 1972 were relocated as close as was possible, based on his published maps and personal communications. Two were precisely located (2 and 5). It is always problematic to make inferences about a portion of a stream based on at-a-station results; however, if the cross sections are representative of large portions of the reach as a whole, then it may be possible to infer overall processes based on the at-a-station results. This is particularly true when average values of geomorphic variables for the entire study reach are desired. For example, the average stream width at a known discharge for six representative cross sections may adequately describe the average width for similar channel reaches (such as at pools, crossovers, riffles, glides, etc.) over the entire study reach.

We tested the representativeness of our cross sections by comparing them to a large data set of cross sections (i.e. transects) measured by Jones & Stokes Associates staff as part of the IFIM study. Sixty transects were measured in the entire Wild Trout Reach, with two to eleven transects occurring within each of our sub-reaches B, C, D, E, and F. We calculated the bank-top cross sectional area for each of these transects, based on the product of average bank-top depth and width (Appendix C). Bank-top width and depth are defined by the cross sectional form that lies between the tops of the right and left banks. On most meandering streams this cross section delineates overbank from within-channel areas (Figure 8). This geometry is easily discernible on the IFIM transects, which are usually defined by about 15 to 25 measured verticals. We divided the IFIM transects into three classes: crossovers, pools, and uncertain.

1. Crossovers and riffles: sections occurring on reaches where the bed and banks tend to change less than in other locations (see Figure 5). Corresponding classes used in the IFIM are meander runs, glides and low-gradient riffles.

2. Pools: sections occurring on reaches where pools were located. Corresponding IFIM classes include corner pools, midchannel pools, backwater pools, lateral scour pools, plunge pools and dammed pools.

3. Uncertain: sections where we were uncertain as to whether the classifications made at low flows still apply at higher flows.

IFIM transects we relocated occurred predominantly near crossovers. Therefore we used the crossover category to determine average bank-top cross sectional area, width and depth.

We found that the average cross sectional area for our measured sections within the Wild Trout Reach was 267 $ft^2$, while the average for the located IFIM transects was 307 $ft^2$. On average, then, our cross sections underestimate bank-top area by only 13 percent. Bank-top width was overestimated by 11 percent, while average depth underestimates by 14 percent. The values of our cross sections, then, fall within one standard deviation of the mean for the located IFIM crossover transects. These values apply to average values for sub-reaches B, C, D, E, and F. Table 3 and Appendix C provide summary statistics and raw data on these IFIM transects on a reach by reach and overall basis.

In summary, on average our cross sections are representative of cross sectional geometries at crossovers in reaches B, C, D, E, and F. Since our sections were nearly equivalent to those measured by Williams in 1972, we may assume that his sections are also, on average, representative of the same types of channel reaches/geometries.

### Changes in hydraulic geometry

Observers have indicated that both widening and deepening of the channel have apparently occurred since 1970. Their claims are based on observations only, without direct field measurements. We have chosen to examine channel hydraulic geometry to explore the extent to which these observations may apply to the entire reach or the 6 DFG subreaches.

Williams (1975) provides hydraulic geometry relationships for the six cross sections used in his study, relating width, depth and velocity to discharge. These power relationships provide a 1972 baseline set of at-a-station observations. For a given discharge (Q), it is possible to estimate at-a-section width (w) and average depth (d) by relationships of the form:

$$w = aQ^b \quad \text{and} \quad d = cQ^f$$

where: a, b, c, and d are empirically derived constants found from field measurements.

It is possible to directly compare the hydraulic geometries at a given station through time. Substantial differences might suggest changes or instabilities in the stream channel. This type of comparison, however, requires precise relocation of the cross section since hydraulic relationships can vary at nearby cross sections. In the event that a cross section cannot be precisely relocated, it might be possible to examine large changes in channel form by examining sections on the same reach. Such comparisons must be made under the assumption that the reach, as a whole, has changed in a similar fashion and that the newly-surveyed section is representative of the original cross section.

We were able to precisely relocate two of the six original cross sections (Sections 2 and 5), and we believe that Sections 3a and 3b bracket Williams' Section 3. Section 4 was relocated as precisely as possible, but it is not known whether it adequately represents Williams' Section 4. Section 6 should not be used for comparative purposes since subsequent conversations with Rhea Williams lead us to conclude that it was located too far downstream to be representative of the original section. Section 1 lies within the heavily modified channel just downstream of Pleasant Valley Dam and we feel that comparisons with Williams' Section 1 should be made with some degree of skepticism.

We re-measured our cross section at discharges of 150, 225 and 400 cfs to establish at-a-station hydraulic geometry relationships. The results are compared with those found by Williams (1975) in Table 4.

It is also possible to compare values of channel width and depth derived from Williams' hydraulic geometry relationships with those actually measured in the field or from aerial photographs. For a given discharge (Q), the results derived from the hydraulic geometry relationship should provide an estimate of channel width and depth for 1972, when the measurements were taken. If actual, 1990 values differ from these estimates, it may be inferred that at-a-station changes have occurred. We compared May 1991 values of width and average depth at 225 cfs with the values derived from Williams' expressions, using 225 cfs as the value for Q. At relocated Sections 2 and 5, there was a 0.4' and 0.1' increase in average depth, respectively. Width decreased by 4.6' at Section 2, while increasing by 6.7' at Section 5 (Table 4).

## Bed sedimentology

The texture of bed sediments was determined by areal counts (Wolman method). In an effort to replicate similar sampling performed by Williams in 1972, we laid out a 30' x 40' area equally divided up and downstream by the line of the section. These samples we termed "whole bed counts" because they sampled the entire bed, regardless of bedforms or local change in bed topography. The area sampled included virtually the entire bed, excluding the vegetated margins and/or slump blocks at the edge of the bed. These were principally taken for comparative purposes and to describe the character of the bed surface as trout habitat. Discrete bars were located at or near Sections 2 through 6. These bars were sampled by a similar method except that the limits of the sampling area were defined by the bar itself.

Comparisons of representative particle sizes -- $D_{16}$, $D_{50}$, and $D_{84}$ ($D_x$ represents the xth percentile rank of particle size) -- show apparent trends in a downstream direction (Table 5). What is surprising is that somewhat contradictory results were obtained from whole bed and bar counts. Whole bed counts show a downstream fining trend between Sections 1 and 3, then an abrupt coarsening occurs between Section 3 and 4, followed by a prolonged fining trend again to Section 6. This suggests either (1) a source of coarse sediment lies between Sections 3 and 4, (2) there is an anomalously high input of fine sediment at or near Section 3 from local bank collapse, (3) coarse sediment is by-passing Section 3, and/or (4) the portions of the bed sampled are not representative of overall streambed textures. It is likely that coarse sediment is supplied from cutbanks, but we were not able to observe such a source. Local bank collapse was extensive at Section 2 and localized mounds of bank collapse blocks occurred on the margins of this section; this suggests local fine material sourcing the bed. It is unlikely that coarse sediment preferentially by-passes the section, since in bedload transport individual coarse size fractions are rarely preferentially transported over and above finer fractions (Wilcock and Southard, 1989). It is possible that whole bed samples do not accurately depict overall textural changes because they include localized sources and concentrations of out-sized material. Gravel bars, products of material that is actually mobilized at higher flows and that reflect some degree of sorting, may be more effective comparators for downstream changes in bed texture.

The results from bar counts show almost the opposite pattern as that found in whole bed samples (Table 5). There is a coarsening trend between Sections 2 and 4, followed by an abrupt fining and renewed coarsening at Section 6. These trends are particularly evident in the $D_{50}$ and $D_{84}$ ranges, while the finer $D_{16}$ shows a more gradual fining between Sections 3 and 5. These trends can most easily be explained by local sourcing of finer sediment above Section 5. Between Sections 4 and 5 the course of the stream has migrated northward to the valley margin at the Chalk Cliffs, where a cutbank has formed in this tuffaceous material. This cutbank provides sediment with $D_{50}$ values in the range of 30-34 mm (sampled pebble count on Chalk Cliffs above cutbank) and $D_{84}$ of 73-75 mm.[1] These clasts would effectively dilute the coarsened bed material with finer grains, producing an overall finer bed than upstream of that point.

This local sourcing of finer-grained bed material is supported by rock-type determinations of each pebble or cobble sampled during textural measurements. All of our samples are dominated by granite and welded tuff, reflecting sediment sources in the mostly granitic Sierra Nevada batholith and the volcanic Bishop

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[1] We sampled an area of colluvial slope deposits on the Chalk Cliffs by a procedure similar to the Wolman method. An area of the face was selected as representative of much of the area and a 2 meter tape was laid out. The clast beneath each 10 cm mark was selected and measured. After the end of the tape had been reached it was moved up slope one meter and the sampling continued in the same manner. This sampling was continued until 100 clasts had been measured.

Tuff, or the river bluffs, respectively. Minor components of metamorphic, carbonate, and basaltic rocks also occur. Figure 9 shows downstream changes in clast composition as a percentage of the total bed material sampled. No rock-type determinations were made by USGS staff in 1972, so comparisons are limited to differences along the channel or between the existing channel and older channels exposed in the banks.

There is a steady increase in granite percentage between Sections 1 and 4, excluding sample 3c. This exclusion is justified in that sample 3c came from a paleobar exposed in the bank at the section and is not representative of modern bed sediments. This increase is not surprising given, first, that Section 1 lies within the Owens River gorge, cut into the Bishop Tuff. We see a greater percentage of tuff, not because of any local decrease in granitic sediment supply but because tuff is entering the stream from the walls of the gorge. As sediment is transported downstream as bedload the less resistant tuff comminutes (breaks, chips, and abrades), while the more resistant granitic clasts remain relatively intact. Greater rates of comminution of tuff results in an apparent increase in granitic clasts relative to tuff. It may also be possible, though unlikely, that the less dense tuff may also be preferentially transported out of the section in upstream reaches further augmenting the percentage of granitic clasts. The fact that sample 3c shows more tuff could signify that the paleo-channel flowed closer to the cliffs. We performed separate rock-type analyses on both the sample and the 23-90 mm fraction, in an attempt to see if there were significant differences in lithology resulting from the inclusion of outliers in our sample populations. We found no significant differences between these two samples.

Perhaps more instructive is the pronounced change in bed lithology downstream from Section 4. Tuff percentages increase abruptly at Section 5, then decrease at Section 6 and the Highway 6 bridge at Laws (data not shown). This pattern reinforces our interpretation of local sourcing at cutbanks and by lateral migration. Tuff is supplied to Section 5 (directly or indirectly) by the same cutbank in the Chalk Cliffs that appears to be responsible for the abrupt textural change previously mentioned.

These textural and lithological data support Williams (1975:47) findings that bed material is supplied by bank erosion, rather than from upstream sources or from

Horton Creek. Additionally, rip-rapping of the channel at the campground, just upstream of reach B and Section 2, does not appear to have appreciably coarsened bed material downstream, also suggesting that in-stream bedload transport of coarse clasts is reduced.

Comparing the texture of the bed from 1972 to 1991, there appear to be no strong systematic changes (Table 6). For most size fractions there is a coarsening of the bed, ranging between 3 and 74 percent. These data must be viewed with some degree of skepticism, however, since precise relocation of 1972 sampling plots was not possible; we may be sampling quite different populations. The lack of systematic coarsening or fining does indicate that the bed is most likely not armored, but active. Bed texture continues to change and stability in the form of an armored bed has not been attained. Some localities may be experiencing some degree of armoring, such as the surface sampled at Sections 5 and 6. Clasts at this section were very difficult to remove from the bed. However, other localities had more loosely packed clasts that were more easily removed from the bed, suggesting that armoring was as yet not complete.

### Total sediment transport

We sampled bedload and suspended load at each of the six cross sections, principally in an attempt to discern any significant changes since the period of Williams 1972 study. Our data plot very similarly to those found in the previous study (Figure 10). Since raw data is not available for Williams' study, we are unable to ascertain the degree of error in our measurements, but it appears that sediment transport rates are comparable at low to moderate flows to those found in 1972 at the time of Williams study.

Total sediment transport was observed to increase at each successive section, moving downstream, both in the 1972 and 1991 samplings. Both bedload and suspended-sediment transport increased at each site downstream during 1991; basic data for 1972 are no longer available (R. Williams, pers. comm.), so it is unclear whether this pattern also prevailed in the earlier studies. The steady downstream increase in both components of total sediment load is another indication that most sediment in transport is derived from the bed and banks of the channel. It also is strongly suggestive that similar processes and influences are affecting channel migration through the entire Wild Trout Reach, and perhaps further downstream as well.

Synthetic bed and bank erosion rates

We have shown that total sediment load measured several times at one flow during 1991 corresponds well with those found by Williams in his 1972 study. We realize that this agreement does not necessarily substantiate his finding, nor does it necessarily imply that sediment transport rates are the same now as twenty years ago. However, since most of our findings do not suggest drastic change over this same time period, it seems reasonable, as a rough first approximation, to assume that transport rates are similar and that Williams' sediment rating curves (Williams, 1975:41) are representative of current processes. With this in mind, we may generate synthetic bed and bank erosion rates to provide order of magnitude estimates of these important processes.

Williams provides an approximate bedload sediment rating curve (1975:41) applicable between his (and our) sections 1 and 3. Under the following assumptions:

(1) all bedload sediment in the study reach is derived either from the bed or the banks, and none is supplied from upstream due to trapping by Pleasant Valley Dam

(2) bedload transport rates between sections 1 and 3 are representative of the entire study reach

(3) Williams' data are reasonably representative of normal conditions

(4) the average bulk density of soil and bank material in the study area is 1.35 gm/cm$^3$ (equivalent to 1.138 ton/yd$^3$ or 84 pounds per cubic ft.)

(5) no net increase in sediment storage occurs within the reach as the channel adjusts to a new equilibrium

We can compute end-member contribution rates for the entire study reach, assuming that all sediment enters the stream from either (a) the bed, or (b) the banks. For example, at a discharge of 140 cfs we have an accurate measurement of the surface area of the entire channel from aerial photographs (Table 1); from Williams sediment rating curve, we find that this discharge corresponds to a bedload transport rate through sections 1 through 3 of 55 tons/year. A bed lowering rate may be computed as

Synthetic Bed Lowering Rate (SBLR) =

$$(55 \text{ tons/year})(1.138 \text{ tons/yd}^3)^{-1}(308995 \text{ yd}^2)^{-1} = 0.006 \text{ inches/year.}$$

This value should be interpreted as the maximum bed lowering rate possible at low discharges of 140 cfs. At the higher discharge of 680 cfs we compute a SBLR of 0.02 inches/year. Over a twenty year period this rate of erosion would lead to 0.4 inches of overall bed degradation. It is clear, however, that this value is an average, and erosion is rarely averaged over an entire streambed. We would expect significantly higher values of erosion along the main channel and in localized points along the thalweg (main bead or thread of flow) of the channel, accompanied by subsequent deposition on point bars and lateral bars.

Similarly, we can compute bank migration rates by assuming, in addition to those assumptions made above, that bank erosion on average operates on approximately two feet (0.6667 yds) of the channel bank above the water line. This is a crude approximation, but reasonable, given our field observations. For the discharge of 140 cfs, the calculation is as follows:

Synthetic Bank Erosion Rate (SBER) =

$$4(55 \text{ tons/year})(1.138 \text{ tons/yd}^3)^{-1}(21711 \text{ yd})^{-1}(0.6667 \text{ yd})^{-1} = 0.48 \text{ inches/year.}$$

The factor of four is added since most bank erosion is focussed on approximately 1/4 the length of channel in cutbanks. This low discharge figure stands in contrast to that found for the higher discharge of 680 cfs of approximately 2.19 inches/year.

As an extremely rough approximation, this analysis suggests that, if all erosion is taking place on the bed, lowering is relatively minor, but may be locally significant. On the other hand, if all erosion is focussed on the banks, erosion may be very significant -- on the order of 22 inches in ten years at high discharges -- and may be responsible for widening and increased conductivity of the channel. Our earlier lithological and grain size analyses seemed to suggest that at least some of the bed material is indeed contributed by the banks and that erosion may very well be focussed there. This analysis suggests that there is an upward limit to flows in order to prevent channel widening and deepening. The actual value of this limit must be determined through further observations and analyses. It must be emphasized that these analyses provide end-member, extreme results, and that it is likely that there is sediment storage along the channel and sediment influx (though minor) from upstream.

# 6. DISCUSSION

Our study points to several conclusions that can be made regarding changes in riparian habitat and channel morphology. The conclusions (addressed in the final portion of this report), however, must be prefaced with a caution: quantification of channel change is extremely difficult, especially without solid baseline observations and a long-term record of observations. Discerning "natural" from "induced" channel changes is even more problematic when there are a multitude of possible causal mechanisms, as is the case for the Middle Owens River Wild Trout Reach. Changes in channel form and riparian habitat may be a result of grazing on the floodplain, clearing of the dense riparian bank vegetation, changes in flood regimes since construction of Crowley Dam, or increasing flow releases from Pleasant Valley Dam. Most likely it is a combination of such factors that induce channel change.

Important in this study is the marked decrease in dense riparian vegetation in the lower reaches, post-1944, followed by its subsequent increase up to 1990. The combination of rising net flows and depleted vegetative cover may result in unforeseen changes in the channel, but subsequent revegetation may actually already be helping to mitigate any deleterious effects of the increased flows. For example, fishermen complained of poor catches and an overall decrease in the trout population in the late 1970's and early 1980's, citing changes in flow regime and riparian habitat as probable causes. This period most certainly would have corresponded to the time when vegetative cover was just beginning to re-establish itself on the floodplain, while flows increased. Increased turbidity, a lack of cool, shaded bank areas, and an increase in fine bedload sediment may have temporarily accompanied this period, particularly in reaches D, E, and F. With increased stabilization of the banks by increased vegetative cover, bank-derived fine sediments would be reduced, turbidity would drop, and riparian overgrowth on banks would provide cover. One can easily envision re-establishment of the trout fishery as vegetation density increased; recent reports (D. Wong, personal communication, 1991) suggest that this may actually be the case. Trout catches have increased and populations seem to be generally on the rise. Re-vegetation, then, might be responsible for at least a portion of this recovery. If flows continue to rise, however, while the stream becomes more confined to the channel by increased vegetative cover, greater stream energy will be expended on the bed and incision may occur. This may result in a degradation of the bed habitat in general.

Much of the aforementioned potential changes are working hypotheses, nothing more. More study is required to establish channel change and causal mechanisms. This study, in combination with the 1972 U.S.G.S. studies (Williams, 1975), establishes a baseline for future monitoring programs. In particular, a long-term and on-going monitoring program for channel change should be implemented to ascertain

(1) at-a-station changes in hydraulic geometry through time, (2) changes in longitudinal bed elevation to ascertain whether the stream is incising or aggrading, in general, (3) changes in bed sedimentology, and (4) changes in riparian vegetative cover.

## 7. MANAGEMENT

### Management issues

#### I. Incision and widening

Several observers have pointed toward a decrease in magnitude or frequency of overbank flows as potentially problematic for the Wild Trout Reach. They have stated that flows on the order of 400-700 cfs no longer saturate the floodplain, thereby inhibiting riparian growth and preventing flushing of alkali soils. Without exception, these observers attribute this reduction in overbank flows to an increase in channel incision, on the order of 2 to 3 feet, and channel widening. Therefore it is critical that we address this question of incision and/or widening.

We found no conclusive evidence for downcutting on the Wild Trout Reach. Sections 2 and 5, both precisely relocated from a previous survey, showed only 0.1 to 0.4 feet of bed lowering. This could all be attributable to the passage of bedforms, since many migratory bars have heights of this same order of magnitude. Likewise, extensive widening is not supported by our data. Therefore alternative explanations for a lack of overbank flooding must be sought.

First, it is possible that our analyses were unable to encounter strong evidence for incision or widening since we are only completely confident of the relocation of two out of six cross sections. Incision and widening may indeed be taking place, but on unmonitored sections of the stream. The paucity of previous data on the Owens Wild Trout Reach prevents us from making definitive statements vis. widening or downcutting.

Second, it may be that flow releases have been curtailed in the last 6 or 7 years due to the persistent drought experienced in this region. Rather than allowing large flood releases on the order of 400 to 700 cfs, smaller peak flows are being released from Pleasant Valley Dam and overbank flooding has not occurred.

Another way of ascertaining the presence/absence of incision or widening is to look at sediment budgets in the reach. Since little sediment is supplied from upstream of the study reach, particularly bedload sediment (since it is trapped behind the dam), we can safely assume that most of the sediment coming out from a downstream section is mostly produced by bed or bank erosion from within the reach. If we see an overall increase in sediment transport rates for a given discharge over those found by Williams in 1972, we might expect this to be an indicator of an overall increase in sediment production within the reach derived from an increase in bed/bank erosion.

We found, however, that for a water discharge of 225 cfs (the discharge on the days our sampling occurred) our sediment discharge data showed no significant increase from those found in 1972 by Williams. If we had found an increase at each section, we might conclude an increase in bed/bank erosion. Instead, we found rates both above and below the sediment rating curves provided by Williams (Figure 10). If these sediment rating curves are accurate, again, we find no conclusive evidence for incision or widening. However, this may also be a factor of having limited observations or inaccuracy of Williams' sediment rating curves.

The relationship between overbank flows and riparian vegetation establishment is not immediately clear and is integrally related to the problem of incision and widening. Vegetation has been establishing itself relatively well in the lower reaches (D, E, and F), even during this period of reported decreases in overbank floods. Meanwhile, reaches B and C have not experienced a similar recovery in woody riparian vegetative cover during this same period. This suggests that a lack of overbank flows may not necessarily be detrimental to riparian communities. Regarding the flushing of alkali soils, however, it seems clear that overbank flows are necessary. The question remains, however: why is there no re-growth in sections B and C, while D, E and F have experienced a net increase in woody bank vegetation? There are several possible explanations.

(1) Incision may be taking place on the upstream reaches more actively than downstream, preventing water from reaching the floodplain only in upstream reaches and inhibiting riparian growth. It is not uncommon for streams to adjust their bed to a new equilibrium profile in "pulses" or waves in either a downstream or upstream direction. It may be that reaches B and C are adjusting to a new equilibrium profile, however, as mentioned earlier, we have insufficient data to corroborate this.

(2) Reaches B and C have experienced more intense use due to their proximity to the campgrounds upstream. More access roads and paths penetrate to the stream and this portion of the Wild Trout Reach is probably, therefore, more intensely fished. Trampling, car traffic, camping and picnicking on these reaches is more intense and this increased intensity could very well inhibit the establishment of riparian vegetation.

(3) It may be possible that we are not seeing a return to the natural riparian conditions even on the lower reaches, but that re-establishment is taking place at this time in an upstream direction. If riparian communities are tied to the seasonality of in-channel flows, then substantial changes may have occurred or are occurring. As the hydrological data show, there has been a shift away from winter-dominated flows to summer-dominated flows. If natural riparian communities are dependent on late winter, early spring flows and these flows are no longer dominant, one might expect these communities to be replaced by plants that are more successful with a summer-dominant flow regime.

Again, regarding riparian vegetation and flow relationships, we have insufficient background knowledge to establish a definitive relationship.

### II. Undercut Banks

Observers of the Wild Trout Reach (Appendix I) noticed a decline in the trout fishery in the early 80's, but now believe that the fishery has improved to historical levels (D. Wong, J. Dienstadt, pers. comm., 1991). One of the reasons most often cited for the decline is the disappearance of undercut banks and other cover suitable for high quality trout habitat. From our observations, we noted that reaches with a more dense woody riparian cover appeared to have more undercut banks and overhanging vegetation suitable for the trout fishery. We propose, as a possible explanation for the return of the fishery the following: increased woody riparian vegetation after the period of very low cover in the 1960s may have led to more undercut banks and overhangs. It may also be possible that a dense grass cover may fix the banks substantially enough to encourage undercutting, however another study would be required to explore the effects of grassland cover on undercut development. From our observations, there were very few localities with a dense enough grassy vegetative cap to provide for undercuts, since the grassy areas were located in reaches B and C and were very sparse. Grass cover may be inhibited by the increased alkalinity of the soils in these reaches and therefore, grass development would be tied to overbank flushing flows that cleanse the soil of alkaline salts.

### III. Higher velocities

Reports of apparently higher velocities along the Wild Trout Reach have also been mentioned as a problem for the trout fishery. These higher velocities could have the tendency to deplete the trout population by effectively washing hatchlings and eggs from the reach or by reducing spawning or rearing habitat.

In an attempt to validate these reports, we were able to calculate an average cross sectional velocity for each of our measured cross sections (1 through 6). Since discharge for the time of those measurements was known (225 cfs) we were able to calculate an average velocity based on the relationship:

$$Q = AV$$

Where:
$Q$ = discharge
$A$ = cross sectional area
$V$ = average velocity

With Q and A known, it is an extremely simple procedure to calculate V. These values of V could be compared with those found by Williams (1975). He derived hydraulic geometry relationships for average velocity, and for a known discharge, we could calculate the 1972 average velocity for each cross section. Table 4 summarizes the results of this comparison.

We find no appreciable flow acceleration since 1972. It may be that velocities have increased on portions of the Wild Trout Reach not covered by either Balance's or Williams' sections, but, again, our analyses suggest that the stream has remained relatively stable.

## Recommendations

It is clear that many of our analyses are inconclusive, insomuch as that reports and observations of channel downcutting on the Wild Trout Reach persist, yet our data fail to conclusively support or identify causes for these processes. It is imperative to emphasize that our observations were limited to one very brief field season and an aerial photographic analysis. Historical records are sparse and previous studies provide only a partial baseline since they are based on at-a-station results and relocation of the original sites is difficult or impossible in some cases.

If the eventual objective is to manage the Wild Trout Reach channels, or to enhance these channels to mitigate for impacts elsewhere in the Owens/Mono system, a more detailed and extended analysis must be undertaken to validate, refute or refine the claims of observers. It is in this light that we recommend the following:

1. Continued monitoring of the six cross sections established by Williams and approximately relocated by Balance Hydrologics. Repeated continued monitoring of at least some of the IFIM transects should also be continued. This monitoring should encompass:

   a. Creation and maintenance of permanent monuments for these cross sections, in the form of cemented pylons and benchmarks, to prevent removal of section markers by trampling, vandalism, or livestock.

   On a 3 to 5 year basis:

   b. Detailed topographic measurement of these cross sections with accurate surveying techniques.

   c. Developing hydraulic geometry relationships for each section, which requires measuring the width of cross sections at a series of different flows to establish these relationships.

   d. Measurement of high-flow bedload and suspended load at the campground footbridge and at Five Bridges Road to develop more precise sediment rating curves for the Wild Trout Reach, and to establish a sediment-transport baseline for this important reach.

2. Sediment transport sampling studies should be performed that address the nature of sediment transport during several release (flood) and sudden drawdown events. These studies should be performed to detect if there is accelerated erosion of bed/bank material on the rapidly rising and falling limbs of flood hydrographs associated with the abrupt releases and draw-downs from Pleasant Valley Dam. These abrupt run-ups and draw-downs may be responsible for some either widening or deepening of the channel.

3. Continued monitoring of riparian (channel and floodplain) vegetation, to establish whether riparian vegetation is becoming re-established in Reaches B and C, and whether this process might warrant assistance. This monitoring should also take into account the effects of possible increase in alkalinity on riparian vegetation and the desirability of providing overbank flushing flows to decrease the presence of alkaline salts in the floodplain soils.

4. Specialists in range and riparian vegetation may wish to consider how the change from winter-dominated flooding to summer-dominated flooding may have affected the structure of the riparian communities and, hence, bank stability.

We note, too, that these are not the only questions or issues to address in refining management plans for the Wild Trout Reach. We are aware of its limitations and values in providing further insight into the functions of a complex fluvial environment as is found on the Owens River. However, we would like to suggest that the following avenues of investigation be pursued:

- more in-depth historical analyses, including site re-photography, a more complete analysis of the flows, and interviews with a wider array of interested and knowledgeable parties.
- surface/ground water exchange may play an important role in the establishment of riparian vegetation and, therefore, bank stability. We were unable to fully consider the role of ground water in the Owens alluvial aquifer, and it may indeed play an important role.
- access to the floodplain by excessive automotive and foot traffic may adversely affect the riparian vegetation communities. The merits and feasibility of selectively limiting access might be explored.
- more knowledge of shallow ground-water fluctuations and salinity in the Wild Trout Reach may be needed, both to assess how bank caving responds to rapid decreases in Owens River flows and to guide evaluation of future alkalinity buildup in soils of the river banks. Manual or continuous-recording piezometers on transects perpendicular to the banks (such as used by Finnerty and Hecht, 1991) are one possible monitoring approach; more complex remote-sensing, time-domain reflectometry, or geophysical approaches might also be considered.

# 8. CONCLUSIONS

1. We repeated measurements made in 1972 at six sites located about 1 mile apart along the Wild Trout Reach. Virtually all measurements were made at flows of approximately 225 cfs, the only sustained releases made by LADWP during the two months designated for field study, while damage to a penstock was being repaired.

2. The six sites are representative of all crossover and riffle segments of the Wild Trout Reach, based on comparisons with the extensive IFIM transect data set. Since the hydraulic geometry of these sections have not changed appreciably since 1972, it is likely that the assumption of dynamic equilibrium is met sufficiently to support the validity of using the IFIM study results into the foreseeable future.

3. We were able to find monuments installed in 1972 at 2 of the 6 sites and were able to precisely describe changes at these two sites. Average downcutting of 0.4 and 0.1 feet was computed for Sections 2 and 5, respectively. Little or no changes in width or velocity were discernible at these sections.

4. Channel length and sinuosity have changed less that 1 percent overall, but changes have been more significant within specific reaches.

5. The banks and bed of the channel are the primary source of both coarse and fine inorganic sediment in all portions of the Wild Trout Reach. Bluff cutting at one location in Reach E is a secondary contributor. Horton Creek and other tributaries upstream of Five Bridges Road do not seem to be significant sources of sediment.

6. While short portions of the bed are distinctly armored, considerable sediment is available for transport, and there appears to be relatively high availability of detachable substrate suited for spawning.

7. Rip-rapping of the reach near the campground and downstream of Pleasant Valley Dam appears to not have added appreciable numbers of discernible cobbles or gravels to sites a short distance downstream.

8. Changes at monumented sections need to be monitored, in particular for hydraulic geometry. This monitoring should be on-going to better describe channel trends and particularly to establish whether net aggradation or degradation is occurring.

9. Further establishment of riparian vegetation in reaches B and C, extending 1.5 miles downstream from the campground, would likely result in a narrower and more diverse (morphologically and with respect to trout habitat) channel. Also, more frequent overflows and flushing of the accumulating alkali soil at the tops of the bank would most likely occur, due to an overall decrease in channel cross-sectional area.

10. Knowledgeable and professional observers note that the number of deeply-undercut banks has diminished markedly over the past two or three decades. Because overall morphologic adjustment of the channel since the 1972 measurements seems to have been limited, likely contributing factors may be:

    a. loss of bank strength associated with the sharp decrease in wooded riparian banks during the 1950s and 1960s (since partially reversed), and

    b. rapid changes in streamflow associated with operations of Pleasant Valley Dam; rapid drops in water level, which were not as prevalent under pre-Crowley Lake flow regimes, may accelerate collapse of suddenly unsupported saturated banks.

    Other factors which may be contributing are considered in the Discussion and Management chapters.

11. Measurements of suspended and bedload sediment transport during flows of 225 cfs at all six sections correspond closely to those observed by U.S. Geological Survey staff in 1972. The recent measurements strongly imply that the 1972 sediment-transport relations still approximate those presently prevailing. We could not verify whether these relations in fact apply at high flows, since high flows could not be released in 1991.

12. Prior U. S. Geological Survey work suggests that sediment transport rates progressively increase at higher flows. Above a range of about 600 to 800 cfs, sediment transport seems to increase especially sharply, based on the 1972 measurements. Since bed and bank erosion is the source of most (or virtually all) sediment being transported, it is likely that bank erosion may be disproportionately affected by such flows. The additional measurements needed to better define conditions of sediment transport and channel migration at these flows are described in the Recommendations section of the Management chapter.

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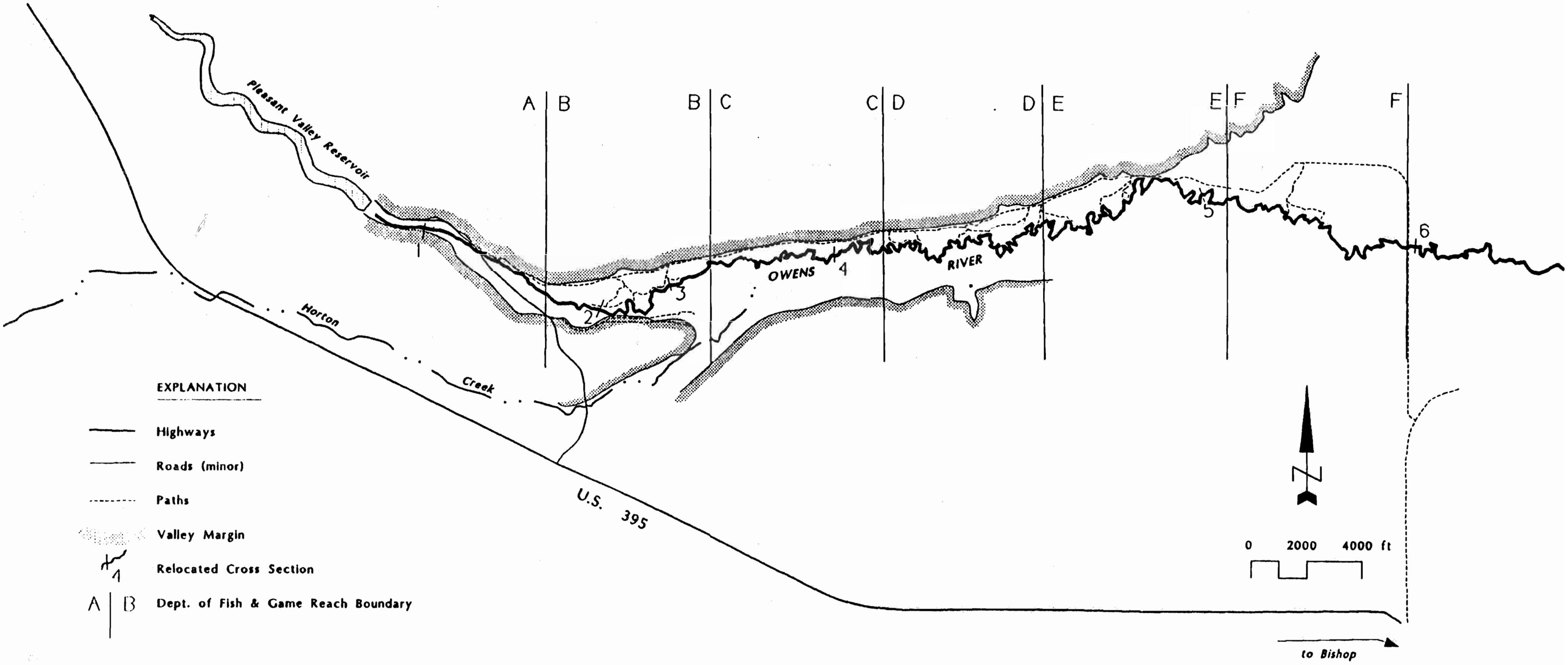
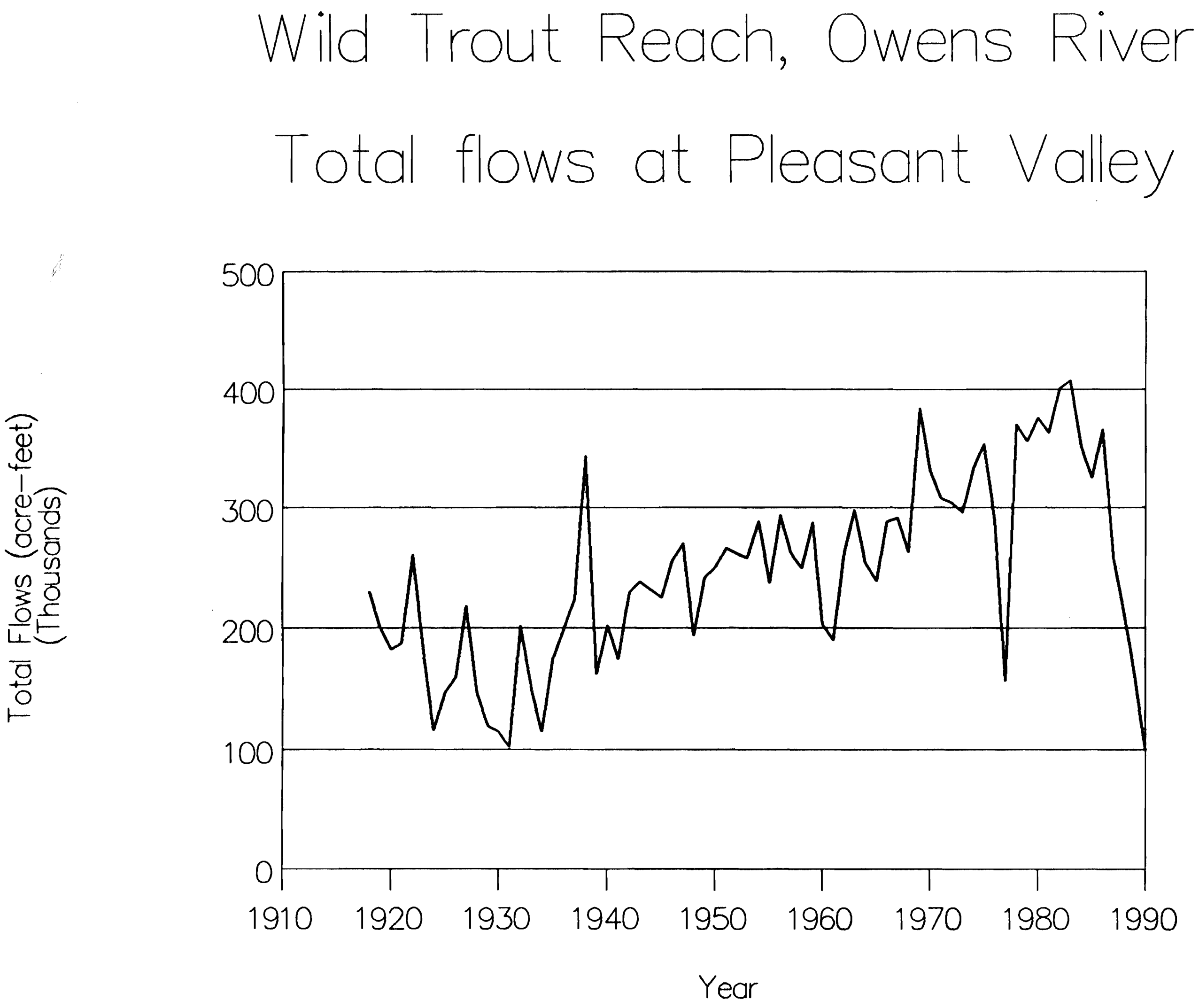


Balance Hydrologics, Inc.

**Figure 1.** **Location of the study area.** The Wild Trout Reach extends downstream from Pleasant Valley Dam and is covered by Department of Fish and Game subreaches A through F.



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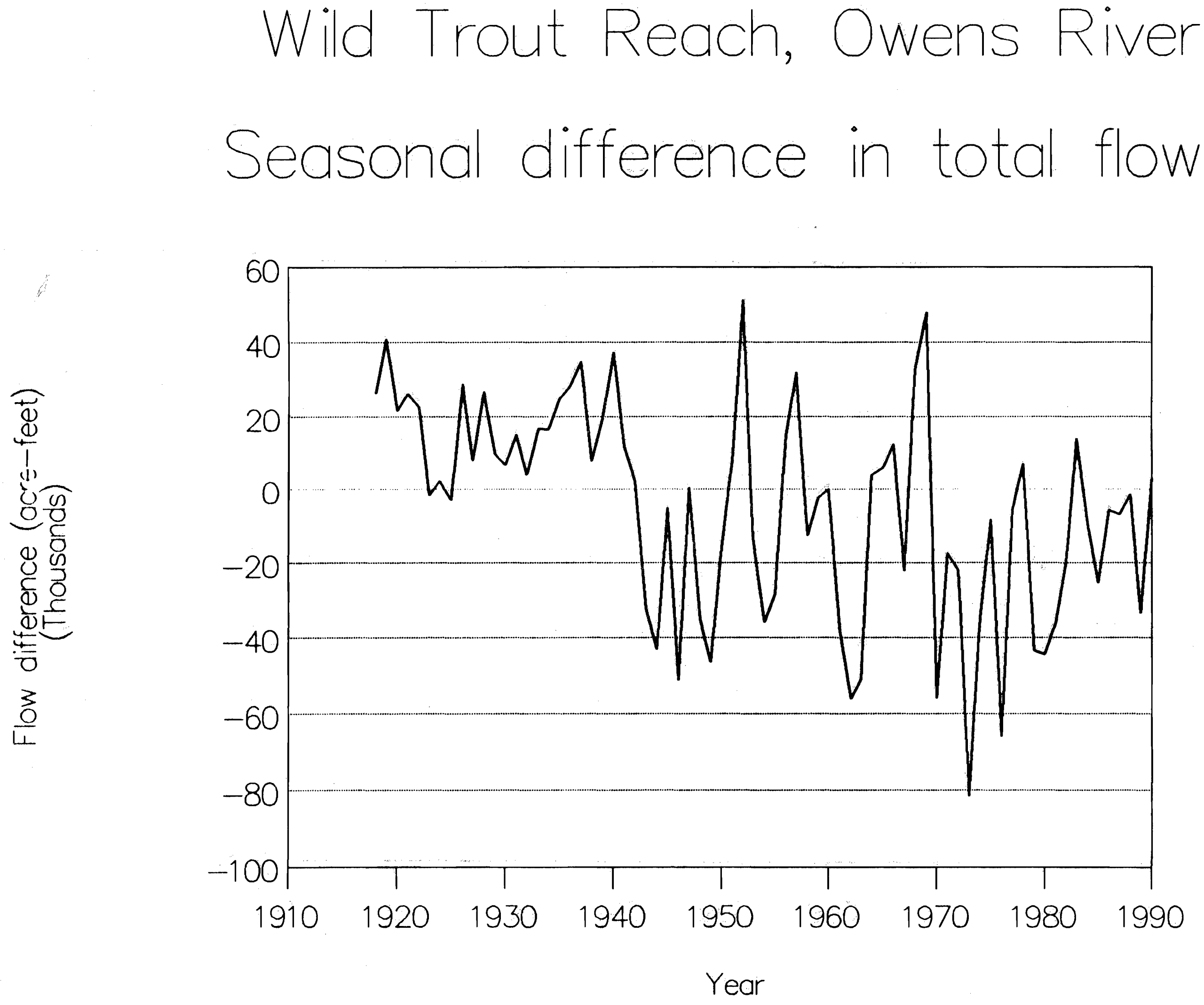
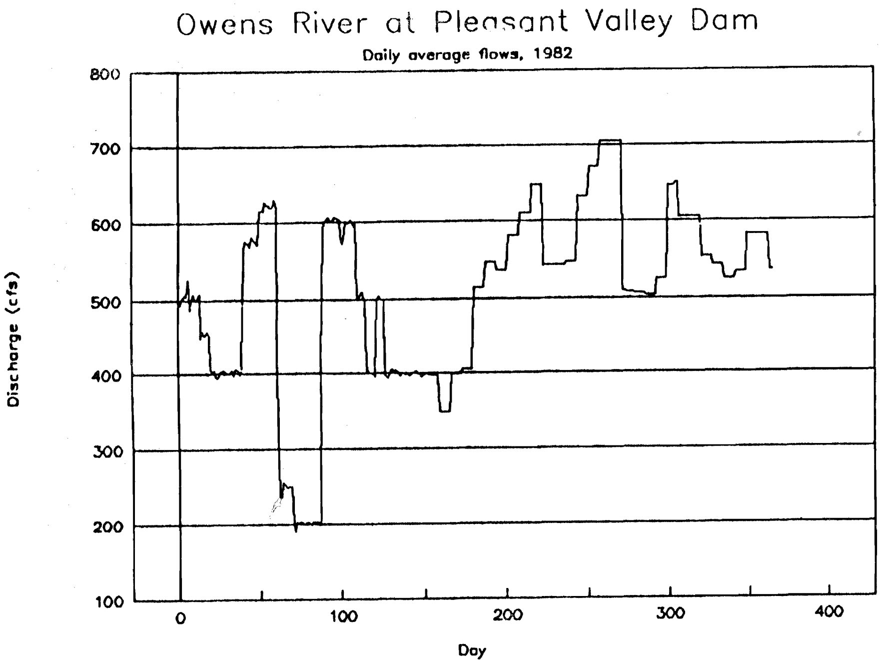
Hydrologics, Inc.

**Figure 2.** **Total yearly flows at Pleasant Valley Dam, Owens River, Inyo County, California (Source: L.A.D.W.P.).** Note the generally increasing trend in total discharge, indicating that a larger total volume of water is being conveyed

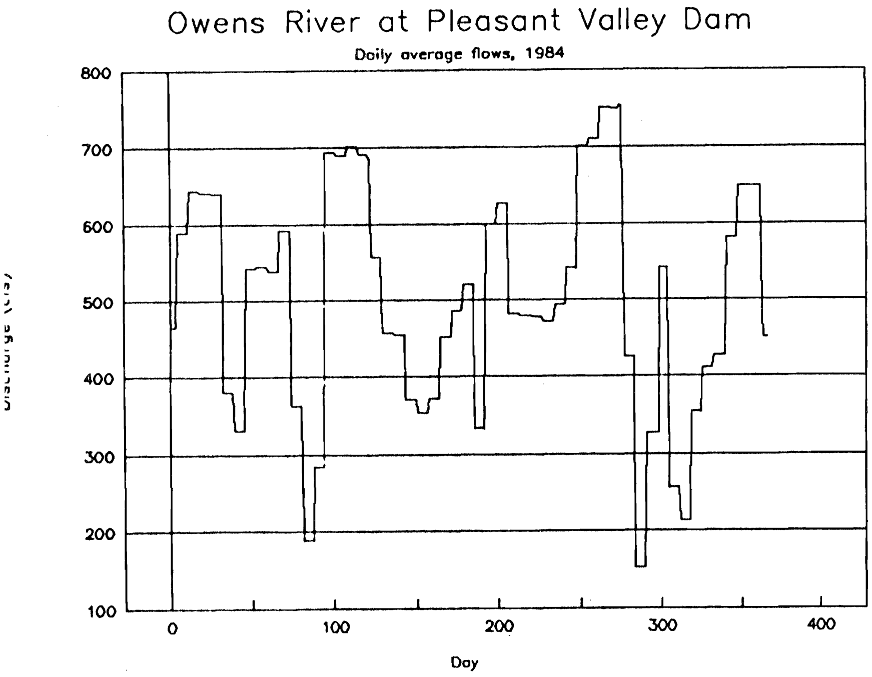


**Balance Hydrologics, Inc.**

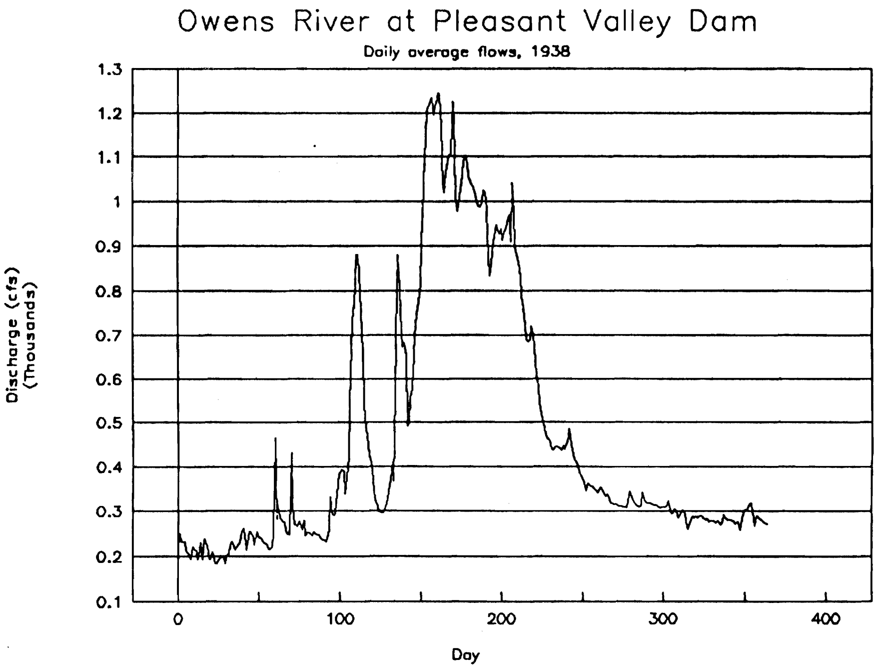
**Figure 3.** **Seasonal difference in yearly flows, Pleasant Valley Dam, Owens River, Inyo County, California (Source: L.A.D.W.P.).** These values were calculated by the formula: Seasonal difference = (total "winter" flows, Oct.-Mar.) - (total "summer" flows, Apr.-Sept.). Positive values indicate those years where winter flow is greater than summer. Note the change from net positive values to net negative values.


Owens River at Pleasant Valley Dam

Daily average flows, 1982

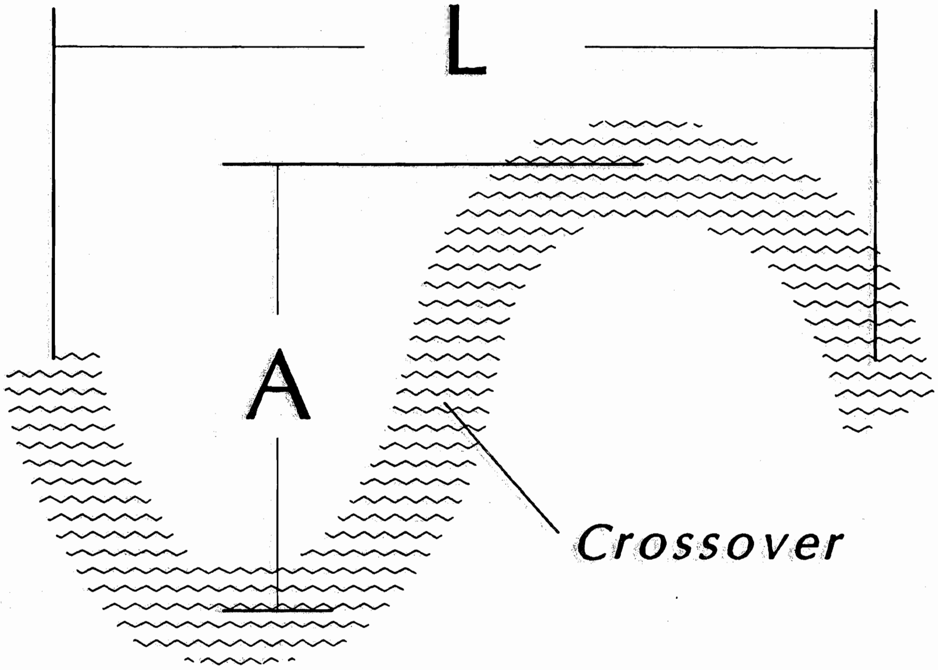

Owens River at Pleasant Valley Dam

Daily average flows, 1984


Owens River at Pleasant Valley Dam

Daily average flows, 1938

**Figure 4.** **Pre- and post impoundment and diversion average daily flows at Pleasant Valley Dam**; data from 1938 and 1982 were chosen because these years of record had very similar total precipitation and were both relatively wet years, when large, channel-forming floods were likely to have occurred. Note the change from a more irregular, "jagged" curve in 1938 to a square curve with attenuated flood peaks and higher baseflow in



*L = Meander wavelength*

*A = Meander amplitude*

**Figure 5. Meander geometry definition sketch.**

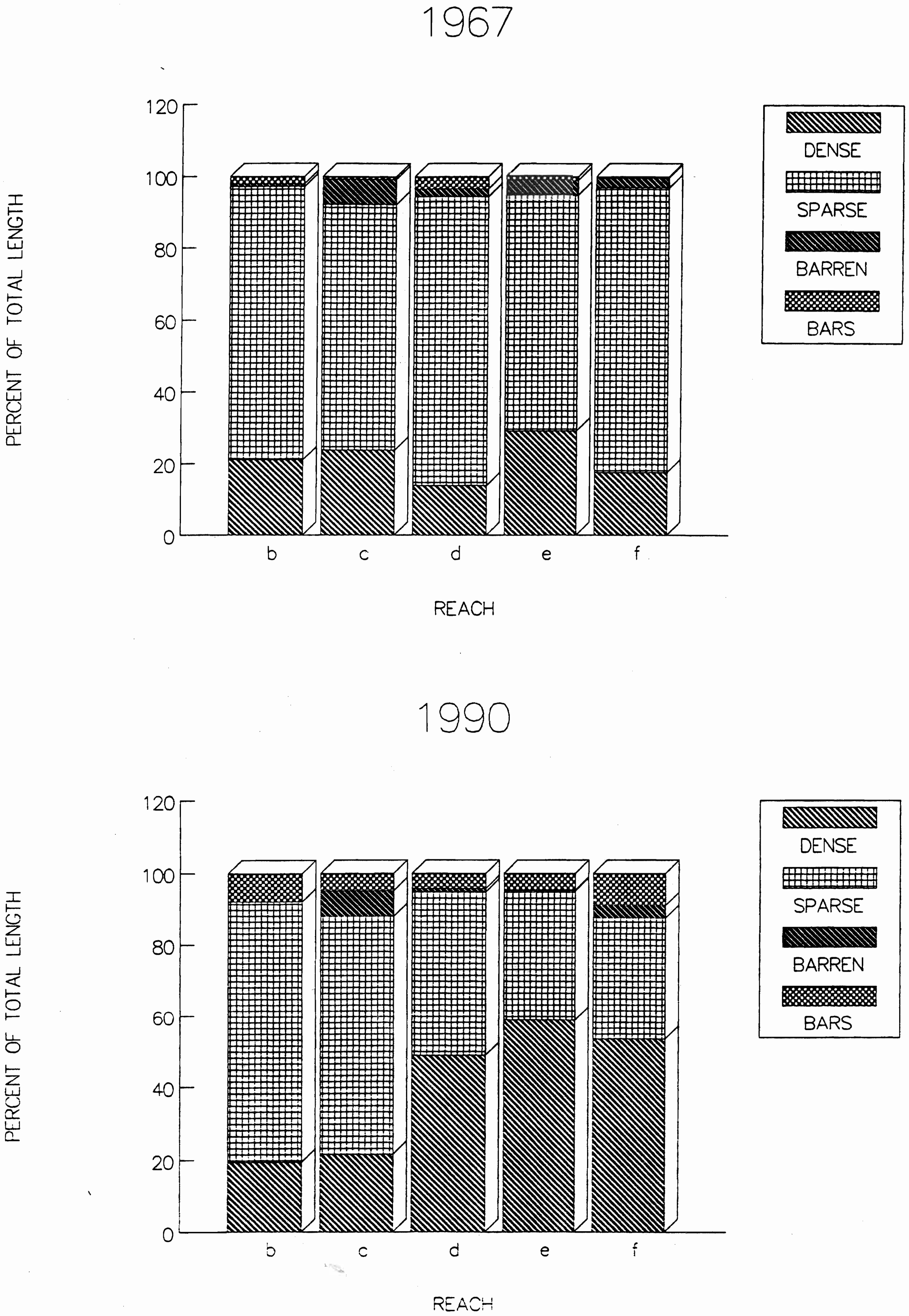


Figure 6. **Downstream changes in bank riparian vegetation lengths, expressed as a percentage of total length.** Note the increase in dense cover in reaches D, E, and F between 1967 and 1990. Photos were taken at high flows in 1967, and at low flows in 1990. See text regarding effects of flows on the date of photography upon the areas of bars and barrens.

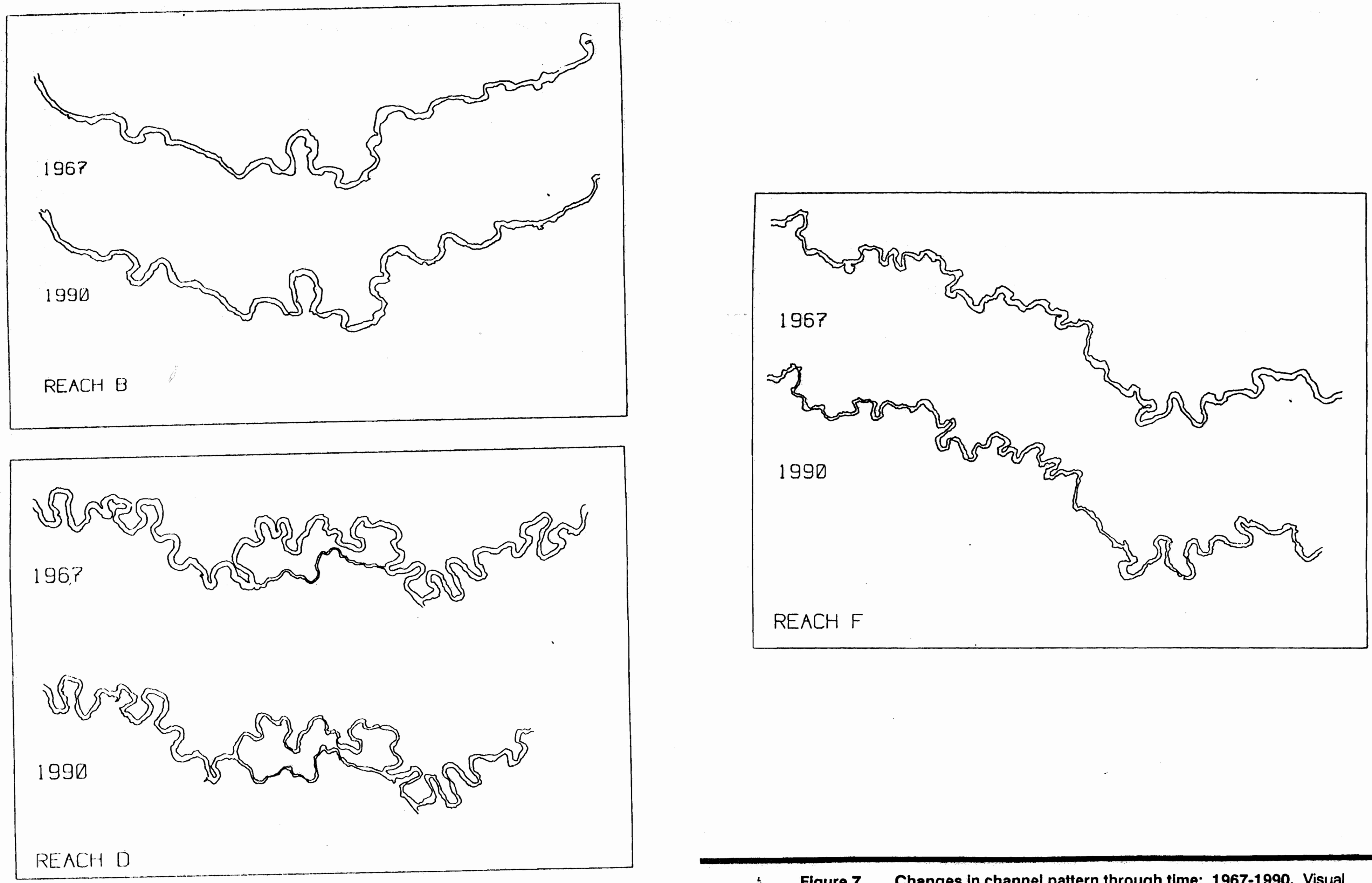
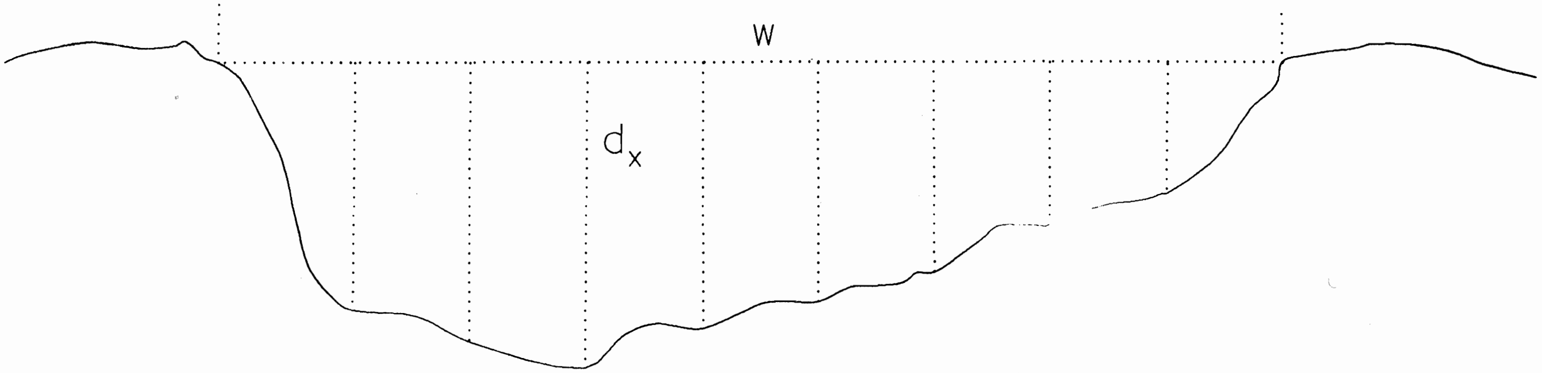


**Figure 7.** **Changes in channel pattern through time: 1967-1990.** Visual comparisons of subreaches B, D, and F. Note changes in meander amplitude and wavelength. Differences in width are a function of the higher discharge for the 1967 flows (686 cfs, versus 144 cfs for the 1990 sketch).



W = bank-top width

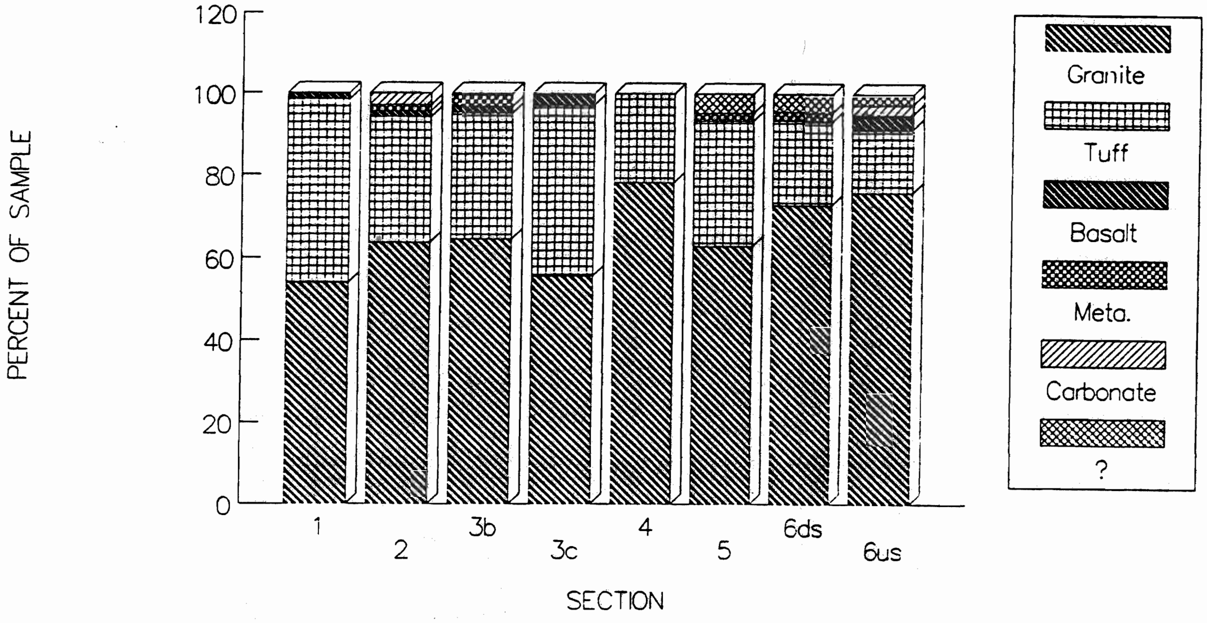
$d_x$ = measured depth from bank top to bed

Average bank-top depth = $(\Sigma\ d_x)/x$

**Figure 8.** **Definition sketch for bank-top width and average depth at a typical channel cross section.**

## Owens River, Clast Lithology Summary

### Whole Sample Percentages



## Owens River, Clast Lithology Summary

### 23–90 mm. fraction percentages

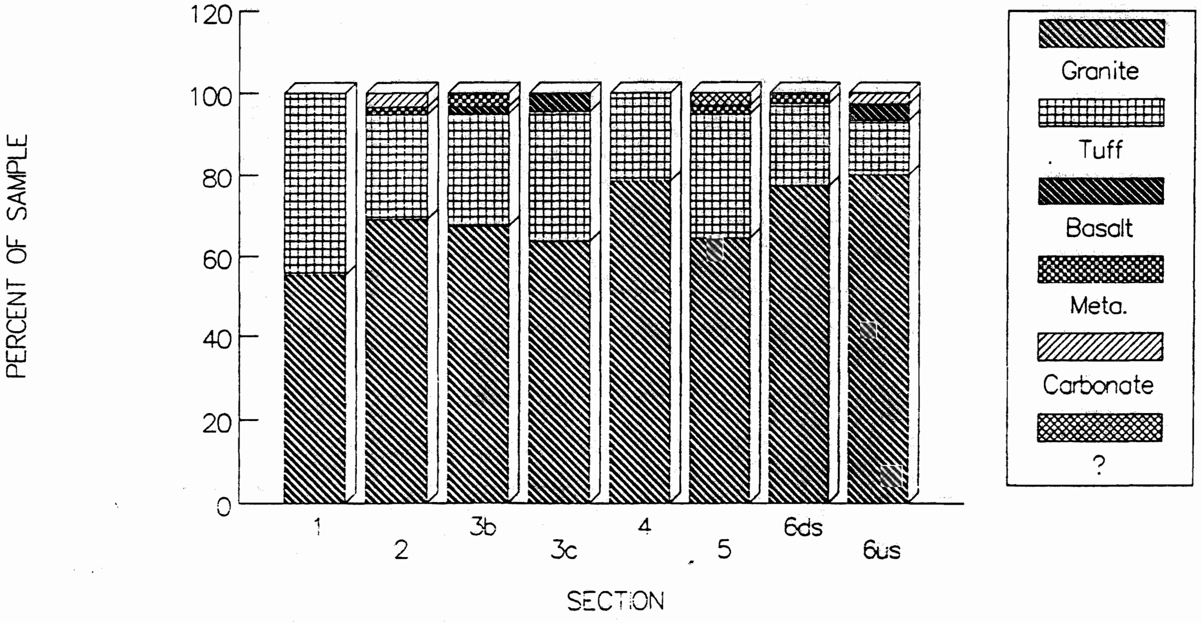


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**Figure 9.** **Downstream changes in clast composition as a percentage of the total bed material sampled.** Sample 3c corresponds to an ancient bar exposed in the banks at cross section 3 and was included for comparative purposes. Note that, with the exception of this paleo-bar, there is a monotonic increase in granitic composition up to section 4, followed by a sharp decrease in granitic clasts and a subsequent monotonic rise to section 6.

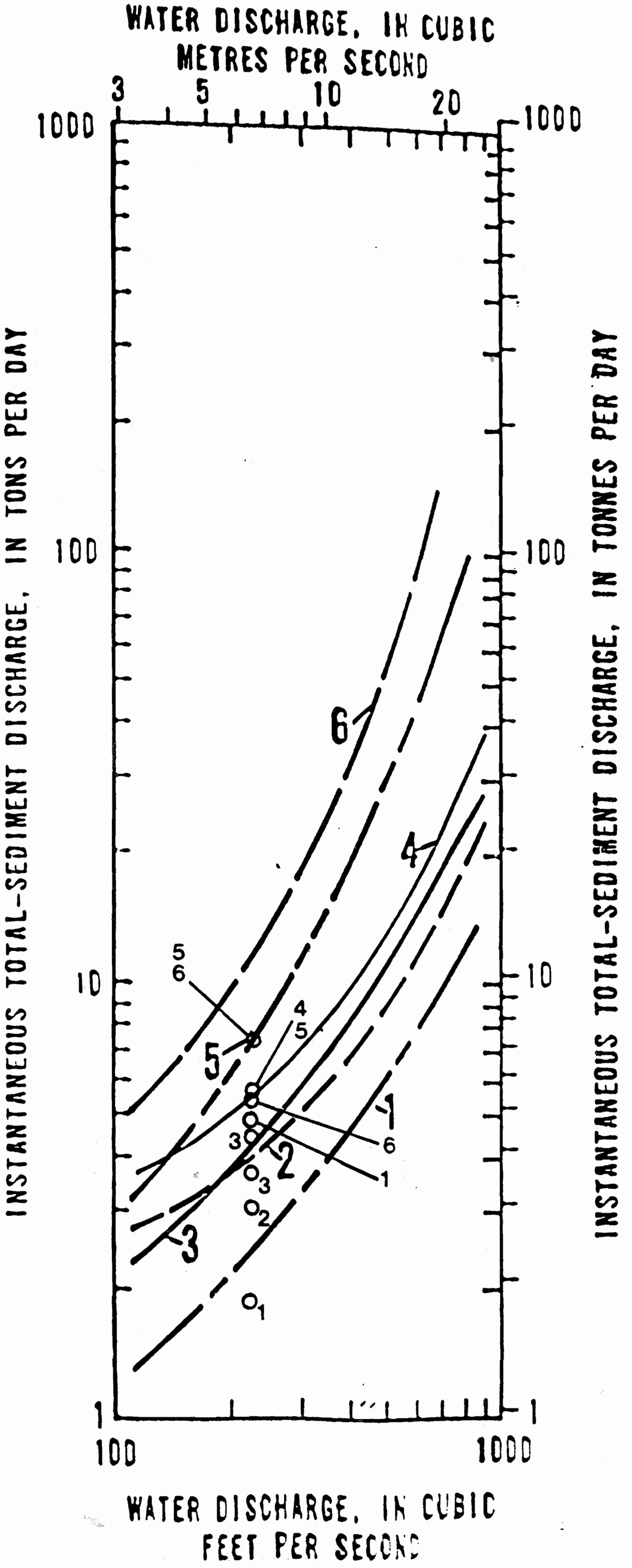

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**Figure 10.** **Total sediment transport rate plotted versus discharge (suspended plus bedload).** Curves are from Williams (1975). Numbered circles correspond to Balance, 1991 measurements for cross sections 1 through 6.

MULTI-TEMPORAL COMPARISONS

| Year (Discharge for date of photography) | 1944 (220 cfs) | | | | | | 1967 (686 cfs) | | | | | | 1990 (144 cfs) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach | B | C | D | E | F | TOTAL | B | C | D | E | F | TOTAL | B | C | D | E | F | TOTAL |
| Geomorphic variables | | | | | | | | | | | | | | | | | | |
| 1. Channel area (sq. feet) | | | | | | | 494894 | 499235 | 939647 | 841284 | 644438 | 3419498 | 511907 | 408299 | 647951 | 644618 | 568183 | 2780958 |
| 2. Channel length (feet) | 8780 | 11334 | 15693 | 16301 | 12100 | 64208 | 8637 | 9068 | 18149 | 18038 | 11701 | 65593 | 9459 | 8973 | 16197 | 17431 | 13072 | 65132 |
| 3. Valley length (feet) | 5837 | 6242 | 5438 | 6778 | 6767 | 31062 | 5837 | 6242 | 5438 | 6778 | 6767 | 31062 | 5837 | 6242 | 5438 | 6778 | 6767 | 31062 |
| 4. Average width [(1)/(2)] (feet) | | | | | | | 57 | 55 | 52 | 47 | 55 | 266 | 54 | 46 | 40 | 37 | 43 | 220 |
| 5. Sinuosity [(2)/(3)] | | | | | | | 1.48 | 1.45 | 3.34 | 2.66 | 1.73 | 10.66 | 1.62 | 1.44 | 2.98 | 2.57 | 1.93 | 10.54 |
| 6. # meander apices | | | | | | | 21 | 30 | 63 | 61 | 50 | 225 | 26 | 41 | 56 | 63 | 55 | 241 |
| 7. Avg. meander wavelength (feet) | 430 | 284 | 308 | 325 | 288 | 1635 | 582 | 381 | 294 | 360 | 315 | 1932 | 476 | 359 | 305 | 332 | 291 | 1763 |
| 8. Avg. meander amplitude (feet) | 131 | 135 | 188 | 145 | 115 | 714 | 223 | 215 | 220 | 208 | 195 | 1061 | 249 | 188 | 215 | 206 | 179 | 1037 |
| Bank riparian vegetation lengths (feet) | | | | | | | | | | | | | | | | | | |
| 1. Dense | | | | | | | 3989 | 5325 | 5337 | 11074 | 4468 | 30193 | 3943 | 5215 | 17046 | 22251 | 15582 | 64037 |
| 2. Sparse | | | | | | | 14404 | 15287 | 30807 | 24839 | 20115 | 105452 | 14877 | 16132 | 16166 | 13689 | 9962 | 70826 |
| 3. Barren | | | | | | | 173 | 1564 | 835 | 1549 | 712 | 4833 | 0 | 1769 | 330 | 132 | 1030 | 3261 |
| 4. Bars | | | | | | | 368 | 155 | 1270 | 374 | 89 | 2256 | 1590 | 1149 | 1439 | 1732 | 2589 | 8499 |

Table 1. **Total changes in geomorphic variables and bank riparian vegetation lengths over time, 1944 to 1990.** These results were derived from photo-interpretive techniques. Most data were not available for the 1944 photography due to its small scale. Also note that the discharge for the date of photography is given in parentheses following the year of the photography.

## CHANGES OVER TIME

| Year | 1944-1967* | | | | | 1967-1990 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Reach | B | C | D | E | F | B | C | D | E | F |
| Geomorphic variables | | | | | | | | | | |
| 1. Channel area (sq. feet) | | | | | | -3 | 22 | 45 | 31 | 13 |
| 2. Channel length (feet) | 1 | 25 | -14 | -10 | 3 | -9 | 1 | 12 | 4 | -11 |
| 3. Valley length (feet) | | | | | | | | | | |
| 4. Average width [(1)/(2)] (feet) | | | | | | 6 | 20 | 30 | 27 | 28 |
| 5. Sinuosity [(2)/(3)] | | | | | | -9 | 1 | 12 | 4 | -10 |
| 6. # meander apices | | | | | | -19 | -27 | 13 | -3 | -10 |
| 7. Avg. meander wavelength (feet) | -26 | -25 | 5 | -10 | -9 | 22 | 6 | -4 | 8 | 8 |
| 8. Avg. meander amplitude (feet) | -41 | -37 | -15 | -30 | -41 | -10 | 14 | 2 | 1 | 9 |
| Bank riparian vegetation lengths (feet) | | | | | | | | | | |
| 1. Dense | | | | | | 1 | 2 | -69 | -50 | -71 |
| 2. Sparse | | | | | | -3 | -5 | 91 | 81 | 102 |
| 3. Barren | | | | | | ****** | -12 | 153 | 1073 | -31 |
| 4. Bars | | | | | | -77 | -87 | -12 | -78 | -97 |

*Comparisons between 1944 and 1967 measurements may be less reliable due to the inaccuracies in measurements made on the much smaller scale 1944 photographs.

**Table 2.** **Percent changes in geomorphic and bank riparian vegetation lengths over time, 1944 to 1990.**

Table 3. Summary of bank-top dimensions for measured 1991 IFIM transects and longer-term monumented cross sections (USGS/Balance) used to describe changes in the Owens River channel over time

| DFG Index Reach (a) (see Fig. 1) | USGS/Balance Section No. | Bank-top Dimensions (b) | | |
|---|---|---|---|---|
| | | Width (ft.) | Depth (ft.) | Cross-Sectional Area (ft2) |
| B | | 61.07 | 4.13 | 270.00 |
| | *2, 3a, 3b* | *68.0* | *4.23* | *287.33* |
| C | | 56.85 | 4.98 | 282.00 |
| | *4* | *102.0* | *3.68* | *375* |
| D | | 59.01 | 4.71 | 282.33 |
| | *none* | --- | --- | --- |
| E | | 51.97 | 5.12 | 262.67 |
| | *5* | *47.5* | *4.30* | *204* |
| F | | 74.35 | 4.12 | 328.50 |
| | *6* | *56.7* | *3.95* | *224* |
| Average (c) 1991 IFIM transects: | | 60.65 | 4.61 | 285.1 |
| *Average (d) 1991 Section 2 through 6:* | | *68.37* | *4.11* | *281.0* |

Notes:

(a) DFG index reaches (described in text) are shown in Figure 1. They are intended for locating only, and have no morphological implications. Locations of the USGS/Balance cross sections are also shown in Figure 1, and are described in Appendix A. Reach A and Section 1 are upstream of the lower campground footbridge, where the channel is disturbed.

(b) Bank-top dimensions are not the same as morphologically-bankfull dimensions, although in many instances the differences may be slight.

(c) Average of the means for the five DFG index-reaches.

(d) Average for the six named sections.

# HYDRAULIC GEOMETRY: PROJECTED VS. ACTUAL VALUES

| | LOCATION | HYDRAULIC GEOMETRY RELATIONSHIP ((Williams, 1975) | DISCHARGE USED FOR PROJECTION | PROJECTED 1990-91 | ACTUAL 1990-91 | PERCENT DIFFERENCE | NOTES |
|---|---|---|---|---|---|---|---|
| DEPTH | Section 2 | $d=0.076Q^{(0.56)}$ | 225 cfs | 1.58 | 1.99 | 21 | Located at monumented section from Williams (1975) |
| | Section 5 | $d=0.317Q^{(0.40)}$ | 225 cfs | 2.77 | 2.91 | 5 | Located at monumented section from Williams (1975) |
| | Average for sections 2,3,4,5,6 | $d=0.279Q^{(0.56)}$ | 225 cfs | 5.79 | 1.78 | 69 | 1. Average hydraulic geometry relationship derived from averages of coefficients & exponents for Williams sections 2, 3, 4, 5, & 6.<br>2. Average actual 1990-91 value derived from average of measured depths for sections 2, 3, 4, 5, & 6 measured in May-91 |

**Table 4.** **Channel hydraulic geometry comparisons.** Projected values based on Williams (1975) published hydraulic geometry relationships. Actual values based on field or photographic measurements.

## HYDRAULIC GEOMETRY: PROJECTED VS. ACTUAL VALUES

WIDTH

| LOCATION | HYDRAULIC GEOMETRY RELATIONSHIP ((Williams, 1975) | DISCHARGE USED FOR PROJECTION | PROJECTED 1990-91 | ACTUAL 1990-91 | PERCENT DIFFERENCE | NOTES |
|---|---|---|---|---|---|---|
| Section 2 | $w=12.6Q^{(0.24)}$ | 225 cfs | 46.2 | 41.6 | 10 | Located at monumented section from Williams (1975) |
| Section 5 | $w=34.7Q^{(0.01)}$ | 225 cfs | 36.6 | 43.3 | 18 | Located at monumented section from Williams (1975) |
| Average for sections 2,3,4,5 & 6 | $w=24.70Q^{(0.12)}$ | 225 cfs | 47.3 | 47.4 | 0.2 | Located at monumented section from Williams (1975) |
| ▪ | ▪ | 144 cfs | 44.8 | 44 | 2 | 1. Discharge is equivalent to that for 1990 aerial photography<br>2. Actual average width based on channel area -channel length as measured on 1990 air photos |
| ▪ | ▪ | 686 cfs | 54.1 | 53.2 | 2 | 1. Discharge is equivalent to that for 1967 aerial photography<br>2. Actual average width based on channel area -channel length as measured on 1967 air photos |
| Average for B & C reaches | $d=0.066Q^{(0.64)}$ | 225 cfs | 2.11 | 1.53 | 28 | 1. Average hydraulic geometry relationship taken from Williams sections 2, 3, & 4, all within reaches B & C<br>2. 0.6' of aggradation |
| Average for D, E, F reaches | $d=0.257A^{(0.43)}$ | 225 cfs | 2.64 | 2.72 | 3 | 1. Average hydraulic geometry relationship taken from Williams (1975) sections 5 and 6.<br>2. 0.1' of incision |

| | SECTION | | | | |
|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 |
| D16 (mm.) | 17 | 19 | 15 | 13 | 26 |
| D50 (mm.) | 40 | 41 | 64 | 36 | 46 |
| D84 (mm.) | 77 | 78 | 92 | 61 | 63 |

Bar counts

| | SECTION | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| D16 (mm.) | 38 | 17 | 19 | 15 | 13 | 24 |
| D50 (mm.) | 73 | 40 | 41 | 64 | 36 | 46 |
| D84 (mm.) | 124 | 77 | 78 | 92 | 61 | 66 |

Whole bed counts

Table 5. **Summary of results of textural analyses for whole bed and bar samples.** "Bar counts" refers to clast counts performed on discrete gravel bedforms, while "whole bed counts" refer to those performed on a roughly 30' x 40' area on the bed at a given cross section. No bar count exists for section 1 due to the high flow velocities encountered at that section, making it impossible to sample bars adequately. $D_{16}$, $D_{50}$, and $D_{84}$ refer to the particle size (mm) of the xth percentile (x=16, 50 and 84) in a cumulative frequency distribution.

| | Particle Size (Percentile rank) | | | | |
|---|---|---|---|---|---|
| Section | D10 | D16 | D50 | D84 | D90 |
| 1 | | | | | |
| Williams, 1975 | 33 | 37 | 67 | 110 | 121 |
| Balance, 1991 | 20 | 38 | 73 | 124 | 175 |
| % difference* | 65 | -3 | -8 | -11 | -31 |
| 2 | | | | | |
| Williams, 1975 | 9 | 12 | 31 | 57 | 63 |
| Balance, 1991 | 13 | 17 | 40 | 77 | 86 |
| % difference | -31 | -30 | -23 | -26 | -27 |
| 3 | | | | | |
| Williams, 1975 | 11 | 18 | 46 | 87 | 101 |
| Balance, 1991 | 14 | 19 | 41 | 78 | 90 |
| % difference | -21 | -5 | 12 | 12 | 12 |
| 4 | | | | | |
| Williams, 1975 | 4 | 14 | 41 | 76 | 94 |
| Balance, 1991 | 11 | 15 | 64 | 92 | 107 |
| % difference | -63 | -7 | -36 | -17 | -12 |
| 5 | | | | | |
| Williams, 1975 | 7 | 13 | 37 | 67 | 85 |
| Balance, 1991 | 8 | 13 | 36 | 61 | 68 |
| % difference | -13 | 0 | 3 | 9 | 25 |
| 6 upstream | | | | | |
| Williams, 1975 | 6 | 9 | 23 | 57 | 68 |
| Balance, 1991 | 23 | 26 | 46 | 63 | 71 |
| % difference | -74 | -65 | -50 | -10 | -4 |
| 6 downstream | | | | | |
| Williams, 1975** | 6 | 9 | 23 | 57 | 68 |
| Balance, 1991 | 16 | 24 | 46 | 66 | 77 |
| % difference | -63 | -63 | -50 | -14 | -12 |

*[(Williams) / (Balance) X 100] - 100

**These are the same values for section 6 upstream.

**Table 6.** **Comparison of characteristic particle sizes between sites sampled by Williams (1975) and those found in our study.** See text for discussion.

# Appendix A

## Locations and descriptions for primary geomorphic cross sections, Wild Trout Reach, Owens River, CA

## Appendix A. Locations and Descriptors for Primary Geomorphic Cross Sections
## Wild Trout Reach, Owens River

| Section No. (a) | Location Description | Pool/Riffle/Glide Position At Bankfull Stage (b) | Rationale for Selection | Remarks |
|---|---|---|---|---|
| 1 | Near east end of PV Dam parking area. LB pin at base of bank immediately downslope from west end of large spoils pile at east edge of parking area. Slightly d/s of easternmost transmission line crossing canyon. | In upper half of riffle at low flow (225 cfs); indications are that this section is head of riffle at high flow. | Nearest hydraulic control to Rhea Williams' section 1, which we could not find. | 1. RB bank pin in brush.<br>2. Not wadable at flows exceeding 275 to 350 cfs. |
| 2 | Approximately 100 yds u/s of bend touching southern valley wall, and about 2,000 feet d/s of footbridge at east end of campground. | Lower riffle | Previous USGS section site. RB monument for former section located. | 1. Evidence of LB retreat in recent years.<br>2. Slight increase in channel sinuosity in recent years.<br>3. Wade 20 yds u/s at flows exceeding 200 cfs; not wadable at more than 300 cfs. |
| 3a | Approximately 500 yds d/s from eastern bend cutting southern valley margin. No other distinguishing landmarks. Located about 50' downstream from bend. R/B pin is at west end of clump of willows. | Head of riffle at most flows; suitable hydraulic conditions for spawning. | Best approximation to probable Williams (1975) site, based on his maps. | 1. Left bank sloughing is very active.<br>2. Probably not possible to accurately pin L/B.<br>3. Difficult to wade at 225 cfs, probably not accessible in flows above 300 cfs.<br>4. Reach section by crossing stream u/s of bend and following R/B to section. |

(continued)

## Appendix A. Locations and Descriptors for Primary Geomorphic Cross Sections
## Wild Trout Reach, Owens River

| Section No. | Location Description | Pool/Riffle/Glide Position At Bankfull Stage | Rationale for Selection | Remarks |
|---|---|---|---|---|
| 3b | Approximately 325 ft d/s of section 3a on bend. Left bank pin on low (4'), willow-covered terrace. | Head of riffle at most flows below 400 to 500 cfs; suitable hydraulic conditions for spawning. | Section could be used in conjunction with 3a to find average cross section, for comparison with Williams (1975). | 1. Section is just downstream of point bar.<br>2. R/B pin at base of 10 to 15' tall willow. |
| 4 | Approximately 800' u/s from westernmost bend that comes very near road on northern edge of valley. | Mid-riffle, with converging flow at low discharges, and diverging flow at high discharges. | Attempted to locate as near as possible to R. Williams' section. | 1. L bank sloughing extensive.<br>2. Local steepening of H2O-surface slope. |
| 5 | Turnoff road 1/2 mile east of where road cuts into chalk bluff (road elevated about 20' above floodplain surface at this point), continue south to stream. About 50' downstream from point where dirt road meets stream. | Head of pool. | Located right bank pin from Williams (1975). | 1. L bank pin in brush on point bar.<br>2. R bank pin in willows above cut bank.<br>3. Dense 10' willows on R bank at section. |
| 6 | Approximately 80 yds d/s of bridge at five bridges | Just below head of riffle at low flows, and mid-riffle at higher flows. Chosen for evidence of long-term stability, hydraulic control, and straight reach | Judged site as good approximation of Williams (1975) site. | 1. Both pins of section in brush.<br>2. R bank pin on steep, very brushy slope.<br>3. L bank overbank area about 5-10' beyond L end of section, may be inundated in flows greater than 300 cfs.<br>4. Access to section at low flow ( <250 cfs) easiest from right bank, just d/s of section.<br>5. May be inaccessible at flows much greater than 300 cfs. |

---

a. Numbers correspond to those used by Williams, 1972.

b. Inferred pool/riffle/glide at flows just filling the banks, where most sediment is transported. Designations may not coincide with conditions at low to moderate flows.

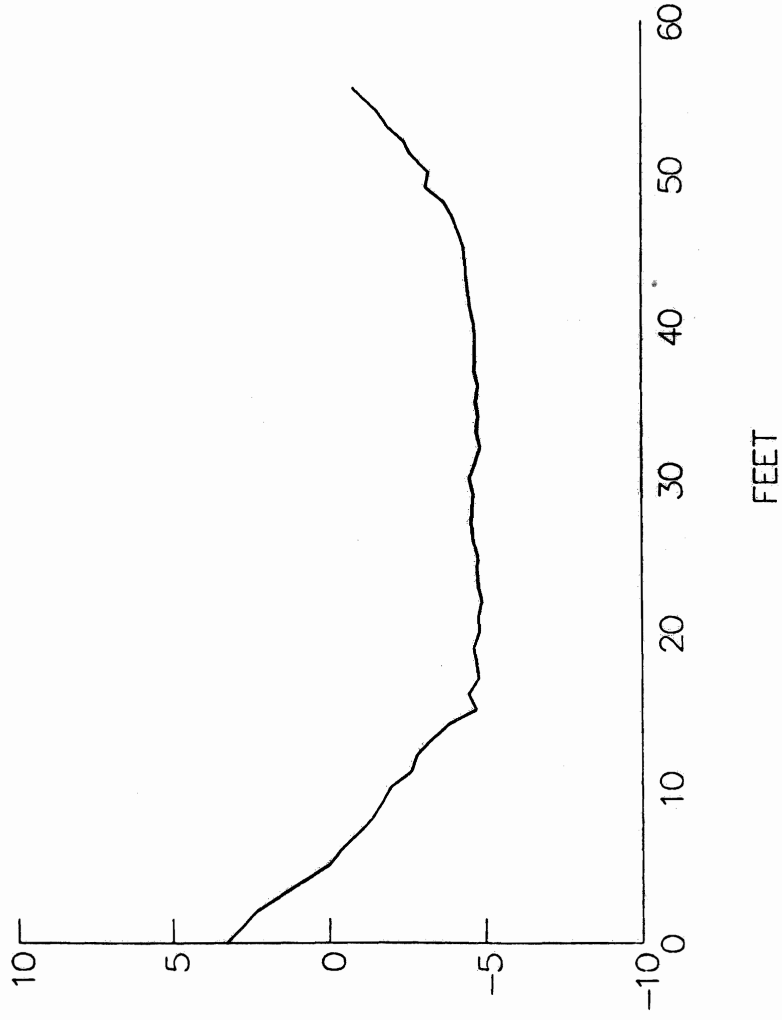
## Appendix B

## Cross section diagrams based on field measurements, May 1991

These cross sections were surveyed by Balance Hydrologics Inc. and are located as nearly as possible to those used in Williams (1975).
NOTE: Horizontal scale varies between sections.

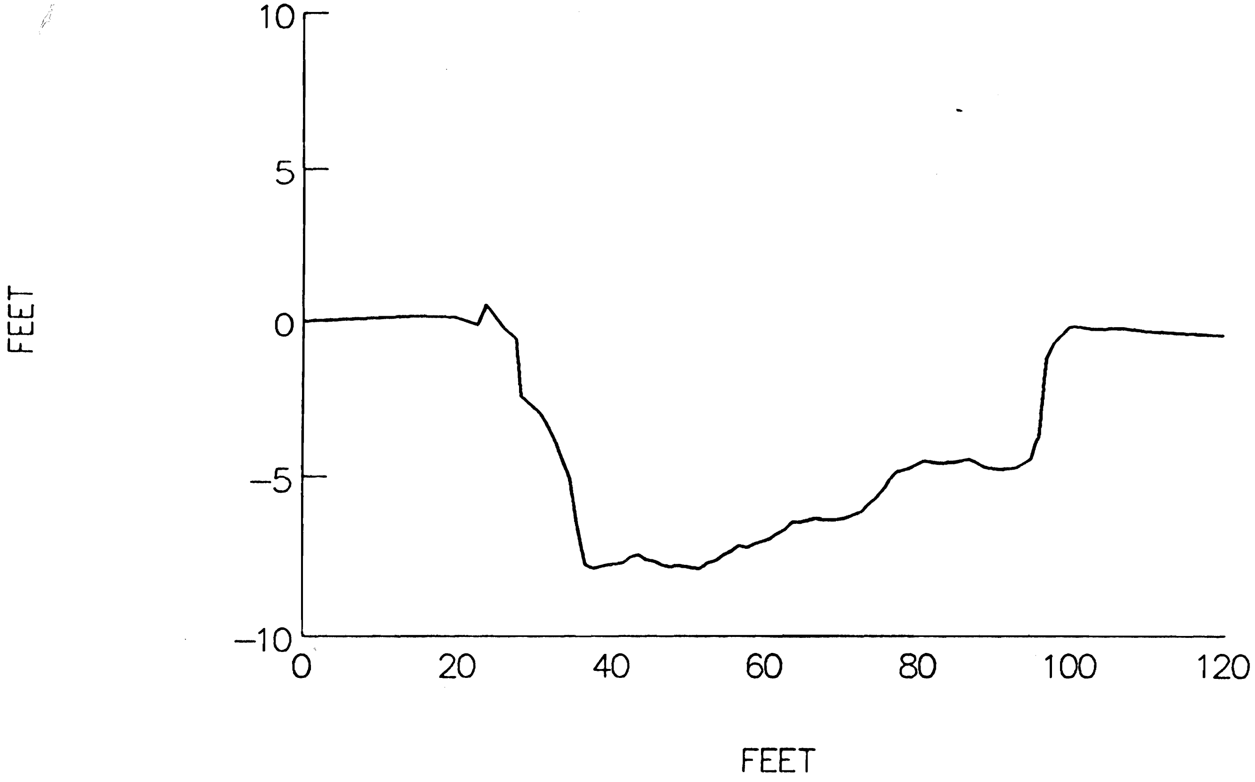
BALANCE SECTION 1

OWENS RIVER, 05/24/91



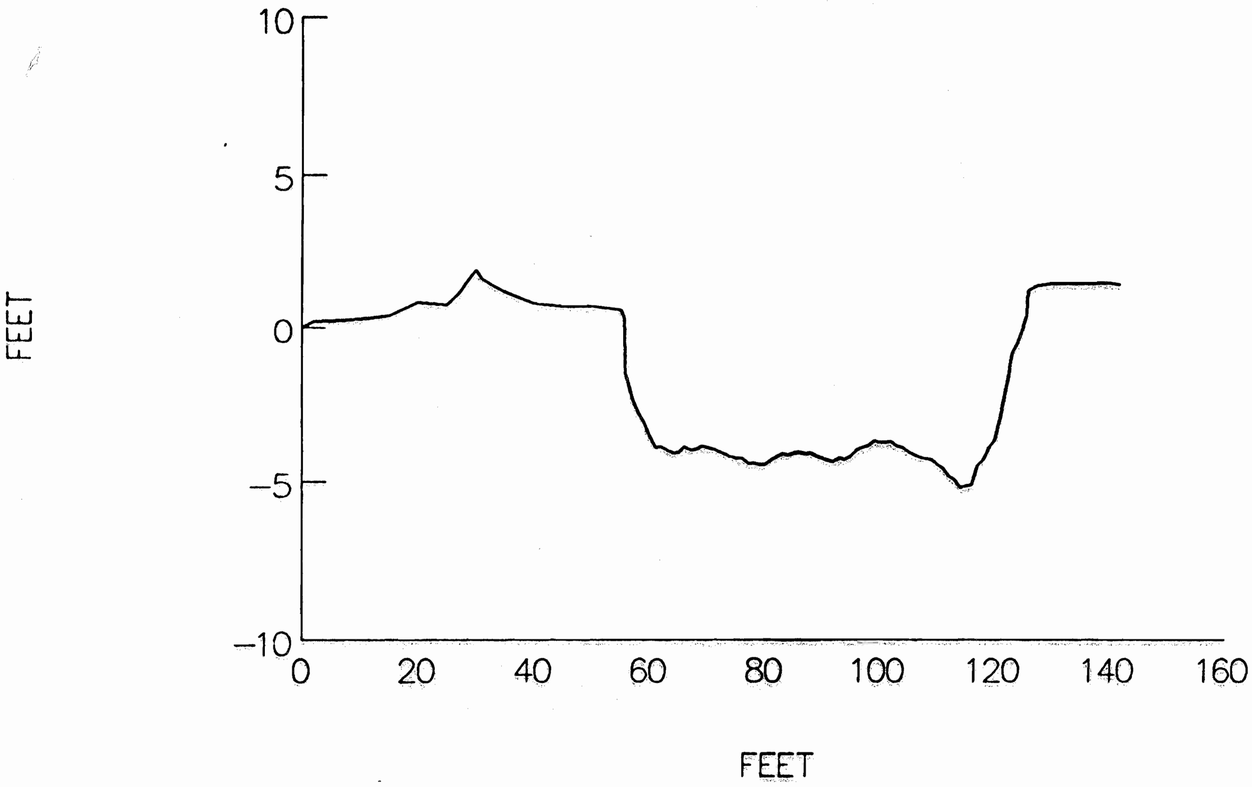
# BALANCE SECTION 2

## OWENS RIVER, 05/22/91

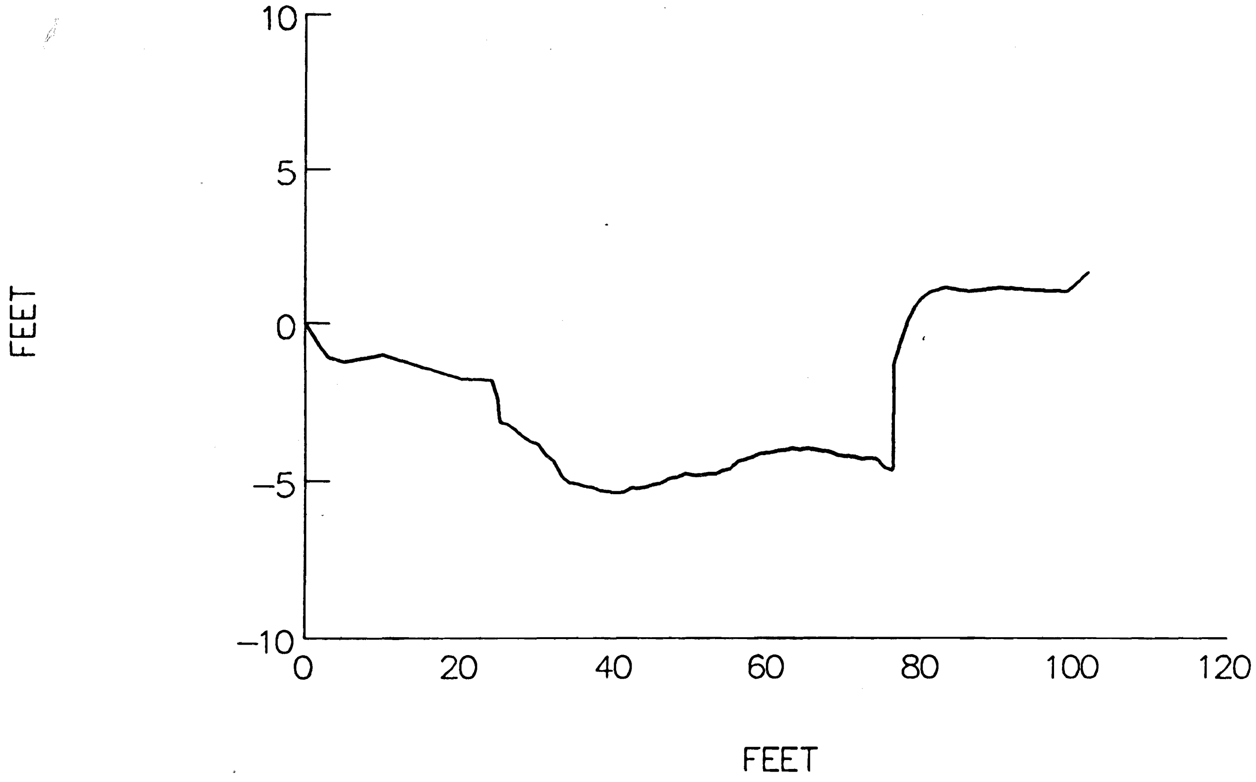


# BALANCE SECTION 3A

# OWENS RIVER, 05/23/91

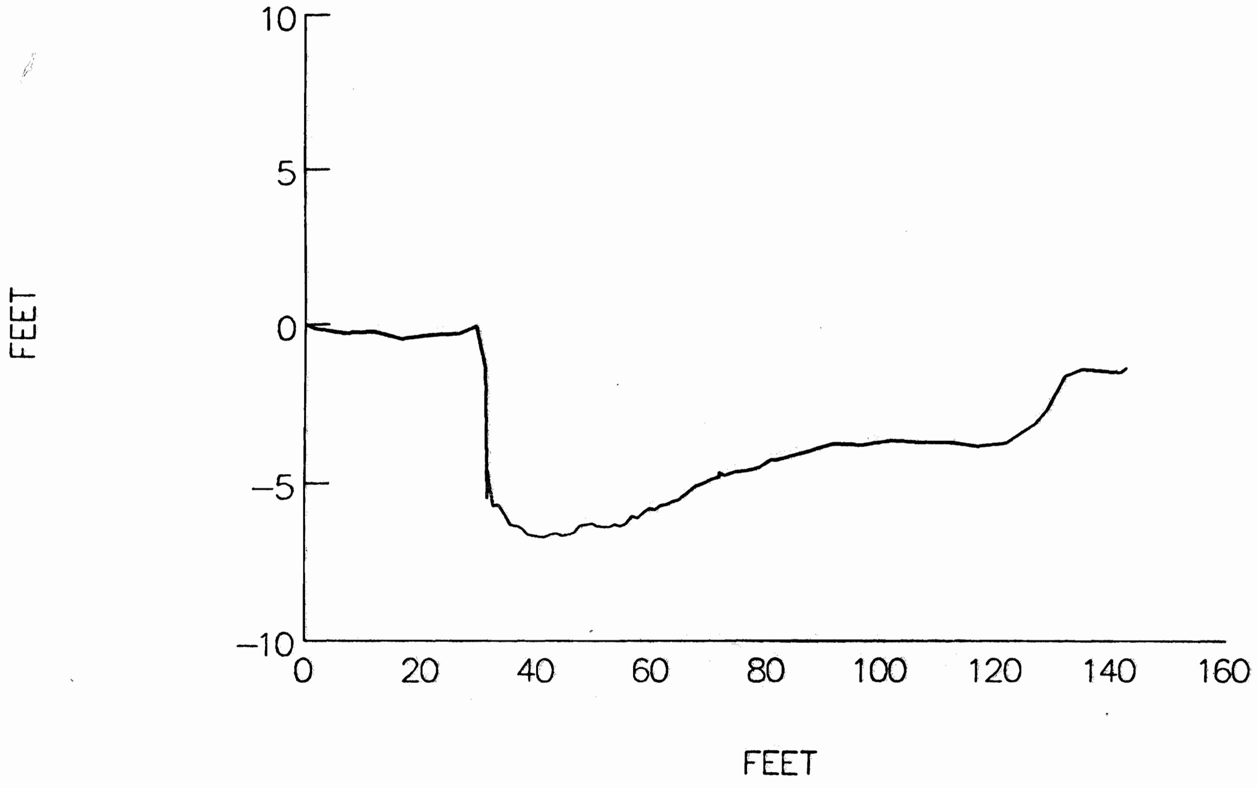


# BALANCE SECTION 3B
# OWENS RIVER, 05/23/91

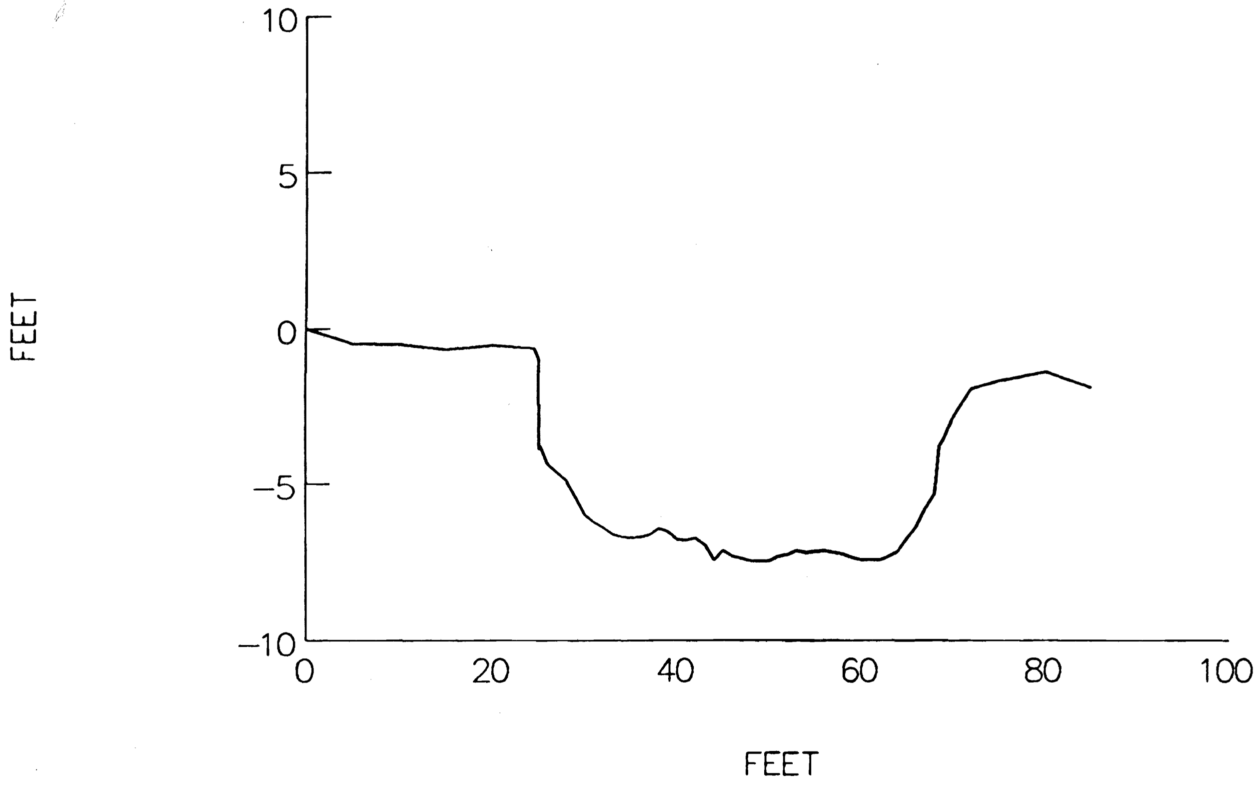


# BALANCE SECTION 4

# OWENS RIVER, 05/24/91

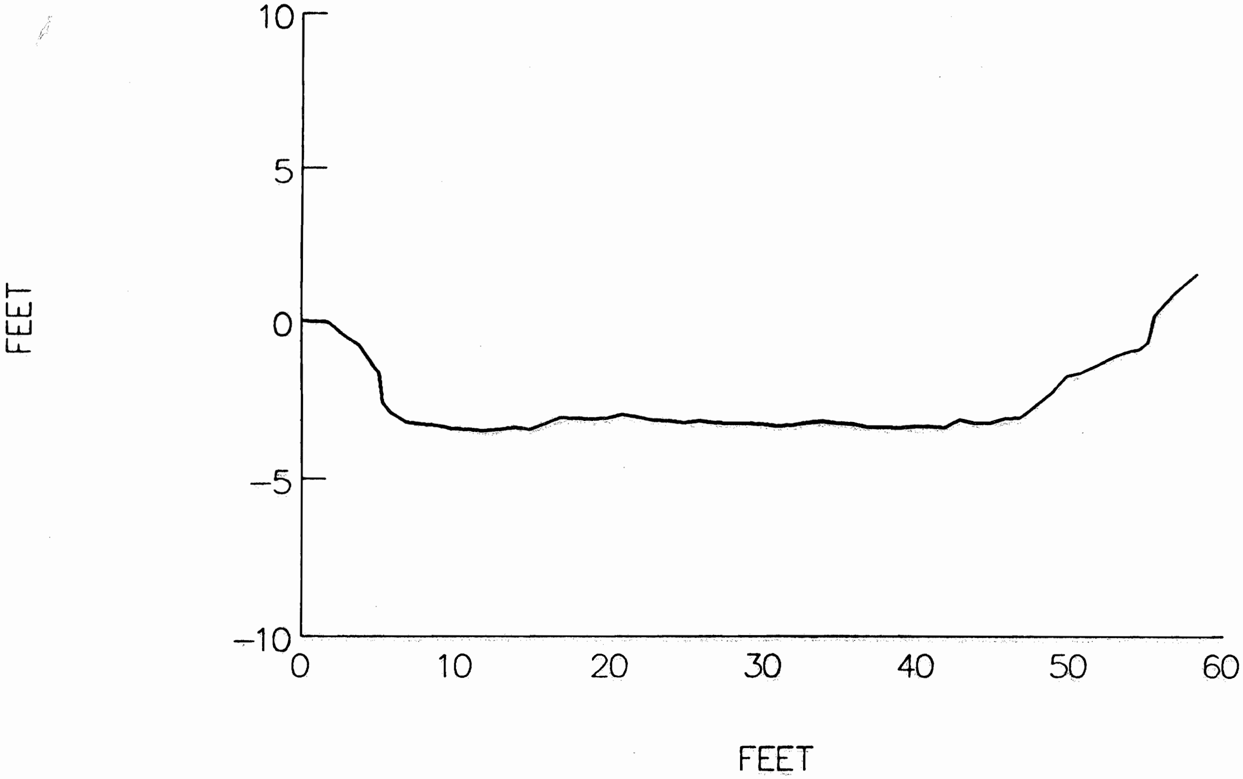


# BALANCE SECTION 5
# OWENS RIVER, 05/22/91



# BALANCE SECTION 6

## OWENS RIVER, 05/25/91



# Appendix C

## Bank-top width, average depth and cross sectional area for IFIM transects

See Figure 8 for definitions of bank-top width and average depth.
Source:  Jones & Stokes Associates, July 1991

CROSSOVERS

| IFIM transect | DFG reach | Bank-top width | Bank-top depth | Bank-top area (sq. ft.) |
|---|---|---|---|---|
| 42 | F | 77.20 | 4.12 | 363 |
| 43 | F | 71.50 | 4.12 | 294 |
| 47 | E | 52.00 | 5.91 | 307 |
| 48 | E | 47.60 | 5.87 | 280 |
| 52 | E | 56.30 | 3.57 | 201 |
| 55 | D | 54.60 | 4.53 | 247 |
| 56 | D | 53.00 | 4.41 | 233 |
| 57 | D | 38.20 | 5.08 | 194 |
| 58 | D | 47.90 | 4.18 | 200 |
| 61 | D | 92.20 | 5.57 | 513 |
| 62 | D | 68.15 | 4.51 | 307 |
| 63 | C | 54.70 | 5.53 | 302 |
| 64 | C | 59.00 | 4.43 | 262 |
| 65 | B | 104.70 | 5.86 | 613 |
| 66 | B | 48.35 | 4.12 | 199 |
| 67 | B | 43.60 | 4.56 | 199 |
| 70 | B | 64.40 | 3.44 | 221 |
| 71 | B | 44.30 | 2.66 | 118 |
| 76 | A | 56.00 | 3.07 | 172 |
| 79 | A | 73.50 | 4.36 | 320 |
| 80 | A | 75.20 | 5.38 | 404 |
| 82 | A | 70.50 | 7.25 | 511 |
| 94 | A | 53.00 | 4.07 | 215 |
| 95 | A | 46.00 | 10.76 | 495 |
| 99 | A | 55.00 | 9.06 | 498 |
| AVERAGE | | 60.28 | 5.06 | 306.72 |
| POOLS | | | | |
| 44 | F | 53.70 | 2.81 | 151 |
| 45 | F | 55.00 | 4.17 | 229 |
| 49 | E | 47.00 | 5.25 | 246 |
| 50 | E | 74.40 | 5.49 | 408 |
| 51 | E | 89.40 | 4.62 | 412 |
| 59 | D | 46.00 | 3.27 | 150 |
| 60 | D | 65.00 | 3.66 | 238 |
| 68 | B | 60.90 | 6.06 | 369 |
| 69 | B | 74.40 | 7.57 | 562 |
| 72 | B | 43.00 | 2.68 | 115 |
| 73 | B | 69.00 | 4.06 | 280 |
| 77 | A | 58.70 | 8.09 | 475 |
| 78 | A | 34.00 | 6.95 | 236 |
| AVERAGE | | 59.27 | 4.97 | 297.77 |

UNCERTAIN

| | | | | |
|---|---|---|---|---|
| 40 | F | 53.30 | 3.17 | 168 |
| 41 | F | 64.50 | 3.46 | 223 |
| 46 | F | 104.00 | 3.54 | 368 |
| 54 | D | 42.70 | 4.65 | 198 |
| 74 | B | 72.50 | 2.99 | 217 |
| 75 | B | 70.00 | 3.11 | 218 |
| AVERAGE | | 67.83 | 3.49 | 232 |

# Appendix D

## Total flow releases at Pleasant Valley Dam, Pre 1941, 1941 - 1971, and 1971 - 1990

Averages are provided for the time intervals 1935-1941 (pre-dates the first Mono aqueduct and Crowley Dam), 1941-1971 (post-dates first Mono aqueduct and Crowley Dam, pre-dates second Mono aqueduct), and 1971-1990 (post-dates second Mono aqueduct). Source: L.A.D.W.P., 1991.

| From: | To: | Release: (acre-feet) |
|---|---|---|
| 1989 | 1990 | 163802 |
| 1988 | 1989 | 213663 |
| 1987 | 1988 | 259903 |
| 1986 | 1987 | 366068 |
| 1985 | 1986 | 325200 |
| 1984 | 1985 | 351964 |
| 1983 | 1984 | 407569 |
| 1982 | 1983 | 401187 |
| 1981 | 1982 | 363132 |
| 1980 | 1981 | 375922 |
| 1979 | 1980 | 356063 |
| 1978 | 1979 | 370009 |
| 1977 | 1978 | 156687 |
| 1976 | 1977 | 288773 |
| 1975 | 1976 | 353715 |
| 1974 | 1975 | 332912 |
| 1973 | 1974 | 296065 |
| 1972 | 1973 | 303888 |
| 1971 | 1972 | 307411 |

1971-1990 (Both barrels of Mono Aqueduct)
Average = 315470.2 acre feet
= 315500 acre feet

| | | |
|---|---|---|
| 1970 | 1971 | 331272 |
| 1969 | 1970 | 383743 |
| 1968 | 1969 | 262746 |
| 1967 | 1968 | 291172 |
| 1966 | 1967 | 287652 |
| 1965 | 1966 | 238915 |
| 1964 | 1965 | 254408 |
| 1963 | 1964 | 297695 |
| 1962 | 1963 | 262677 |
| 1961 | 1962 | 189627 |
| 1960 | 1961 | 203081 |
| 1959 | 1960 | 287173 |
| 1958 | 1959 | 249673 |
| 1957 | 1958 | 261940 |
| 1956 | 1957 | 293547 |
| 1955 | 1956 | 237535 |
| 1954 | 1955 | 288241 |
| 1953 | 1954 | 258097 |
| 1952 | 1953 | 261252 |
| 1951 | 1952 | 265540 |
| 1950 | 1951 | 250073 |
| 1949 | 1950 | 241380 |
| 1948 | 1949 | 193830 |
| 1947 | 1948 | 269490 |

1941-1971 (Single barrel of Mono Aqueduct)
Average = 257178 acre feet
= 257200 acre feet

(continued)

| | | | | |
|---|---|---|---|---|
| 1946 | 1947 | 255457 | | |
| 1945 | 1946 | 225325 | | |
| 1944 | 1945 | 231972 | | |
| 1943 | 1944 | 238379 | | |
| 1942 | 1943 | 229432 | | |
| 1941 | 1942 | 174016 | Crowley Dam completed | |
| 1940 | 1941 | 202162 | 1935-1941 | |
| 1939 | 1940 | 161893 | Average= | 217419.5 |
| 1938 | 1939 | 343621 | | |
| 1937 | 1938 | 224109 | | |
| 1936 | 1937 | 198809 | | |
| 1935 | 1936 | 173923 | | |

# Appendix E

## Cumulative frequency curves for full area and bar clast counts, sampled by Balance Hydrologics Inc., May 1991

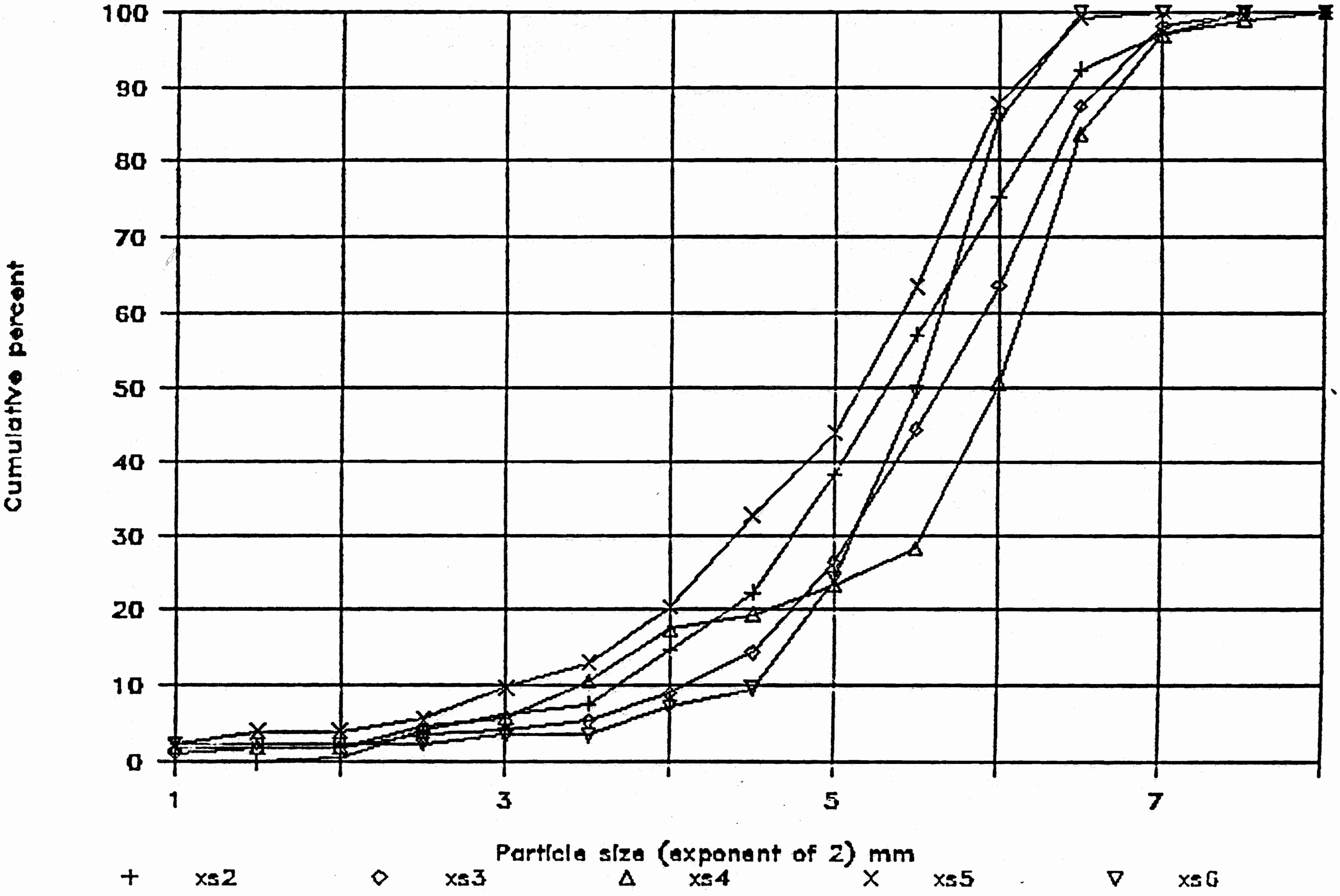
Symbols on curves refer to cross section locations where
sample taken (xs1, xs2, etc.).

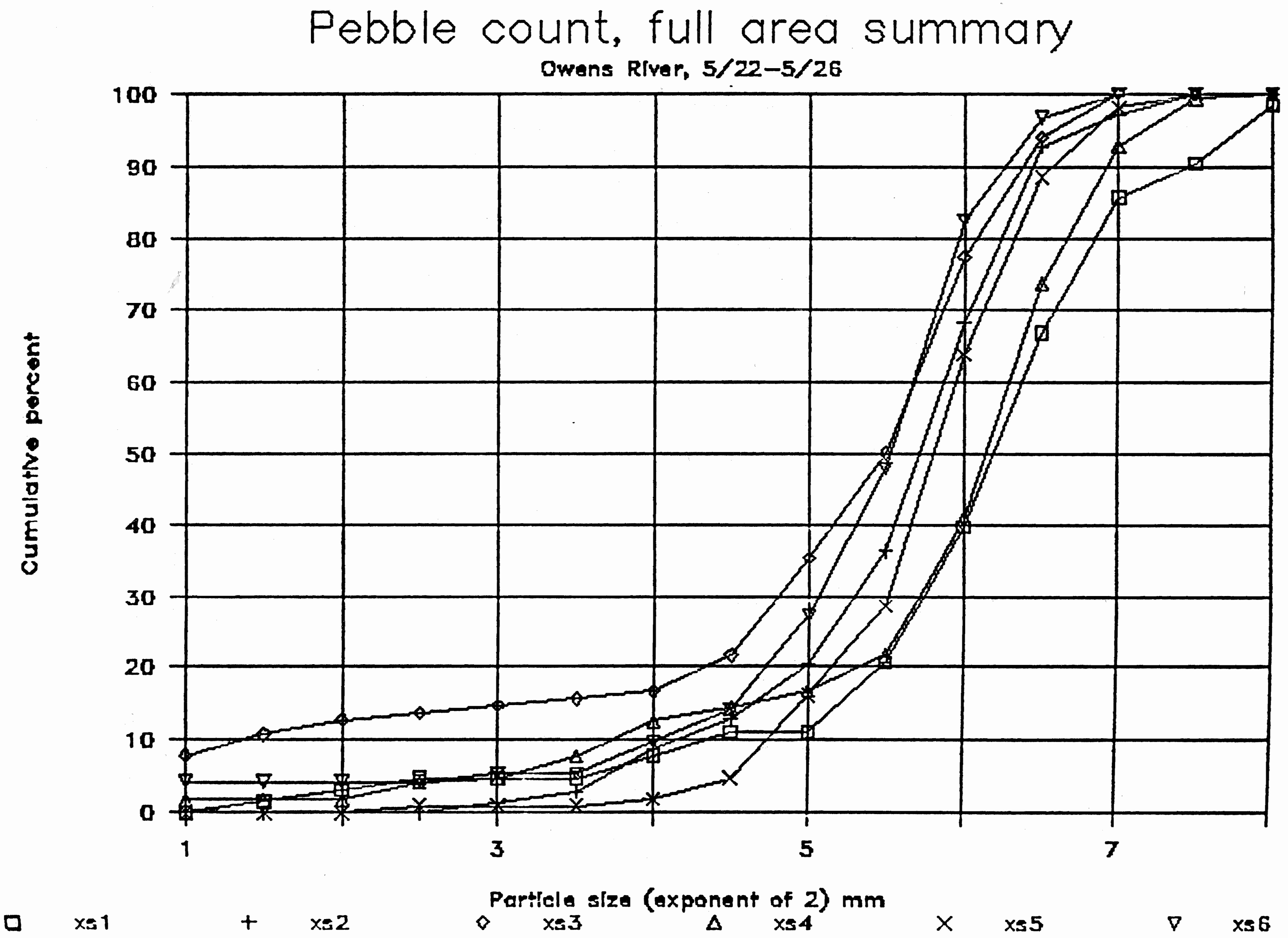
Note: Exponents of 2 on size axis corresponds to:

2 = 4 mm.
3 = 8 mm.
4 = 16 mm.
5 = 32 mm.
6 = 64 mm.
7 = 128 mm.
8 = 256 mm.

Pebble count, bar count summary

Owens River, 5/22–5/26




Pebble count, full area summary
Owens River, 5/22–5/26
Cumulative percent
0
10
20
30
40
50
60
70
80
90
100
1
3
5
7
Particle size (exponent of 2) mm
□ xs1
+ xs2
◇ xs3
△ xs4
× xs5
▽ xs6

## Appendix F

## Summary of lithologic composition of bed material for Sections 1 through 6

3c is a sample of a paleobar in the bank at cross section 3. 6ds and 6us refer to a downstream and an upstream sample taken near cross section 6.

LITHOLOGY SUMMARY

| | | Granite | Tuff | Basalt | Meta | Carbonate | ? |
|---|---|---|---|---|---|---|---|
| Section 1 | Whole sample % | 54 | 44 | 2 | 0 | 0 | 0 |
| | 23-90 mm. fraction | 55 | 45 | 0 | 0 | 0 | 0 |
| Section 2 | Whole sample % | 64 | 30 | 1 | 1 | 3 | 0 |
| | 23-90 mm. fraction | 69 | 26 | 0 | 2 | 3 | 0 |
| Section 3b | Whole sample % | 65 | 31 | 2 | 3 | 0 | 0 |
| | 23-90 mm. fraction | 67 | 28 | 2 | 3 | 0 | 0 |
| Section 3c | Whole sample % | 56 | 42 | 3 | 0 | 0 | 0 |
| | 23-90 mm. fraction | 64 | 32 | 5 | 0 | 0 | 0 |
| Section 4 | Whole sample % | 78 | 22 | 0 | 0 | 0 | 0 |
| | 23-90 mm. fraction | 78 | 22 | 0 | 0 | 0 | 0 |
| Section 5 | Whole sample % | 63 | 30 | 0 | 2 | 0 | 5 |
| | 23-90 mm. fraction | 64 | 31 | 0 | 2 | 0 | 3 |
| Section 6ds | Whole sample % | 73 | 21 | 0 | 2 | 0 | 4 |
| | 23-90 mm. fraction | 77 | 20 | 0 | 3 | 0 | 0 |
| Section 6us | Whole sample % | 76 | 16 | 4 | 0 | 2 | 2 |
| | 23-90 mm. fraction | 80 | 13 | 4 | 0 | 3 | 0 |

# Appendix G

## Results of bedload and suspended load analyses, Wild Trout Reach, Owens River, California

Our sample identification numbers provide information as to cross section, date and time of sampling as follows:

First digit: Cross section I.D. number (1-6)
Next six digits: Year, month, and day of sampling
Last four digits: Time of sampling (24-hour clock)

| BED LOAD | | | | |
|---|---|---|---|---|
| SECTION | SAMPLE NUMBER | BEDLOAD TRANSPORT RATE (TONS/DAY) | BEDLOAD TRANSPORT RATE (TONS/YEAR) | D50 (mm.) |
| 1 | 19105241025 | 0.001 | 0.299 | 0.315 |
| | 19105250930 | 0.008 | 2.738 | 0.300 |
| 2 | 29105221030 | 0.007 | 2.482 | 0.297 |
| | 29105241400 | 0.008 | 3.025 | 0.310 |
| | 29105251005 | 0.004 | 1.333 | 0.331 |
| 3 | 39105231409 | 0.091 | 33.102 | 0.347 |
| | 39105251045 | 0.004 | 1.630 | 0.310 |
| 4 | 49105241715 | 0.013 | 4.600 | 0.318 |
| | 49105251120 | 0.038 | 13.792 | 0.173 |
| 5 | 59105221550 | 0.000 | 0.070 | NA |
| | 59105241855 | 0.000 | 0.045 | NA |
| | 59105251155 | 0.001 | 0.207 | 0.297 |
| 6 | 69105242015 | 0.043 | 15.674 | 0.153 |
| | 69105251430 | 0.006 | 2.017 | 0.302 |

| SUSPENDED LOAD* | | | |
|---|---|---|---|
| SECTION | SAMPLE # | TOTAL SUSPENDED SEDIMENT (mg/l) | TOTAL SUSPENDED SEDIMENT (TONS/DAY) |
| 1 | 19105241041 | 8 | 4.86 |
| | 19105251935 | 3 | 1.82 |
| 2 | 29105220855 | 37 | 22.48 |
| | 29105241340 | 5 | 3.04 |
| | 29105251955 | 5 | 3.04 |
| 3 | 39105221330 | 7 | 4.25 |
| | 39105241815 | 7 | 4.25 |
| | 39105251035 | 6 | 3.65 |
| 4 | 49105241555 | 250** | 151.88 |
| | 49105251115 | 9 | 5.47 |
| 5 | 59105221420 | 10 | 6.08 |
| | 59105241630 | 10 | 6.08 |
| | 59105251140 | 12 | 7.29 |
| 6 | 69105242000 | 12 | 7.29 |
| | 69105251415 | 9 | 5.47 |

*Sample analyses performed by Soil Control Lab, Watsonville, CA 95076, by the whole-sample filtration method, using pre-washed 0.45 micron glass-fiber filters. Laboratory control number 90332-15-4205. Certified analytical report on fil

**Anomalously high result. Discarded from analyses, due to high probability of sample contamination during sample collection or analysis.

# Appendix H

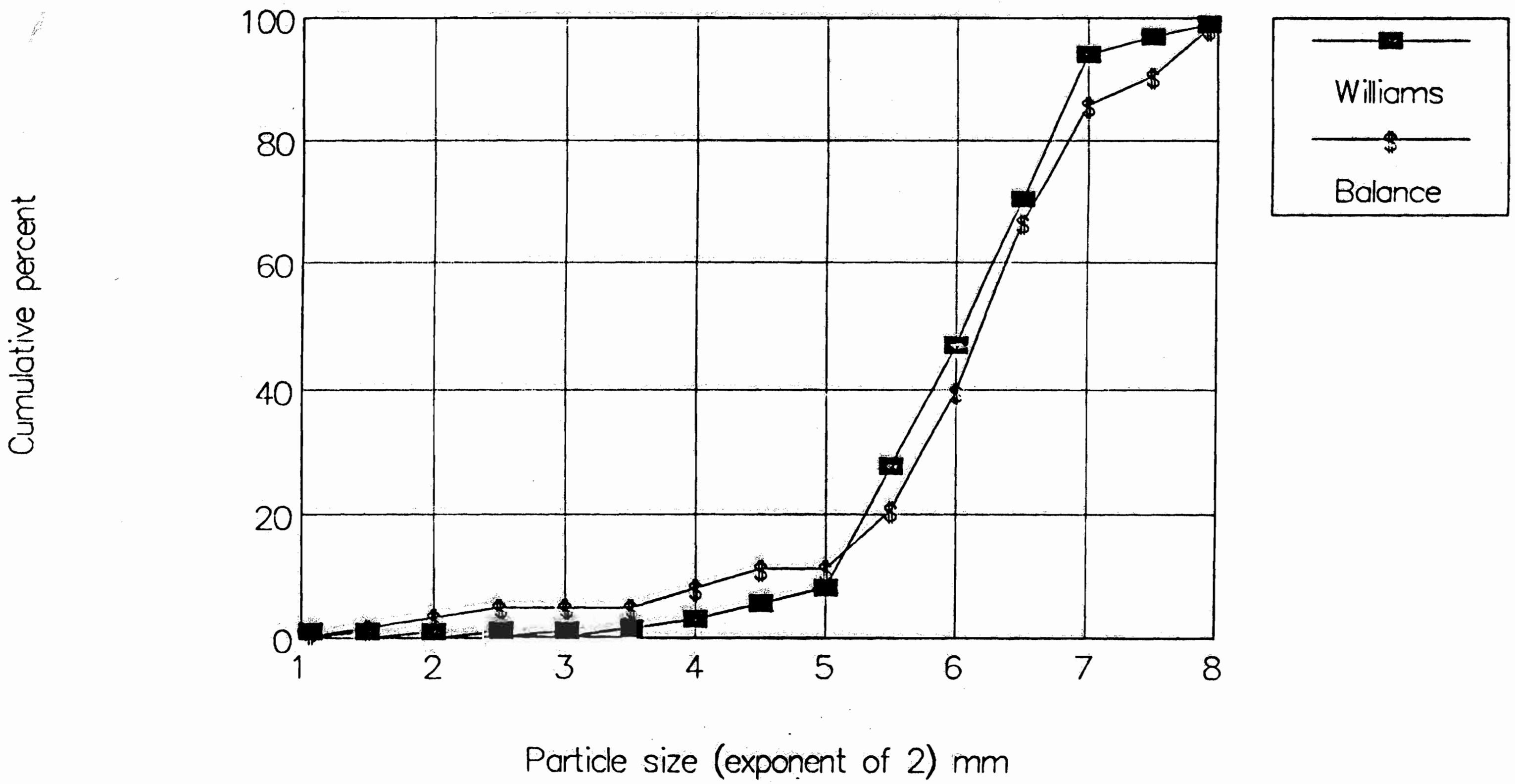
## Cumulative frequency distributions: comparisons between Williams (1975) and Balance (1991) data for whole bed counts

Note: Exponents of 2 on size axis corresponds to:

2 = 4 mm.
3 = 8 mm.
4 = 16 mm.
5 = 32 mm.
6 = 64 mm.
7 = 128 mm.
8 = 256 mm.

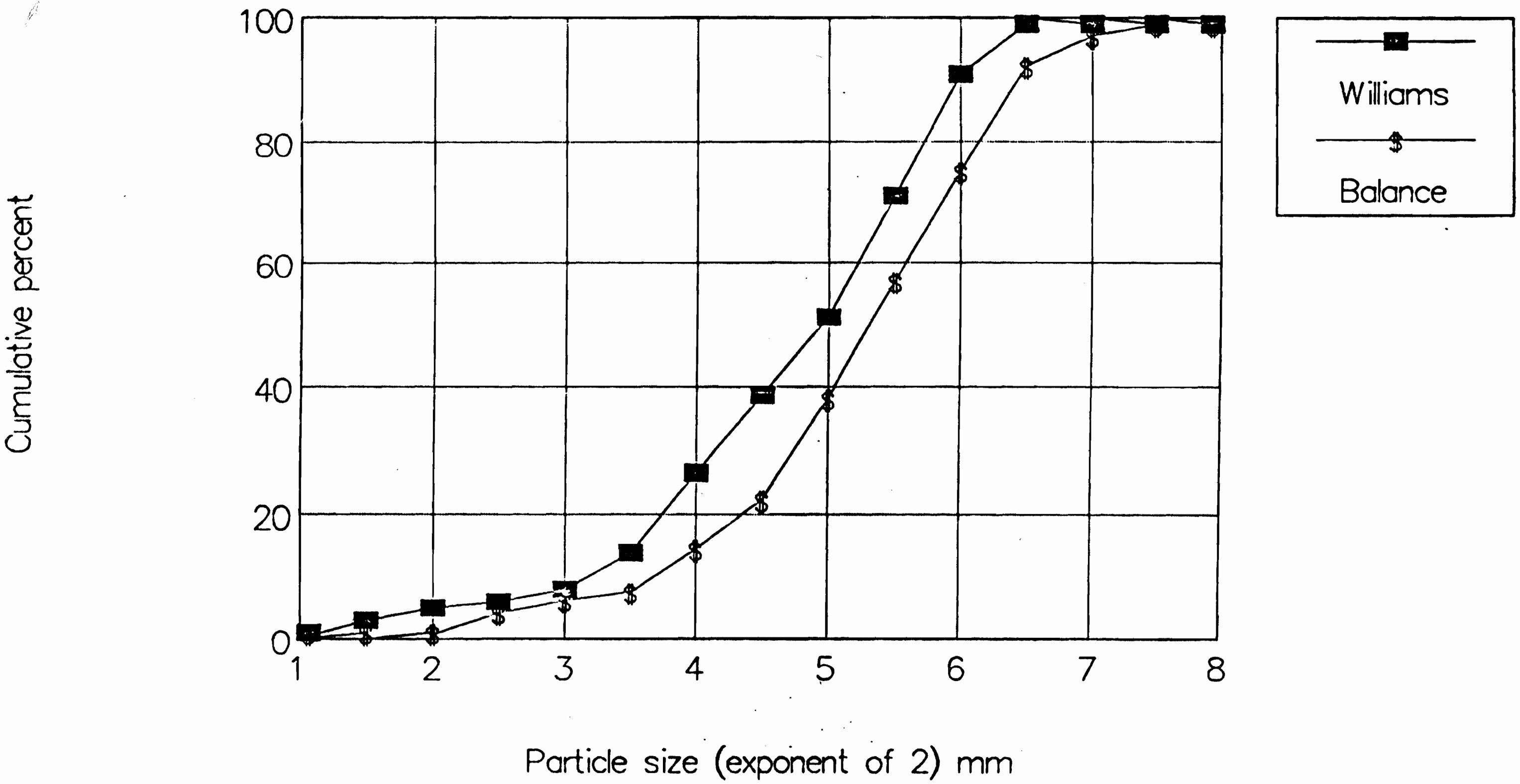
# Pebble count section 1 comparison

## Owens River



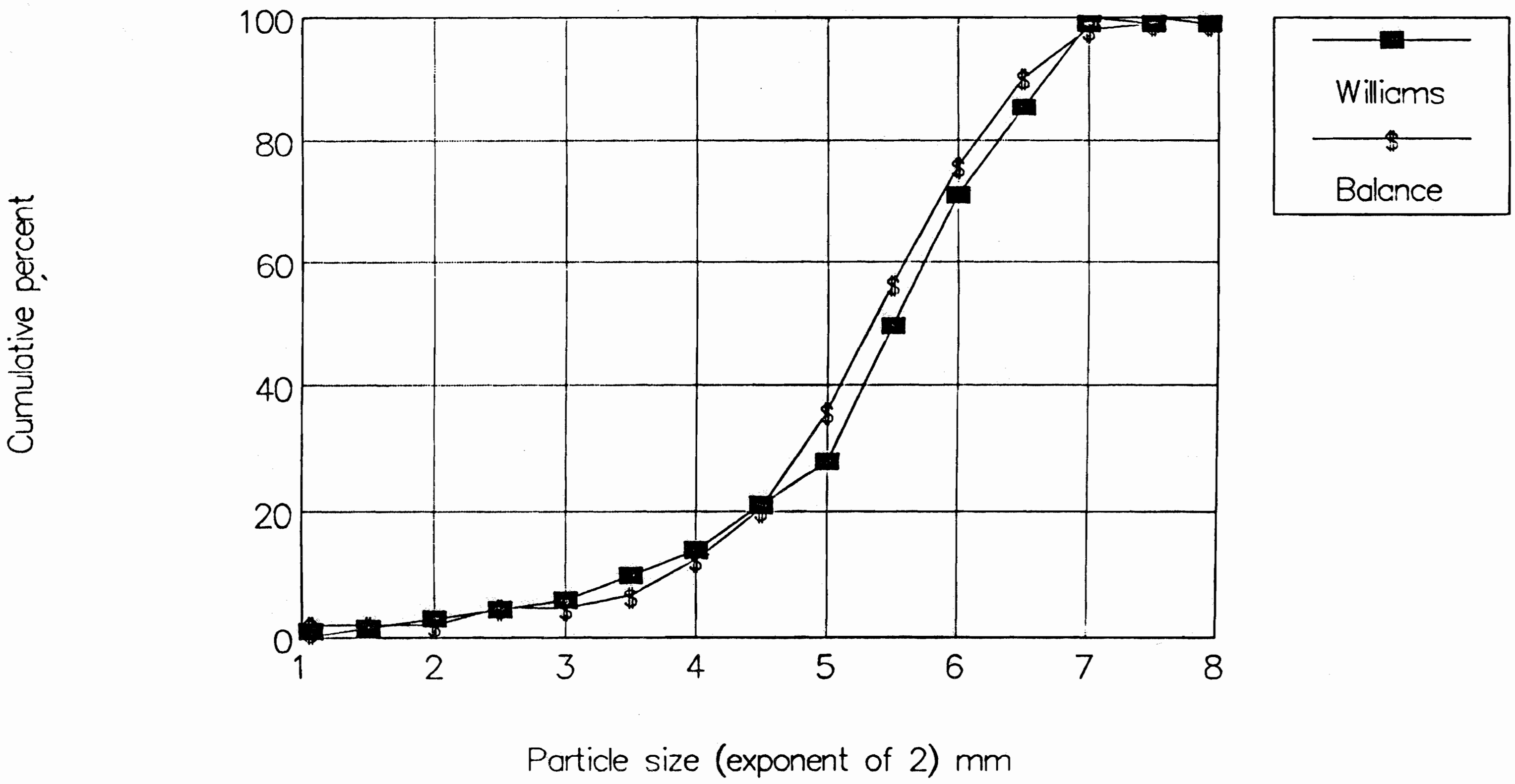
# Pebble count Section 2 Comparison

## Owens River

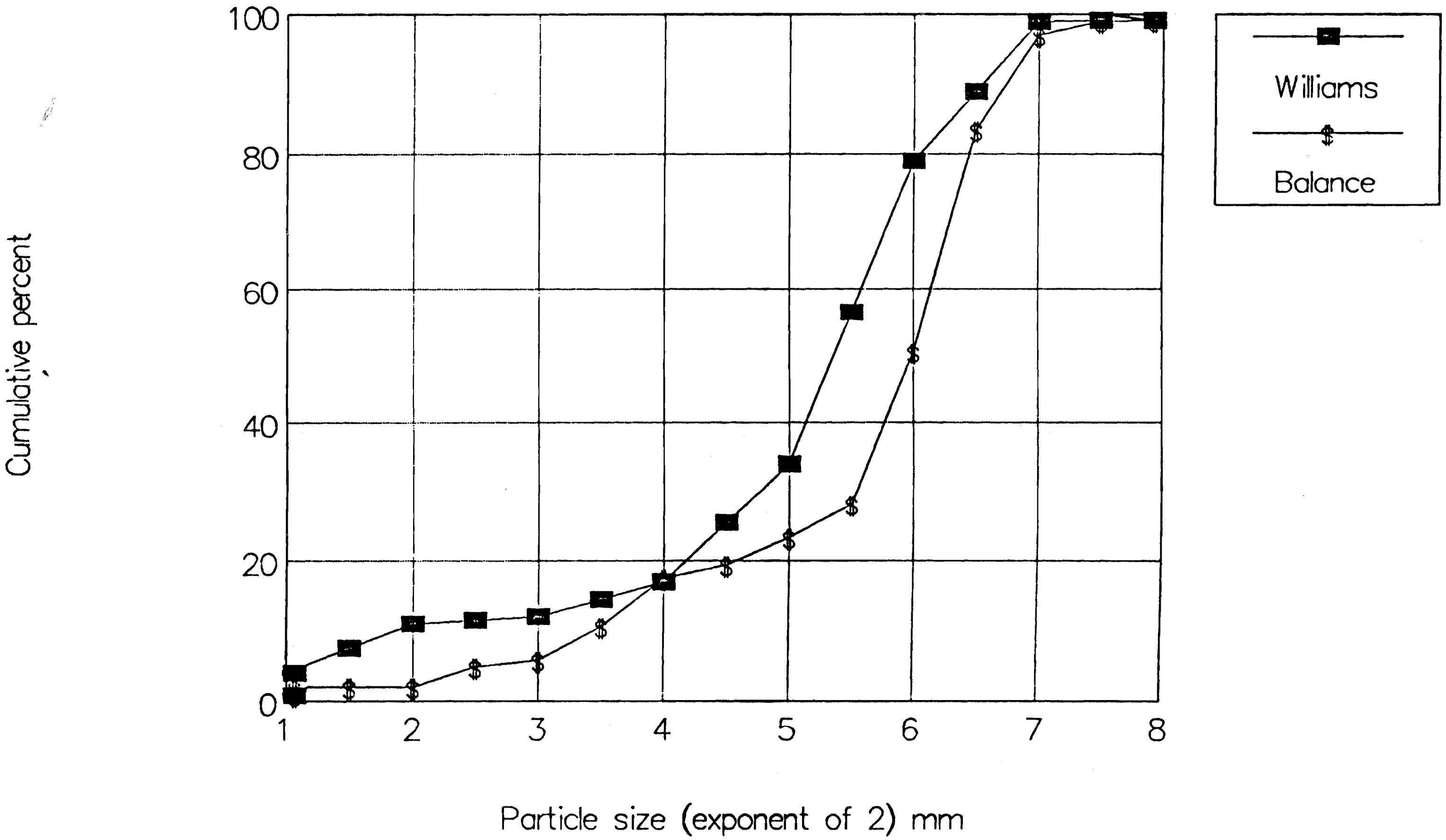


# Pebble count section 3 comparison

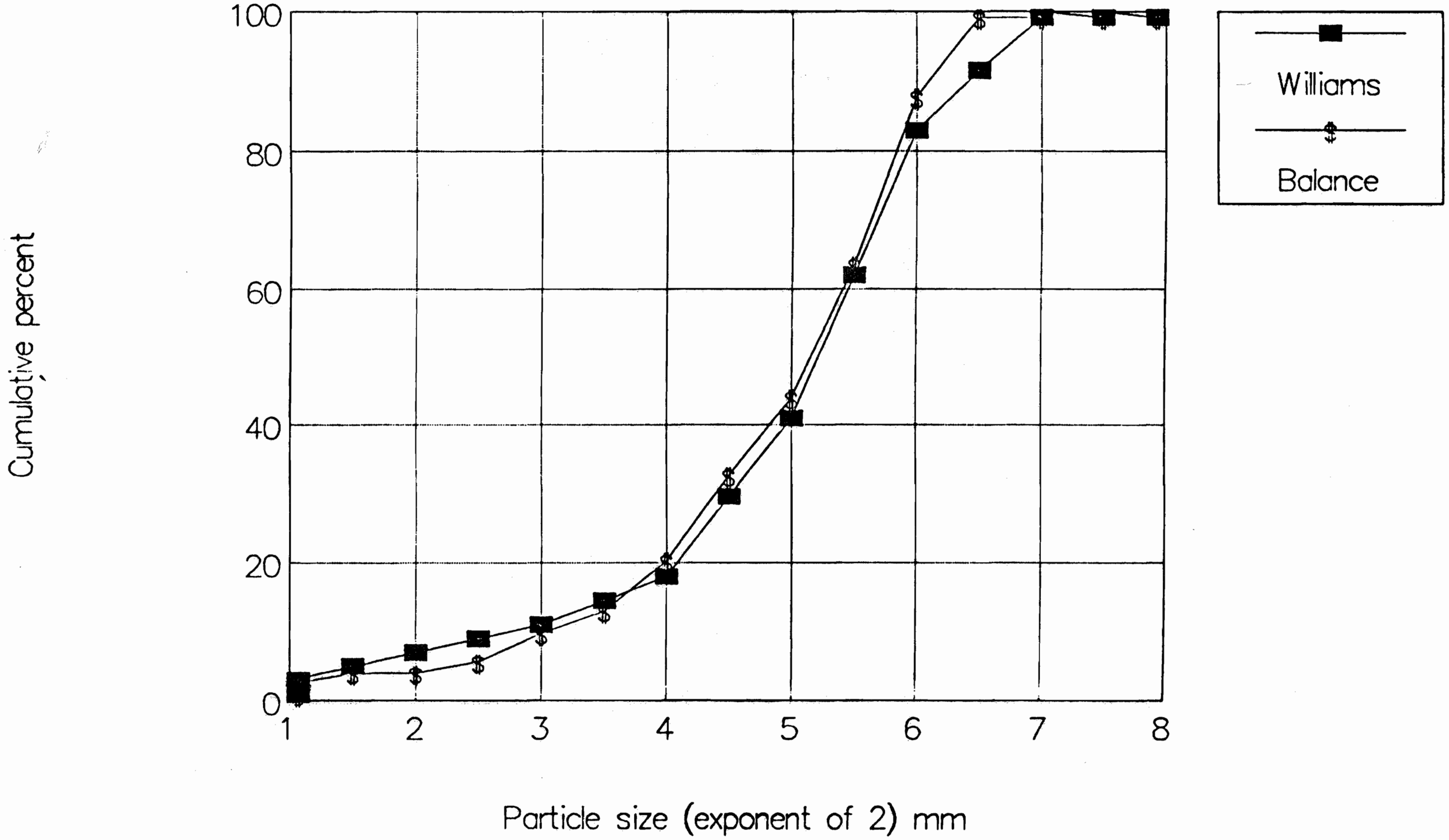
## Owens River



# Pebble count Section 4 Comparison

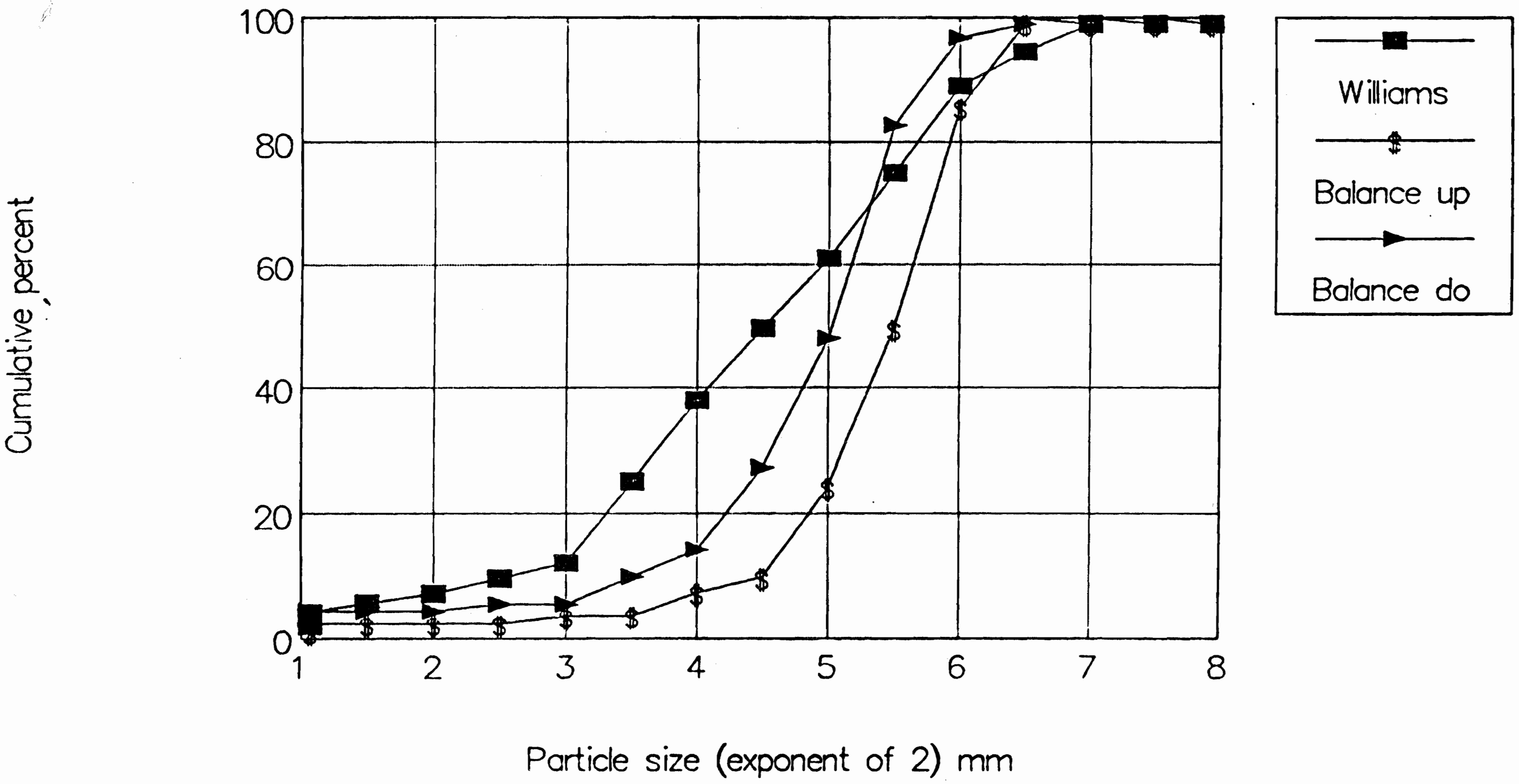


# Pebble count Section 5 Comparison



# Pebble count section 6 comparison

## Owens River



# Appendix I

## Reports of discussions with informed observers of the Wild Trout Reach

9076.3 Middle Owens River

# MEMO

To: File
From: Barry Hecht
Subject: Report of discussions with Darryl Wong and Alan Pickard, Department of Fish and Game
Date: May 27, 1991

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1. On May 23rd, Tom Hickson, Eric Larsen and I were able to meet in the field with Gary Smith, Alan Pickard, and Darryl Wong, of the Department of Fish and Game. Darryl has been the Associate Fisheries biologist responsible for most management-related issues in this reach of the Owens River since the late 1970's. Prior to assuming his present position in Bishop, Darryl avidly fished this reach of the river every chance he could get for 10 years or more. Alan has recently been transferred to the Bishop office, but began his government career there in 1972 and 1973 when Rhea Williams and Kevin Scott were conducting their geomorphic studies. Much of our conversation was in a car trip down Chalk Bluffs Road from the vicinity of our site to (about 2000 feet downstream of the campground) the eastern end of Chalk Bluffs Road.

2. We discussed changes to the stream upriver from station 2. Darryl reports that on at least one occasion beavers have colonized the south channel of the Owens River, within the campground area, markedly reducing the density of Willow and Cottonwood along the channel. During Darryl's tenure in Bishop, he recalls at least a couple of population spikes of beaver which affected the entire reach above Five Bridges and lasted for a year or so. He and we speculated that the beaver activity would result in some loss of habitat, but increase the diversity of habitat, introducing large areas of low velocities, not ordinarily present except at high-water when oxbows may be connected to the main channel.

Also, in recent years, the city has raised the berm at the entrance to the South Channel, to increase the flow into the spawning channel upstream. The South Channel now carries much less flow than before.

The first northside meander downstream of the campground was considered as a potential site for a second spawning channel in the past.

On two separate occasions, the county has riprapped major sections of eroding banks within the campground. The heaviest activity of this type has been in the vicinity of the footbridge at the lower end of the campground; however, a number of cutbanks throughout the campground, particularly in the upper end of the north channel were protected with large blocks of volcanic rock from the adjoining slopes. Installation involved removal of the riparian trees and shrubs, not all of which have grown back. At two or three locations, meander migration has continued, resulting in some of the larger boulders being isolated in mid-channel, and eventually undercut; these now form large plunge pools and locally direct the flow into the bank.

3. Near site 2, an attempt was made several years ago to restore riparian vegetation. An effort was made to cut willow wattles from one of the drier sites and from one of the willow species thought to be most tolerant to drought. Both wattles and rooted, cuttings were planted; the latter were protected from grazers with wire mesh. Several isolated trees remain, one of which is about 100 feet upstream of section 2. Lack of summer irrigation during the first season is thought to be a major reason that this program did not take.

4. We reviewed with Darryl and Alan and Gary Smith the boundaries of the various sub-reaches which are recognized in the DFG notes over the years. Generally, the boundaries coincide with major landmarks such as fence lines, section lines, or distinctive trees or large boulders which have fallen from the adjoining cliffs. These subreaches are each about one mile long, beginning from the upper campground bridge and ending at Five Bridges. They were established initially to pinpoint the results of creel censuses, but also may reflect subtle differences in both the character of the river and in adjoining land use which have been recognized by the DFG biologists over the years. Most subsequent DFG work on this reach has been referenced to these subreaches. We agreed to define our measurements by sub-reach to assist in location. Subreaches do not need to be recognized for overall channel morphology or IFIM work.

5. Prior channel habitat/geomorphology/physical factors work is practically nonexistant, with the exception of the U.S.G.S. study (Williams, 1975). At one point a thermograph was maintained along the river at, or very near, our site 5. A full year of data was collected. Other isolated observations and historical aerial photos might be obtained through John Deinstadt, now stationed at D.F.G.'s Rancho Cordova office; John, of course, is the great white eminence and scholar for this reach of the river, with service dating back into the early 1960's. Additionally, the fisheries biologist who served in the interim between John Dienstadt and Darryl Wong did make a number of channel cross-sectional measurements. These were apparently measured down from the water surface, even in riffles. The locations of these sections are not known, although Darryl has made some effort to find them. This biologist (Bob Brown?) is now deceased. No other records are known.

6. The single most dramatic change during Darryl's years on the stream is the major meander cutoff near the downstream end of subreach B. Darryl recalls this happening during the early eighties, during one of the very wet years, perhaps 1983. A second cutoff is developing in Section D, where we observed active flow through the cutoff. No other major changes are expressly known downstream from the campground.

7. Each of the four individuals with whom I spoke who have known the river for 10 years or more have noted the gradual disappearance of gradually undercut banks. The overhangs, deep pools with reverse flows, and varied water conditions which develop in the undercuts are highly valued by the brown trout. The biologists believe that perhaps the single most important geomorphic management goal is to restore the prevalence of these deep undercut banks.

8. All the senior DFG biologists we spoke with believe that the stream is becoming deeper, and possibly wider. One key line of evidence from their experience which supports this view is the abundance of wet ground or standing water through which they had to pass before reaching the stream from the north in the sixties and seventies. Knee boots were de rigueur during some seasons of the year. In recent memory, these overflows have not been occurring. Biologists also suspect that part of the demise of the undercuts is that the stream is getting

deeper, inhibiting water availability during the driest parts of each year, perhaps leading to the sparser, more scattered appearance of the grassland.

9. All three observers with whom we spoke at this site indicated that the grasslands had been denser and lusher in previous years. They emphasized that grass, more so than woodland roots, provided the main support of the overhanging banks. Grazing, possibly less availability of water, and damage to the soil from especially intense scraping near the channels when the riparian woodland was cleared, are all thought to be factors which contribute to less lush grass. The remains of the piles of riparian brush that were cleared are now prominent along some streambanks--particularly the north one.

10. During the early 1980's, Fish and Game staff noted what appeared to be a general and long-term decline in both angler success and in their qualitative and quantitative measurements. Productivity is now higher at levels not greatly different from the historic norms. Both the amount of periphyton and the density of aquatic invertebrates seem to have increased in recent years. Darryl suspects that both the fish and benthic populations have benefitted from the lower flows which have prevailed for the last 5 or 8 years; sustained high flows of the early 1980's may have harmed the overall habitat quality. He raised this speculation and noted it as such, largely to identify velocity distributions as an item we should consider; in general the more diverse the velocity distributions, the stronger the fishery is likely to be on this segment of the Owens, he suspects.

11. Darryl noted that tree and brush clearing activity along this reach of the river was especially aggressive during the 1950's and early 1960's. We should contact John Dienstadt who may know more. Both Darryl and Alan noted that it is their belief that 2,4-D was heavily applied in at least one year for brush and broadleaf control, to provide better pasturage and improved access. Alan noted that it was his impression that there had been some increase in growth of brush along the river, but that all the individual spots where he worked in conjunction with USGS were originally free of brush or woodland and remain so.