BEFORE THE COLORADO WATER CONSERVATION BOARD

STATE OF COLORADO

IN THE MATTER OF PROPOSED INSTREAM FLOW APPROPRATION IN WATER DIVISION 4: SAN MIGUEL RIVER (confluence Calamity Draw to confluence Dolores River)

PREHEARING STATEMENT OF WESTERN RESOURCE ADVOCATES AND THE WILDERNESS SOCIETY

Pursuant to the June 1, 2011, Notice of Prehearing Conference & Deadlines for Submission, and Rule 5n(2) of the Rules Concerning Instream Flow and Natural Lake Level Program, 2 CCR 408-2 ("ISF Rules"), Western Resource Advocates ("WRA"), and The Wilderness Society ("TWS") (collectively, "Conservation Groups"), by and through it undersigned counsel, submit the following Prehearing Statement in support of the Staff ISF Recommendation on the San Miguel River, Water Division No. 4. *See* Notice of Contested 2011 ISF Appropriations (May 26, 2010), before the Colorado Water Conservation Board ("CWCB" or "Board").

I. Factual and Legal Claims

The Conservation Groups support the Staff ISF Recommendation and Board intent to appropriate an in-stream flow water right for the San Miguel River. We urge the Board to ensure protection of the environment—including special status native fish and riparian communities in the San Miguel—by increasing the flow recommendation to the flow levels prescribed in the Woodling Memo, *attached as* Exh. 1, or in the alternative, approving the Staff ISF Recommendation.

Based upon expert biological analysis by John Woodling, Ph.D., the Conservation Groups recommend that the Board increase the proposed ISF appropriation as follows:

1. A flow of 500 cfs from April 15 through June 14,

2. A flow of 170 cfs from June 15 through July 31,

3. A flow of 115 cfs from August 1 through April 14.

According to Woodling, this flow regime is more consistent with the habitat needs of the the Flannelmouth Sucker, Bluehead Sucker, and Roundtail Chub (collectively, the "Three Species"). *Id.*

This Staff ISF Recommendation on the San Miguel River, approved by the Board in January 2011, recognizes the urgent need to protect habitat for the Flannelmouth Sucker, Bluehead Sucker, and Roundtail Chub. State wildlife agencies in six western states, including Colorado Division of Wildlife ("CDOW"), as well as the Bureau of Land Management ("BLM"), National Park Service ("NPS"), and the Jicarilla Apache Tribe signed the Range-wide Conservation Agreement and Strategy for Roundtail Chub, Bluehead Sucker, and Flannelmouth Sucker ("Conservation Agreement") (Sept. 2006). Attached to the CDOW-BLM Stakeholder recommendation at 24[1]. The Conservation Agreement is intended to minimize threats that could lead to listing of these fish species under the Endangered Species Act, 16 U.S.C. §§ 1531-1544. CDOW-BLM Stakeholder recommendation at 24.

The Conservation Agreement details the decline in habitat for the Flannelmouth Sucker, Bluehead Sucker, and Roundtail Chub over the last fifty years. "Available literature suggests that the three species were common to all parts of the [Colorado River Basin] until the 1960s." *Id.* at 60. However, now the three species occupy approximately 50% or less of their historic habitat in the Colorado River Basin. *Id.* at 62-63; *see also* Woodling at 3.

The Conservation Agreement emphasizes the importance of physical habitat characteristics, including flows, to the survival of the Three Species:

> Habitat is an important component of metapopulation and species survival. Loss of available habitat may lead to the loss of individuals or populations that in turn may cause loss of metapopulation dynamics. Important physical habitat characteristics may include (but are not limited to) substrate, instream habitat complexity, and flow regimes.

CDOW-BLM Stakeholder recommendation at 50. The Conservation Agreement further suggests the use of instream flow programs to protect habitat for the Three Species. *Id.* Finally, the Conservation Agreement suggests that signatories "[p]rovide flows needed for all life stages of the subject species." *Id.* at 67.

The Woodling Memo emphasizes the importance of deeper water to the Three Species. Woodling notes that the Three Species "are more likely to be captured in the deepest part of the river or stream where the appropriate habitat is being sampled." Woodling at 4. Shallow water "does not result in elimination of these two native suckers and the roundtail chub but does result in the presence of smaller fish." *Id.* Woodling notes that for bluehead suckers in particular, average depths of one foot are considered "marginally suitable" in the riffle area habitats preferred by the bluehead sucker.

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[1] For ease of reference, page citations for the CDOW-BLM Stakeholder recommendation refer to the "PDF" page number of the electronic file posted on the CWCB 2011 Contested ISF Appropriation webpage, http://cwcb.state.co.us/environment/instream-flow-program/Pages/2011ContestedAppropriations.aspx.

Average depths of one foot in riffle areas assures that deeper water will be present in the run and pool areas preferred by flannelmouth sucker and the roundtail chub. *Id.* at 5.

Protecting flows in the San Miguel could be a linchpin for the larger river system. The record indicates that populations of roundtail chub in the Dolores River above the confluence with the San Miguel may be impacted by low and inconsistent flow regimes. According to CDOW's June 2003 Riverine Flow Investigations, The Dolores River at Big Gypsum:

> had the highest composition of roundtail chub of all sites and the highest composition of native fish in general. However, there was instability in species composition between years at Big Gypsum. This instability was probably related to the much different flow conditions between years, with lower flows in 2001. Even though native fish composition was high at the Big Gypsum site, other fishery factors indicate that the habitat conditions at this site were severely degraded.

Id. at 508-09. CDOW noted that habitat availability, rather than predation by invasive species, was most likely to blame for a lack of large roundtail chub in the Dolores:

> In the Dolores River, small fish (<15 cm) were abundant, but large fish (> 25 cm) were very rare. The Dolores does not have obvious predation impacts. The channel catfish was the only non-native predator species and typically small sized fish disappeared by predation. **<u>The lack of large fish was likely a function of a lack of habitat</u>**.

Id. at 514 (emphasis added).

In another document, CDOW aquatic biologist Dan Kowalski emphasized the importance of the San Miguel to native fish in the Dolores River, stating, "[t]he Dolores River upstream from the confluence [with the San Miguel] has been impacted by low base flows and the San Miguel could be acting as a refuge for suckers in the lower river." *Id.* at 92. Kowalski's findings suggest that habitat provided by the claimed reach of the San Miguel may be import to at least some populations of native fish species in the Dolores, as well as the San Miguel. *See also* Woodling at 9. Thus, this proposed ISF could play an important role in ensuring that the Three Species are not listed under the Endangered Species Act.

A. <u>There is a natural environment in the claimed reach that can be preserved to a reasonable degree by the Staff ISF Recommendation.</u>

The Colorado Division of Wildlife ("CDOW") and the Bureau of Land Management ("BLM") placed ample data into the record that clearly establish (1) the existence of an important natural environment in the claimed reach of the San Miguel River, and (2) that the Staff ISF Recommendation will help preserve the natural environment to a reasonable degree. A 2008 CDOW fish survey of the San Miguel from

Uravan to the Dolores confluence found that 78% of its catch was native fish species, including 155 Flannelmouth Suckers, 140 Bluehead Suckers, and 19 Roundtail Chub. Based upon this survey, CDOW aquatic biologist Dan Kowalski concluded:

> The lower San Miguel River contains and excellent native fish community and should continue to managed as a category 100 native fish conservation water. Efforts should be taken to protect the flow regime of this reach of river including spring peak flows and especially base flows. Major tributaries like Tabeguache Creek and Atkinson Creek that could be used seasonally for spawning should also be protected. The San Miguel River has a relatively natural hydrograph as far as spring peak flows but is impacted by water diversions in the late summer severely reducing base flows (Figures 4 and 5). Of special concern is the late summer period from about mid August to October when base flows in the upper basin average around 100 cfs at Placerville **but routinely drop to near 50 cfs at Uravan. The decreased instream flows in late summer not only degrade the quality and quantity of native fish habitat but provide conditions more favorable to non-native fish like channel catfish and smallmouth bass**. The Dolores River upstream from the confluence has been impacted by low base flows and the San Miguel could be acting as a refuge for suckers in the lower river. Management efforts should also be taken to prevent the further introduction of nonnative fish and to minimize the numbers and spread of channel catfish and smallmouth bass in the river.

Attached to the CDOW-BLM Stakeholder recommendation at 92 (emphasis added). Kowalski's analysis emphasizes the importance of base flows to the native fish species that depend upon the San Miguel River.

Portions of the claimed reach, particularly those above Uravan, also provide habitat for high-value riparian plant communities. Colorado State University's Colorado National Heritage Program ranked parts of the claimed reach as having "Very High Biodiversity Significance" and stated that:

> This site contains an excellent (A-ranked) occurrence of a plant community which is imperiled globally (G2). In addition to the critically imperiled New Mexico privet riparian shrubland community, there are over 20 other targeted riparian communities within the site, including riparian forests dominated by both narrowleaf and Fremont cottonwoods (and their hybrids), and montane riparian shrublands dominated by river birch, skunkbrush, coyote willow or silver buffaloberry. There are several occurrences of rare plants; Payson lupine and San Rafael milkvetch. The rare plant populations have not been updated in recent years.

Attached to the CDOW-BLM Stakeholder recommendation at 84.

The contesting parties appear to agree that the claimed reach has a natural environment and that the Staff ISF Recommendation will help preserve the natural environment in the claimed reach. The GEI Memo attached to Montrose County's Notice to Contest acknowledges CDOW data showing that there is an aquatic environment in the claimed reach that can be preserved. GEI Memo at 1-2. GEI further acknowledges that the Staff ISF Recommendation will help preserve the aquatic environment in the claimed reach, even if GEI claims that a lower volume of water will preserve the natural environment to a reasonable degree. *Id.* Similarly, Farmer's Water Development Company ("FWDC"), in its "Notice of Contest" contests the amount that will preserve the natural environment to a reasonable degree, but appears to agree that there is a natural environment to preserve and that the Staff ISF Recommendation will help preserve it.

However, the contesting parties erroneously assert that the Staff ISF Recommendation is in excess of the amount of water that will preserve the natural environment to a reasonable degree. Importantly, Woodling notes that while the Staff ISF Recommendation was developed using "[t]echnically sound methods," the Staff ISF Recommendation is "not based solely on the biological needs of the native sucker species . . . ." Instead, the agencies adjusted the flow recommendation downwards to address considerations of water availability. Woodling at 5-6. Woodling finds that the Staff ISF Recommendation is less than the 500 c.f.s. peak that is "appropriate to protect bluehead sucker habitat" and less than the 115 c.f.s. base flow that is "adequate to protect . . . bluehead sucker habitat from September through February." *Id.* at 6. Woodling concludes that future reductions in flows allowed by the Staff ISF Recommendation "may well result in negative impacts to the Three Species compared to existing population dynamics." *Id.*

According to Woodling, GEI's "Alternative Flow Recommendations" would result in mean riffle base flows that create approximately half the water depth that is "marginally suitable" for bluehead suckers for a period of seven and a half months a year. Woodling at 7. Furthermore, Woodling notes that GEI's characterization of 20% of optimum habitat for bluehead suckers as "appropriate" is unsupported. *Id.* According to Woodling, low base flows may be an environmental "bottleneck" that may constrain populations of the Three Species in the San Miguel River. *Id.* at 7-8.

Woodling concludes that GEI's suggestion that higher spring flows may adversely affect younger life stages of west slope native suckers is "not correct." Woodling cites studies examining the relationship between flows and sucker reproduction and concludes that "[h]igh spring and summer snowmelt events enhance reproductive success in bluehead suckers and flannelmouth suckers." Woodling concludes that higher spring flows are needed for reproduction, even if they are not in themselves "optimum" habitat. *Id.* at 8.

Assertions that the hydrology of the San Miguel River justifies a lower flow recommendation appear similarly unfounded. FWDC misplaces its reliance upon the

Bikis[2] report in alleging that "the proposed flows are too high." WRA hydrologist Laura Belanger, P.E., found numerous flaws in the November 2009 Bikis analysis. First, Belanger found that Bikis' claim that only 68 c.f.s. is needed at Calamity Draw to create an 80 c.f.s. flow "anywhere in the reach" is unfounded. She notes,

> Calamity Draw *is* the upper terminus of the ISF reach. . . . For there to be 80 cfs "anywhere in the reach" – including the river at and immediately below Calamity Draw - there needs to be 80 cfs at Calamity Draw not 68 cfs as the Bikis Report states.

Belanger Memo at 1-2 (emphasis in original), *attached as* Exh. 2.

Belanger also questions Bikis' conclusion that the claimed reach of the San Miguel gains water from the groundwater. Belanger cites prior scientific studies (Cooper & Arp, 1999; Cooper & Conovitz, 2001) concluding that the San Miguel loses water to the groundwater in most reaches. Belanger at 2. Belanger further notes that the likely source of the gains in flows cited by Bikis is not groundwater, but rather irrigation return flows that mostly occur in September and October and are not evenly distributed through the winter months. *Id.*

Therefore the Staff ISF Recommendation is foundational to preserving the natural environment in the San Miguel River to a reasonable degree and does not reserve a higher flow than is needed to preserve the natural environment to a reasonable degree. The parties appear to agree that there is a natural environment that can be preserved by the Staff ISF Recommendation. Thus, the Board should find that there is a natural environment in the claimed reach that can be preserved to a reasonable degree by the Staff ISF Recommendation.

B. The natural environment in the claimed reach will be preserved to a reasonable degree by the water available for this ISF Appropriation.

As discussed above, Woodling' s proposed flow regime will do more to protect existing populations of the Three Species in the claimed reach of the San Miguel River. However, the Staff ISF Recommendation will help preserve the natural environment to a reasonable degree.

CDOW and BLM analyzed historic USGS gage data at Uravan and concluded that the Staff ISF Recommendation is physically available at least 50% of the time. CDOW-BLM Stakeholder recommendation at 11. Furthermore, CWCB Staff's representation of the Geometric Mean Daily Q shows that flows fall near or below the Staff ISF Recommendation in late fall and winter months. CWCB Staff Executive Summary at 10.

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[2] FWDC cites an April 2009 version of Bikis, of which WRA does not have possession. However, CWCB provided a November 2009 version of the Bikis analysis that is the subject of the Belanger Memo.

Belanger notes that although, on average, excess flows are not available year round, there are substantial average excess flows above the Staff ISF Recommendation. Belanger calculates that there is an average of 167,183 AF/yr of excess flows physically available above the Staff ISF Recommendation. Belanger at 3. Indeed, Belanger's Figure 1 illustrates that there are annual excess flows at or above 50,000 AF/yr in about 85% of all years. *Id.* at 4. Therefore, water is physically available for the Staff ISF Recommendation.

C. Such environment can exist without material injury to water rights.

The Conservation Groups incorporate by reference legal briefing on this issue by the State Attorney General's Office and Sheep Mountain Alliance.

D. This ISF Appropriation is consistent with present uses or exchanges of water being made by other water users pursuant to appropriation practices in existence on the date of such appropriation, whether or not previously confirmed by court order or decree.

Pursuant to C.R.S. section 37-92-102(3)(b), all ISF appropriations "shall be subject to the present uses or exchanges of water being made by other water users pursuant to appropriation or practices in existence on the date of such appropriation, whether or not previously confirmed by court order or decree." If a person establishes a documented and verified "present use or exchange of water" within the meaning of C.R.S. section 37-92-102(3)(b), then, as a matter of law, such use is entitled to protection against injury by this ISF application.

The Conservation Groups support CWCB Staff's proposed language under C.R.S. section 37-92-102(3)(b) (sent in a July 5, 2011 email from Linda Bassi to the parties entitled "Proposed Language for San Miguel River ISF appropriation" (hereinafter "Bassi email")). The Conservation Groups agree that any such uses should be adequately documented and verified within six months of the filing of the water court application as proposed in the Bassi email.

E. This ISF Appropriation is consistent with the beneficial use of the water of the people of the State of Colorado under law and interstate compact.

The Staff ISF Recommendation advances the beneficial use of the water of the people of the State of Colorado. Under C.R.S. § 37-92-103(4), "beneficial use" includes "the appropriation by the state of Colorado in the manner prescribed by law of such minimum flows between specific points or levels for and on natural streams and lakes as are required to preserve the natural environment to a reasonable degree." As described in Section I, Part A above, the Staff ISF Recommendation will help preserve the natural environment of the San Miguel River to a reasonable degree. Therefore, the Staff ISF Recommendation is consistent with – and advances – the beneficial use of the water of the people of the State of Colorado.

Furthermore, the Staff ISF Recommendation leaves ample water that is physically available for other beneficial uses in the San Miguel River. Belanger calculates that there is on average 167,183 AF/yr of excess flows physically available beyond the Staff ISF Recommendation. Belanger at 3.

In addition to these points, the Conservation Groups incorporate by reference legal briefing on this issue by the State Attorney General's Office and Sheep Mountain Alliance.

F. Other Legal Issues to be Decided.

Other legal issues that the Board should decide include:

a. Pending conditional water rights applications are not relevant under C.R.S. § 37-92-102(3) or Rule 5i of the ISF Rules.

b. Potential future changes of existing water rights are not relevant under C.R.S. § 37-92-102(3) or Rule 5i of the ISF Rules.

With respect to these issues, the Conservation Groups incorporate by reference legal briefing by the State Attorney General's Office and Sheep Mountain Alliance.

II. Exhibits, Reports, or Other Documents to be Introduced at Hearing

The Conservation Groups submit the following technical documents, attached to this prehearing statement:

A. Memorandum by Laura Belanger, P.E., Re: Evaluation of Bikis Water Consultants' "Evaluation of Technical Basis for Lower San Miguel River CWCB Instream Flow Recommendations" (July 12, 2011), *attached as* Exh 2.

B. Memorandum by John Woodling, Ph.D. Re: "The relationship of proposed instream flow regimes in the San Miguel River to native fishes" (July 13, 2011), *attached as* Exh 1.

The Conservation Groups anticipate providing legal argument at the hearing and reserve the right to submit legal memoranda in support of their position and for rebuttal purposes.

III. Witnesses

The following witnesses may testify at the hearing as described below, may give rebuttal testimony, and may be available at the hearing to answer questions from the Board:

A. Laura Belanger, P.E., Water Resources and Environmental Engineer for Western Resource Advocates (resume attached to the end of Exh. 2), may testify regarding physical water availability in the San Miguel River.

B. John Woodling, Ph.D., Contract Biologist (resume attached to the end of Exh. 1), may testify regarding the habitat needs of Flannelmouth Suckers, Bluehead Suckers, and Roundtail Chub.

IV. Written Testimony

The Conservation Groups are not submitting written testimony with this prehearing statement, but may submit written testimony with their rebuttal statement.

V. Conclusion

Wherefore, the Conservation Groups hereby request that the Board increase the flow recommendation to the flow levels prescribed in the Woodling Memo, or in the alternative, approve the Staff ISF Recommendation for the San Miguel River (confluence Calamity Draw to confluence Dolores River).

Respectfully submitted this 15th day of July, 2011.

/s Robert K. Harris___________________________
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CERTIFICATE OF SERVICE

I hereby certify that on July 15, 2011, the above **Prehearing Statement of Western Resource Advocates and The Wilderness Society** upon all parties herein by Federal Express, email, or depositing copies of the same in the U.S. mail, postage prepaid and addressed as follows:

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s/ Robert K. Harris____________________
Robert K. Harris
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E-filed per C.R.C.P. 121
Duly signed original on file at Western Resource Advocates

MEMORANDUM

TO: Western Resource Advocates and The Wilderness Society
FROM: John Woodling, Ph.D., Woodling Aquatics
DATE: 7/13/2011
SUBJ: The relationship of proposed instream flow regimes in the San Miguel River to native fishes

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Introduction

The Colorado Division of Parks and Wildlife (DPW) and the US Bureau of Land Management (BLM) have recommended an instream flow right in the claimed reach of the San Miguel River River to protect native fish species. Three of these native fish species the bluehead sucker (*Catostomus discobolus*), the flannelmouth sucker (*Catostomus latipinnis*) and the roundtail chub (*Gila robusta*) are the object of interstate efforts designed to halt the decline in range and numbers of the fish. I have worked with these three species since April 1974 when I did my first survey of the San Miguel River as a researcher for the Colorado Water Quality Control Division. I have sampled both the San Miguel River and these three species repeatedly from 1978 through 2003 as a fishery biologist with the Colorado Division of Wildlife. As a biologist for the Colorado Division of Wildlife I was fortunate to write a book about fish species not normally targeted by anglers titled "Colorado's Little Fish" that was published in 1982. This book included descriptions of over 40 fish species including life history information, range descriptions, habitat, etc., including the bluehead sucker, flannelmouth sucker and roundtail chub. I currently am altering a method of aging flannelmouth sucker fin rays as part of a college level Fishery biology course I will teach.

I believe the analysis and data generated by DPW/BLM in this matter are excellent and were done in a professional manner. However some of the flow recommendations of the DPW/BLM do not appear to be adequate to protect the native fish assemblage of the San Miguel River, specifically the proposed spring flow of 325 cfs and the late winter flow of 80 cfs. The alternate flow recommendations offered by Montrose County are not appropriate at all, partly because such flows would be deleterious to the reproduction of the bluehead sucker and flannelmouth sucker. In my opinion the DPW/BLM flow recommendations of 500 cfs for the San Miguel River as developed for the bluehead sucker in the spring time period and 115 cfs for the winter period are instream flows that should be adopted to protect the native fish assemblage in the claimed reach of the San Miguel River River. I recommend that instream flows be approved for the claimed reach of the San Miguel River River based on analyses performed by the DPW/BLM as follows,

1. A flow of 500 cfs from April 15 through June 14,
2. A flow of 170 cfs from June 15 through July 31,
3. A flow of 115 cfs from August 1 through April 14.

The need to adopt a minimum stream flow in the San Miguel River is based on the status of the "Three Species," the bluehead sucker, flannelmouth sucker and roundtail chub throughout the species range and also status of native fish species assemblage throughout the western slope of Colorado. The following sections address the status of the native fish assemblage on the western slope of Colorado, the status of the flannelmouth sucker the bluehead sucker and the roundtail chub in the San Miguel River Basin, the influence of water diversions on flannelmouth and bluehead suckers, the importance of water depth to the flannelmouth sucker and bluehead sucker, and the proposals of the DPW/BLM and Montrose County. Each of these topics is addressed separately in the following sections.

Analysis instream flow recommendations

Native Fish Assemblage

Only 13 fish species are currently thought to be native to waters of the western slope in Colorado (Table 1), a relatively depauperate fauna compared to most major river basins in the Continental United States. Five of these species are currently federally and/or state listed as threatened or endangered including the razorback sucker (*Xyrauchen texanus*), the Colorado pikeminnow (*Ptychocheilus lucius*), the humpback chub (*Gila cypha*), the bonytail chub (*Gila elegans*), and two lineages of the native cutthroat trout (*Onchorhynchus clarkii*). The exact taxonomic status of the cutthroat trout is somewhat confused (Table 1). The mountain sucker (*Catostomus platyrhynchus*) is also listed as a species of concern by the State of Colorado. The flannelmouth sucker, the bluehead sucker and the roundtail chub are considered by many groups to currently warrant federal or state listing. The US Bureau of Land Management (BLM) considers the flannelmouth sucker, bluehead sucker and roundtail chub to be "sensitive" species. The roundtail chub, bluehead sucker and flannelmouth sucker are referred to as the "Three species."

The Three Species are a Colorado River Basin fish assemblage component that is often treated as a single management unit. The Three Species are the focus of a multi-state and federal effort. Protection and enhancement of existing populations of the Three Species are a component of many state and federal fish management programs. All three taxa appear to be restricted to about 45% of the species' historic range in the Upper Colorado River Basin (Bezzerides and Bestgen 2002). The Upper Colorado River Basin is that portion of the Colorado Basin upstream of Glen Canyon Dam. The objective of the state and federal efforts is to avoid federal listing of any of these three species. Reproducing populations of the bluehead sucker, flannelmouth sucker and roundtail chub inhabit the lower reaches of the several Colorado Rivers including the lower portion of the San Miguel River, from Nucla downstream to the confluence with the Dolores River.

The fish assemblage of the Dolores River Basin (which includes the San Miguel River) is less diverse than that of the entire Colorado River Basin. About eight of the fish species found on the west slope of Colorado are not expected to occur in the Dolores Basin including the Paiute sculpin, the mountain whitefish, the mountain sucker, the bonytail chub, the humpback chub, the razorback sucker and Colorado pikeminnow. The Paiute sculpin, the mountain whitefish and the mountain sucker are generally restricted to the northwestern part of Colorado while the bonytail chub, humpback chub, razorback sucker and Colorado pike minnow seem to be found in the lower mainstem Gunnison River and Colorado River within the state. However, the flannelmouth sucker, bluehead sucker and roundtail chub are found in the Dolores River (Anderson 2003 and DPW Fort Collins data base) and the San Miguel River. At best, five native fish species could possibly be abundant in the Claimed reach of the San Miguel River River. The five native fish species that could maintain naturally reproducing populations in the Claimed reach of the San Miguel River River are the mottled sculpin, the speckled dace, the flannelmouth sucker, the bluehead sucker and roundtail chub.

In total, nine of the 13 fish species (69%) of the native fish species on the western slope of Colorado have declined in numbers and distribution to the point that some form of designation has been applied to the taxa (Table 1). The decline in the fish assemblage on the west slope of Colorado can be compared to a similar nationwide phenomenon. A total of 37% of the native fish species in the United States have declined in abundance and distribution to the point that the species have some form of official designation as imperiled (Master et al. 2000). In contrast, 69% of the fish assemblage on the western slope of Colorado has declined to a point where some level of designation has occurred. In general, the native fish assemblage of Colorado's western slope has experienced twice as much of a decline as the rest of the United States. Such declines in fish throughout Colorado have resulted in design and implementation of a variety of recovery endeavors to protect these species. The problem of conserving these species is compounded by the fact that at least five of these declining species are endemic to the Colorado River basin and found nowhere else in the United States.

Any further decline in distribution and abundance of the Three Species is significant in any Colorado river. Most western slope Colorado Rivers still support reproducing populations of the Three Species, although the flannelmouth sucker and bluehead sucker have disappeared from the Gunnison River upstream of Blue Mesa Reservoir (Woodling 1982). The relative robust Colorado Three Species populations are somewhat of an anomaly compared to the status of the populations throughout the entire native range of the species group. Overall the Three Species appears to have disappeared from about 45% of the taxa's native range (Bezzerides and Bestgen 2002). The distribution of the Three species is also different for the individual fish species. Flannelmouth sucker are still found in most of the species historical range in Wyoming and Colorado but the species has disappeared or become less abundant throughout the remainder of the species range, California, Utah, Arizona and Nevada (Rees et al. 2006b). Thus a decrease in abundance or distribution of the Three Species in Colorado has more influence on the status of the taxa than in other states where most populations have disappeared. The failure to protect Colorado populations could lead to the listing of one or more of the

Three Species on the national level, an occurrence that could have relatively more implications in Colorado where the taxa are still found in most of their native range.

Water Diversions

Water diversions are one human related action that has resulted in a decrease in numbers and species of native fish throughout the western slope of Colorado. A variety of other human related impacts have caused declines in fish species abundance and distribution including urbanization, agriculture, mining, roadways, silviculture, etc. The list is long. However, water diversions are the one form of human activity that has most often occurred in on Colorado's Western Slope. Water diversions have been influencing the distribution of fish since the late 1870's in Colorado.

Two general forms of water depletion often occur, those associated with water storage and water loss associated with direct crop irrigation. Water is often diverted from rivers to be stored for future use. This storage often occurs during the spring snowmelt periods when stream flows are elevated. Reduced spring snowmelt flows can have a deleterious impact on fish species that spawn in relation to the rising or declining hydrograph associated with the spring snowmelt period. The San Miguel River has a natural hydrograph in relation to spring peak flows compared to most Colorado river systems. However, water diversions in late summer and early fall months reduce the base flow condition of that season. During the late irrigation season (August through October) San Miguel River streamflows upstream of Calamity Draw are heavily influenced by irrigation diversions. Irrigation diversions downstream of Horsefly Creek can be used to remove a high percentage of the streamflow recorded at the upstream Placerville gage. As such, water depletions reduce the amount of water in the San Miguel for eight to nine months a year. The reduced flows in the claimed reach of the San Miguel River River travel down through a stream channel that developed over many decades based on native flow patterns not the flow pattern resulting from current water use patterns. Currently, the claimed reach of the San Miguel River River is both shallower and slower than conditions found only a century ago, a short time in development of a river channel.

Water depth and velocity

Water depth is the key factor when sampling for flannelmouth sucker, bluehead sucker and roundtail chub. Samplers know that the Three Species will be most abundant when water is deepest in principal habitat used by each species, deep runs and pools for flannelmouth sucker, deepwater riffles or runs for bluehead sucker and pools for the roundtail chub. Flannelmouth suckers are often encountered in deep runs when water is from waist to chest deep while bluehead suckers are often collected in slightly faster waters that may be a little shallower. The roundtail chub seems to use deeper water in the day and shallower water in the nighttime hours. Roundtail chub are associated with diverse habitat where water is relatively deep, and structure is more prevalent, including areas of undercut banks, large rocks on the substrate or stream bank and even overhanging shrubs and trees. The pattern however, is the same. These three species are more likely to be captured in the deepest part of the river or stream when the appropriate habitat is being sampled.

Published data support the qualitative observations of field biologists using electro-fishing techniques to sample the Three Species. The optimum depth for flannelmouth suckers in Colorado waters appears to be a depth between 1.3 feet and 6.6 feet (Anderson and Stewart, 2003, page 56, Figure 8). Flannelmouth in Wyoming selected waters from 1.6 feet to 3.3 feet in depth (Sweet 2007). Bluehead suckers do not appear to select for water as deep as flannelmouth suckers. The optimum depth for bluehead suckers in Colorado waters appears to be a depth between 1.6 feet and 5 feet (Anderson and Stewart, 2003, page 55, Figure 7). Bluehead suckers in Wyoming selected waters from 1.6 feet to 3.3 feet in depth (Sweet 2007). Specific information regarding roundtail chub and water depth is lacking. However adults and juveniles are usually taken in comparatively deep water with low water velocity (Rees et al. 2005) and in stream reaches with a complex combination of pool and riffle habitat and cover (Bezzerides and Bestgen 2002).

Shallow water does not result in elimination of these two native suckers and the roundtail chub but does result in presence of smaller fish. Flannelmouth suckers are found in Yellow Jacket Creek in the southwest corner of Colorado. The runs were about 1.5 feet deep and the largest flannelmouth suckers were less than 14 inches in length. Yellow Jacket Creek water depth was the low end of “optimum” for flannelmouth sucker but lack of deeper runs and pools resulted in comparatively smaller fish. Flows in the Dolores River are even lower and flannelmouth suckers only reach a maximum length of eight to ten inches (R. Anderson, personal communication). In contrast flannelmouth sucker can be 25 inches in length in streams and rivers with runs and pools in excess of 3.3 feet deep. A decrease in size may well lead to a lower fecundity in smaller reproducing adults and a lower fitness of the population as a whole.

Water depths may become so low that the fish populations become extirpated. An average depth of 1.0 foot is considered “marginally suitable” habitat for bluehead suckers (Anderson and Stewart 2003). At any given flow stream depth will be shallowest in the riffle areas preferred by bluehead suckers. Fish such as the bluehead sucker do not disappear when average depths are less than 1.0 foot but size and numbers decrease.

Water depth is directly related to water velocity. Water velocity and water depth increase as the flow volume increases during spring snow melt time periods, during summer thunderstorms or as irrigation return water enters the claimed reach of the San Miguel River River. Water velocities in riffles, runs and pools increase as water volume increases. Both flannelmouth and bluehead suckers may select different areas within the stream as flow levels change. For example, flannelmouth sucker may well be in deep water runs at water velocities of 3 ft/sec to 4 ft/sec but move to slower current pool areas when water velocities exceed 4 ft/sec at higher stream flows. Bluehead suckers may move to deepwater runs and flannelmouth sucker may move to pool areas with slower current. Movement of bluehead sucker and flannelmouth sucker within rivers like the claimed reach of the San Miguel River is a coordinated pattern depending on fluctuations in flow rates that influence both water depth and water velocity and sensitive stages of the fish species’ natural history.

The numbers and size of the Three Species currently inhabiting the claimed reach of the San Miguel River River are determined to a certain extent by current flow regime. The abundant numbers of native fish and size of fish are a response to the current flow regime. Much of the water present in summer and fall months in the claimed reach of the San Miguel River is comprised of irrigation return flows (Dan Kowalski, personal communication). These flows are less than historic native stream flows. Consequently water depth in riffles, runs and pools is probably less than what was present prior to the introduction of an irrigation based agricultural system in the late 1800's. Thus, the DPW/BLM instream flow recommendations are based on the current flow regime in a stream channel that developed over the last several hundred years. The current habitat of the claimed reach of the San Miguel River River is not pristine and current flows are less than what was present historically.

DPW/BLM, Montrose County flow recommendations

Technically sound methods were used by the DPW/BLM to create the instream flow proposal for the claimed reach of the San Miguel River River. The procedure used to the model flows was created using data from two river systems, the Colorado River and the Yampa River. Fish population data for bluehead sucker and flannelmouth suckers were analyzed with flow data to create support for instream flow recommendations. Additional sampling in later years resulted in databases for the Gunnison River and Dolores River that validated the conclusions and observations used to interpret and analyze data from the Yampa River and the Colorado River (Anderson and Stewart 2007).

The DPW/BLM balanced depth and velocity requirements against the amount of water present in the San Miguel River to create flow recommendations supportive of native suckers based on habitat models. Protection of deepwater riffles for bluehead suckers provides protection for not only bluehead suckers but also the flannelmouth sucker and roundtail chub (Stewart and Anderson 2007). The DPW/BLM proposal requests different minimum flows for five time periods throughout the year (Table 2). The maximum DPW/BLM flow recommendation is 325 cfs for the time period of April 15 through June 14 (Colorado Division of Wildlife 2010). A flow of 325 cfs is less than the DPW/BLM analysis that indicates a spring early summer flow of 500 cfs is appropriate to protect bluehead sucker habitat (Colorado Division of Wildlife 2010). The minimum DPW/BLM flow recommendation is 80 cfs for the time period of September through February. A flow of 80 cfs is less than the DPW/BLM analysis that indicates a flow of 115 is adequate to protect to protect bluehead sucker habitat from September through February. Mean riffle water depth is 0.8 feet at a flow of 115 cfs (DPW staging table data, Site X1).

The Montrose County government is objecting to the DPW/BLM flow requests and has proposed an alternative set of minimum stream flows for considerations (Conklin 2011). Stream flows suggested by Montrose County are less than those proposed by DPW/BLM (Table 2). Montrose County asserts that a flow of 200 cfs is appropriate during the spring and early summer (Table 2) while a flow of 60 cfs is considered appropriate for a 7 and ½ month period from September 1 through April 14. Mean riffle water depth is 0.52 feet at a flow of 60 cfs (DPW staging table data, Site X1).

Comparison of DPW/BLM recommendation to Montrose County recommendation

The DPW/BLM instream flow recommendations were based in part on the amount of water believed to be seasonally available in the lower section of the San Miguel River from Nucla to the confluence with the Dolores River. The flows requested are the seasonal amounts of water believed by the DPW and BLM to be available 50% of the time, not higher water volumes present less than 50% of the time. Thus, the DPW/BLM recommendation was not based solely on the biological needs of the native sucker species but addressed seasonal water quantity fluctuations. The DPW/BLM recommendations do not request that existing seasonal flow patterns be maintained in the claimed reach of the San Miguel River River. Water in excess of the DPW/BLM proposal is currently present in the river seasonally on an annual basis. The existing flow regime provides the habitat that supports the current numbers and size groups of the Three Species in the claimed reach of the San Miguel River River. The population demographics of the Three species is a response to the current flow regime not the flow regime that may exist based on an instream flow right as requested by the DPW/BLM. Future reductions in water may well result in negative impacts to the Three Species compared to existing population demographics.

Future water depletions could be possible in the claimed reach of the San Miguel River River even after instream flow rights are established. Future diversions could be approved for all flows in excess of those granted to the DPW/BLM. Approval of future water rights could decrease flow compared to current patterns. Water depths could well decrease compared to existing levels. Shallower water could well impact both numbers and size of the Three Species. Colorado's instream flow program is designed for "reasonable protection" of aquatic resources not a total protection. The Three Species are relatively long-lived fish where adults can be present many years in a river. The presence of adults from many age classes increases the level of difficulty in assessing status of these species.

Base flows

Base flows are a critical component of the life history of the Three Species in the claimed reach of the San Miguel River River. Bluehead sucker numbers are higher in deeper riffle areas while roundtail chub feed in riffle areas. Base flows in streams and rivers supporting Three Species populations are critical. Riffle areas with a mean depth of one foot and mean flow greater than 1.3 ft/sec provide marginally suitable bluehead sucker habitat (Anderson and Stewart 2003).

A flow of 115 cfs (as recommended by the DPW/BLM for both a short fall time period and a short early spring time period, Table 2) results in a mean depth of 0.8 foot in riffle areas. DPW/BLM however, created an additional time period of September 1 through February 29 with a flow request of 80 cfs (mean riffle depth of 0.6 foot). Neither a flow of 80 cfs or 115 cfs results in a water depth of 1.0 foot in riffle areas. As such the habitat would actually be less than marginally suitable for bluehead suckers.

Instream flows (60 cfs) proposed by Montrose County would result in riffles with a mean water depth of 0.5 foot for a period of seven and a half months a year, a level that is half of the 1.0 foot depth deemed "marginally suitable" for bluehead sucker (Table 2). Montrose County asserts that a minimum flow of 60 cfs would result in "approximately 20% of optimum habitat for bluehead suckers" for the period of September 1 through April 14 and that such flows are "appropriate" (Conklin 2011). No scale exists that indicates when a habitat (or flow) becomes unsuitable for colonization by a fish species. The habitat of the Dolores River is such that adult flannelmouth suckers, bluehead suckers and roundtail chub are much smaller than in the San Miguel River. In addition, nonnative fish species are more prevalent in the Dolores River, perhaps due to stress associated with low flows. A flow that results in 20% of optimum habitat is probably closer to a condition where adult fish are smaller and nonnative fish more of an environmental issue than a river reach that has a native historic flow regime. No proof exists that 20% of optimum habitat is appropriate or provides the "reasonable protection" as defined by the instream flow program.

I recommend that an instream minimum flow of 115 cfs be adopted for the claimed reach of the San Miguel River River for the entire time period of August 1 through April 14. Such a flow still does not attain a mean depth of one foot in the critical riffle cross section but is closer than the depths associated with the 80 cfs suggested by DPW/BLM or 60 cfs suggested by Montrose County (Note that the DPW/BLM requests a base flow of 80 cfs if flows are available). No matter what instream flow is adopted if the mean depth of riffles is less than 1.0 foot then the habitat will be less than marginally acceptable. Low base flows of less than one foot may prove to be an environmental "bottleneck" for the Three Species in the claimed reach of the San Miguel River River. A bottleneck is an event that decreases the fitness of a population through time. Low base flows could result in a variety of impacts to fish. One observable impact would be smaller adult fish such as those in the Dolores River.

Spring flows

Montrose County opposes an April 14 through June 14 instream spring flow of 325 cfs (Conklin 2011) as proposed by the DPW/BLM. Instead, Montrose County asserts a lower flow of 200 cfs from April 14 to June 14 "likely would be more suitable for younger life stages of (native) suckers which are more sensitive to higher velocity" and that spring and summer flows of 325 cfs and 170 cfs "may be too high and limit the survival of these life stages" (Conklin 2011). These assertions are not correct. Studies have demonstrated that trout reproduction and recruitment is better when spring snowmelt flows are comparatively low (Nehring and Anderson 1993, Woodling and Rollings 2005). However the exact opposite is true for west slope native suckers where high recruitment was documented in years with high spring snowmelt flows (Burdick 1995). A strong bluehead sucker year class in the Gunnison River was associated with a "normal" spring snowmelt in 2003 and low flows in the 2002 drought year resulted in poor bluehead sucker reproductive success (Anderson and Stewart 2006). Sweet (2007) indicated that low spring flows might have contributed to poor reproductive success in bluehead sucker and flannelmouth sucker in a headwater Wyoming river. High spring and summer snowmelt events enhance reproductive success in bluehead suckers and flannelmouth suckers. The habitat for the Three Species may well not be “optimum” during the days of maximum spring snowmelt but elevated flows appear to be needed to support robust populations of the Three Species.

High spring and early summer flow will enhance natural reproduction of the bluehead sucker and flannelmouth sucker populations in the claimed reach of the San Miguel River River, not low spring and early summer flows. The 200 cfs instream flow suggestion of Montrose County would be deleterious to the Three Species in the claimed reach of the San Miguel River and is not supported by available life history information for the bluehead sucker and flannelmouth sucker. The 325 cfs DPW/BLM recommendation was selected to protect flannelmouth sucker habitat and is lower than the 500 cfs flow that will protect bluehead suckers, the riffle areas.

A flow of 500 cfs as determined by the DPW/BLM modeling suggests that an adequate flow rate for the time period of 14 April through June 14 is the 500 cfs. Higher spring flows may offset negative impacts of low base flows of less a mean of 1 foot in riffle areas. A higher spring flow may result in increased reproduction that would offset population impacts that may occur due to insufficient base flow periods in the claimed reach of the San Miguel River River. Managing the claimed reach of the San Miguel River River to protect existing populations of the Three Species is a challenge. One component is flow. The stream flow recommendations proposed by the DPW/BLM with the alterations I propose in this document still do not fully protect the Three Species. The base flow recommendation is still less than adequate and would be expected to negatively impact the abundance or physiology (as indicated by growth) of the Three Species to some degree.

Influence of San Miguel River water on Dolores River

The lower Dolores River exemplifies the magnitude of impact water diversions can have on a native fish assemblage. Base low flows in the lower Dolores River are low in comparison to other Colorado River systems. The Three Species are found in the lower river but low flows influence these populations. Flannelmouth sucker greater than 8 inches in length are rarely collected in the Dolores River upstream of the San Miguel River confluence. However, flannelmouth sucker downstream of the confluence with the San Miguel River are more robust. Instream flows for the San Miguel River may well result in protecting water flows in the Dolores River, further helping the preservation of the Three Species in the Dolores River Basin.

Summary

Instream flows are needed to protect existing population of the “Three Species” (bluehead sucker, flannelmouth sucker and roundtail chub) in the claimed reach of the San Miguel River River. Protection of Colorado populations of the Three Species is a critical component of an interstate attempt to avoid future listing of the Three Species on a federal level.

Technically sound methods were used by the DPW/BLM to create the instream flow recommendations for the claimed reach of the San Miguel River River. Techniques for creating instream flow recommendations for the Three Species were developed and refined using data from four river systems in Colorado (Anderson and Stewart 2007).

I recommend that instream flows be approved for the claimed reach of the San Miguel River River based on analyses performed by the DPW/BLM as follows,

1. A flow of 500 cfs from April 15 through June 14,

2. A flow of 170 cfs from June 15 through July 31,

3. A flow of 115 cfs from August 1 through April 14.

The flow of 500 cfs was the result of the PHABSIM/RHABSIM data analysis performed by the DPW/BLM personnel involved in creating the instream flow for the claimed reach of the San Miguel River and is the flow needed to maximize habitat for bluehead suckers and to increase the reproductive success of the bluehead sucker and the flannelmouth sucker. The DPW/BLM recommended a flow of 325 cfs based on flannelmouth sucker for the time period of April 15 through June 14.

A flow of 115 cfs from August 1 through April 14 is needed to help maintain a mean depth in riffles to 0.8 feet for the entire base flow period. The DPW/BLM recommended a flow of 80 cfs for the time period of September 1 through February 29 that would result in an average depth in riffles of 0.63 feet for a 6-month period. A water depth of 1.0 foot provides marginally suitable habitat for bluehead suckers. .

Flow recommendations suggested by Montrose County are not appropriate for the claimed reach of the San Miguel River River. A suggestion of 200 cfs for the spring period of April 15 through June 14 would decrease reproductive success in the claimed reach of the San Miguel River River. A flow of 60 cfs could result in mean water depths as low as 0.5 foot in riffle areas for a 7-month period where a depth of 1.0 foot is needed to provide “marginally suitable habitat” for Bluehead suckers.

Instream flows approved for the claimed reach of the San Miguel River River would also help provide protection for the Three Species in the Dolores River downstream of the Dolores River/San Miguel River confluence.

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Table 1. Native Fish Species and legal status of fish species on the western side of the Continental Divide in Colorado. * Taxonomy of native cutthroat on western slope is in question at present. Two lineages are present, *O. clarki pleuriticus* = Colorado River cutthroat which is Colorado species of concern and *O. clarki stomias* = Green back lineage which is federally listed threatened species.

Species		Status
Minnows Cyprinidae		
Colorado pikeminnow	*Ptychocheilus lucius*	Federal endangered state threatened
Roundtail chub	*Gila robusta*	BLM sensitive, "Three species" Colorado species of concern
Bonytail chub	*Gila elegans*	Federal and Colorado endangered
Humpback chub	*Gila cypha*	Federal endangered Colorado threatened
Speckled dace	*Rhinichthys osculus*	
Suckers Catostomidae		
Razorback sucker	*Xyrauchen texanus*	Federal and Colorado endangered
Bluehead sucker	*Catostomus discobolus*	BLM sensitive, "Three species"
Flannelmouth sucker	*Catostomus latipinnis*	BLM sensitive, "Three species"
Mountain sucker	*Catostomus platyrhynchus*	Colorado species of concern
Sculpin Cottidae		
Paiute sucker	*Cottus beldingi*	
Mottled sculpin	*Cottus bairdii*	
Salmonidae		
Cutthroat trout *	*Onchorhynchus clarkii*	See title information*
Mountain whitefish	*Prosopium williamsoni*	

Table 2. San Miguel River water depth and associated water velocity for two representative cross sections at flows proposed by DPW/BLM and Montrose County. Cross section 1 = riffle, cross section 7 = pool.

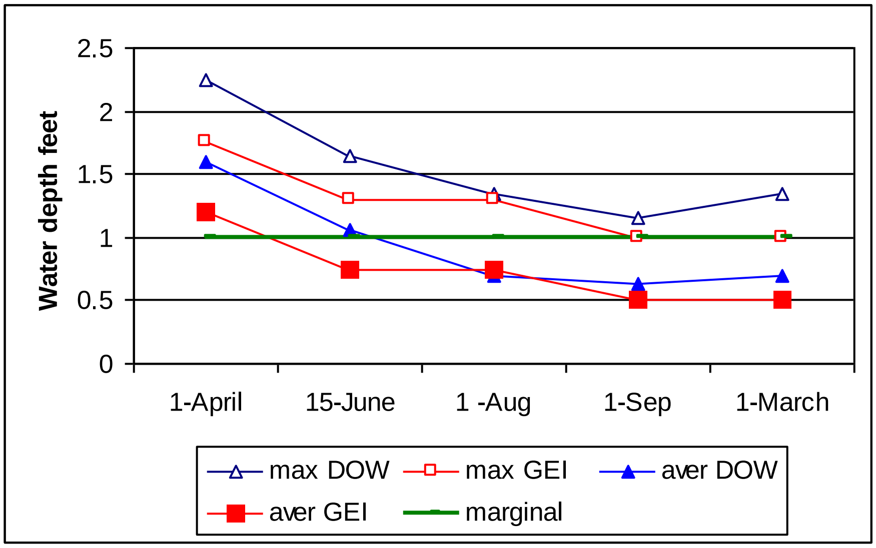
DPW/BLM recommendation

Cross section		April 15 – June 14	June 15 – July 31	August 1 – August 31	September 1 – February 29	March 1 – April 14
	Recommended flow	325	170	115	80	115
1	Cross section flow, cfs	334	172	112		112
	Average depth	1.6	1.06	0.7	0.63	0.7
	Max depth ft	2.25	1.65	1.35	1.15	1.35
	Velocity ft/sec	3.8	3.1	2.8	2.65	2.8
7	Cross section flow, cfs	320	165	108	80	108
	Average depth	2.1	1.95	1.88	1.8	1.88
	Max depth ft	4.2	3.95	3.8	3.7	3.8
	Velocity ft/sec	2.4	1.4	1.01	0.79	1.01

GEI recommendation

Cross section		April 15 – June 14	June 15 – August 31	September 1 – April 14
	Recommended flow	200	100	60
1	Cross section flow, cfs	195	103	59
	Average depth	1.2	0.75	0.5
	Max depth ft	1.75	1.3	1.0
	Velocity ft/sec	3.2	2.7	2.55
7	Cross section flow, cfs	190	94	59
	Average depth	1.9	1.8	1.7
	Max depth ft	4.0	3.7	3.6
	Velocity ft/sec	1.6	0.9	0.62

Figure 1. Comparison of DPW/BLM flow recommendation for riffle areas to GEI (Montrose County) recommendation. Y axis = depth in feet. Marginal = marginally suitable water depth for bluehead suckers (Anderson and Stewart 2003). First date of each time period given in figure. GEI recommendation has only three time periods. Max = maximum, aver = average.



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EDUCATION

Ph.D., Biology Major, University of Colorado, Boulder, Colorado, 1993.

Title of Doctoral Dissertation: "Factors Effecting Toxicity of Metals To Brown Trout, An In Situ study of the Arkansas River"

M.S., Biology Major, Chemistry Minor, University of Louisville, Louisville, Kentucky, 1971.

Masters Thesis: "Biological, Chemical, and Physical Characteristics of Brashears Creek, Spencer and Shelby Counties"

B.S., Biology Major, Mathematics Minor, Southern Colorado State College, Pueblo, Colorado, 1968.

PROFESSIONAL EXPERIENCE

Jan 2007 Present — **College Instructor**
Mesa State College, Grand Junction, Colorado. Aquatic Entomology and technical writing (Undergraduate)

Jan. 2004 Present — **Consultant, Woodling Aquatics, LLC.**
Clients include Colorado Trout Unlimited, Colorado State Land Board, Colorado Division of Hazardous Materials and Waste Management, West Slope Water Network, Sierra Club and Eagle River Watershed Council. Represent organizations at Colorado Water Quality Control rulemaking hearings and testify as expert witness in US District Court.

Jan. 1994 Present. — **University Instructor**
University of Denver, Community College, Environmental Policy Management
Instructor , Wetland Ecology, General Ecology, Aquatic Toxicology, Research Writing, Endangered Species and Introduction to Water Quality (Graduate level classes).

Jan 1998 Present — **Research Associate**
University of Colorado Boulder, Colorado. Awarded US EPA grant in 2003 to study impacts of estrogenic compounds on Colorado fish populations.

Jan. 1997 2003 — **University Instructor**
University of Colorado, EPO Biology. Instructor, Stream Biology.

July 2002 - Retired May 2003 — **Cost Center Supervisor**
Colorado Division of Wildlife (DOW), Denver Colorado
• Principal duty was to manage and supervise water unit of the habitat section, including water quality and Water Quantity aspects of agency goals and objectives.
• Develop budget and work objectives used by DOW to respond to water resource issues.
• Supervised and directed water unit employees to achieve program goals
Designed and developed web-based model to analyze fishery and habitat data for DOW use.
• Participated in state and federal Superfund and CERCLA by review and/or development of remedial investigation documents, feasibility studies and remedial action plans; negotiate for the state in settlement actions, testify in water quality related hearings and court cases.

July 1987 - June 2002. — **Water Quality Program Specialist**
Colorado Division of Wildlife (DOW), Denver Colorado
• Principal duty was to represent the DOW in all matters pertaining to water quality issues.
• Developed policy and programs used by DOW to respond to water quality issues.

• Designed and performed laboratory and field research studies of rivers throughout Colorado to define and quantify impacts of pollutants to aquatic ecosystems. Current projects include efforts to create biological stream standard proposals for Colorado's eastern plains warm water streams and rivers and mountain trout streams. Potential biological stream standards may be developed using results from genetic analysis of trout and aquatic macroinvertebrates, fish community structure modeling and stress hormone response studies on a variety of fish species. Ancillary studies include a multi-year monitoring program of the Eagle River, Arkansas River and Clear Creek to assess efficacy of remediation programs and systematic studies of the fish genera Phoxinus and Cottus in Colorado.
• Applied for and received grants from US EPA, Colorado Department of Public Health and private enterprise to fund field and laboratory studies.
• Participated in state and federal Superfund and CERCLA by review and/or development of remedial investigation documents, feasibility studies and remedial action plans; negotiated for the state in settlement actions involving fish kills and CERCLA actions.
• Created DOW position in rulemaking hearings for the Colorado Water Quality Control Commission (WQCC) through which stream standards and use classifications are adopted.
• Member Colorado 319 Nonpoint Pollution Task Force.
• Appointed by WQCC to rewrite Colorado Stream Standards for nitrogen compounds.
• Testified as expert witness in court proceedings and rulemaking hearing of the WQCC.

April 1984 - July 1987 — **Coldwater Program Specialist**, DOW
• Developed, implemented and monitored statewide DOW coldwater fishery program.
• Developed annual budgets for DOW–fish hatcheries, aquatics section and aquatic research–$6 million/year.
• Developed statewide DOW fish program budget.
• Assisted DOW fish hatcheries in increasing production and efficiency.
• Co-authored report that resulted in the reorganization of the DOW fish hatchery system.
• Provided WQCC with technical information regarding water quality issues such as mine drainage.

July 1979 - April 1984 — **Warmwater Program Specialist**, DOW
• Developed, implemented and monitored statewide DOW warmwater fishery program.
• Prepared DOW response to legislative queries regarding annual budget.
• Worked with fish hatcheries to increase production and efficiency.
• Provided WQCC and Colorado Wildlife Commission with technical information regarding water quality issues such as nutrient enrichment and acid rain.

Sept. 1978 - July 1979 — **Aquatic Ecologist and Project Manager**
Camp, Dresser and McKee, Denver, Colorado.
• Prepared bids, planned and directed interdisciplinary studies. Wrote final reports for these studies.
• Represented power companies, coal mining and other underground mining corporations.

Sept. 1973 - Sept. 1978 — **Research Biologist**
Colorado Water Quality Control Division, Denver, Colorado
• Planned and performed stream and river basin studies concerning impacts of mining, milling, agricultural, domestic and industrial effluents on water quality.
• Monitored and analyzed biological, chemical and physical components of aquatic ecosystems to determine impacts from effluents on these systems.
• Performed in situ assays to determine toxicity of pollutants to resident fish populations.
• Served as expert witness at public hearings and adjudicatory hearings.
• Served as member of subcommittee to develop Colorado water quality standards and use classifications.

Jan. 1971- May 1971 — **College Instructor**
• Taught Human Anatomy and Physiology, University of Southern Colorado.

Sept. 1971- June, 1972 — **High School Teacher**
Cathedral High School, Denver, Colorado.
• Taught high school biology and coached football and wrestling.

July 1968- Dec, 1970 — **Research Assistant**
University of Louisville, Louisville, Kentucky

• Implemented a pre-impoundment study of the Salt River in central Kentucky. Collected and analyzed water quality samples, collected and identified aquatic macroinvertebrate and fish samples.
• Collected and analyzed samples measuring the movement of radioactive nucleotides through a spring-fed system, Doe Run in Kentucky.

Sept. 1966- **Laboratory Assistant**
Dec. 1967. Southern Colorado State College, Pueblo, Colorado.
• Taught laboratory sections in zoology, botany, plant physiology and ecology

PUBLIC SERVICE

Colorado 319 Nonpoint Pollution Council. Voting member 1989-2001.

Cherry Creek Basin Authority. Voting member 2001-2005. Appointed by Governor of Colorado.

American Fisheries Society. Member Continuing Education Committee. 2010-present

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Memorandum

To: Robert Harris

From: Laura Belanger, P.E.

CC: Bart Miller

Date: July 12, 2011

Re: Review of Bikis Water Consultants' "Evaluation of Technical Basis for Lower San Miguel River CWCB Instream Flow Recommendations"

Background

I have reviewed the Colorado Water Conservation Board's (CWCB) San Miguel River instream flow (ISF) recommendation, including appendices, and the following documents:

- Bikis Water Consultants, LLC (Bikis, 2009). (Draft) Evaluation of Technical Basis for Lower San Miguel River CWCB Instream Flow Recommendations[1];
- Colorado Department of Wildlife (CDOW) and the Bureau of Land Management (BLM), letter to the CWCB regarding the Bikis Report (Uppendahl & Smith, 2010); and
- Cooper, D.J. and Arp, C.D. (1999). Riparian Vegetation of the Middle and Lower San Miguel River: Surface and Ground Water Interactions, Plant Water Sources, Plant Water Status, and Susceptibility to Impacts from Changing River Base Flows.

The Bikis Report (Bikis, 2009) was referred to by several of the contesting parties, their technical experts, and stakeholders. This memorandum evaluates the hydrologic analyses completed by Bikis. I defer to the CDOW and BLM and their letter to the CWCB (Uppendahl & Smith, 2010) regarding Bikis' use of instream flow methodologies and their interpretation of model results.

"Increase in Flow in Reach"

Based upon an evaluation of data from three stream gages, the San Miguel at Brooks Bridge near Nucla ("Nucla", USGS # 09174600), the San Miguel at Naturita ("Naturita", USGS # 09175500) and the San Miguel at Uravan ("Uravan", USGS # 9177000) (see Figure 1), Bikis concludes that the proposed ISF segment of the San Miguel River is a gaining reach due to shallow groundwater inflow during the low flow September through February period and that "for 80 cfs [cubic feet per second] to be found anywhere in the reach under base flow conditions, only 68 cfs is needed in the river at Calamity Draw. The amount of flow should, therefore, be reduced if the ISF is to be 80 cfs" (Bikis, 2009). I disagree with this conclusion because the San Miguel River at Calamity Draw *is* the upper terminus of the ISF reach.

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[1] In their Notice of Contest, the Farmer's Water Development Company refers to a 4/20/09 Bikis Report. GEI, in a January 14, 2011 memo to the Montrose County Commissioners refers to a technical memo "prepared by Bikis Water Consultants, LLC from April 2010". I reviewed a November 2009 version of this report which was provided to Western Resource Advocates by the CWCB which is the most current version the CWCB had received. Though the report was labeled "Preliminary and Confidential – For Internal Use Only" it has been widely distributed and referred to.

For there to be 80 cfs "anywhere in the reach" – including the river at and immediately below Calamity Draw - there needs to be 80 cfs at Calamity Draw not 68 cfs as the Bikis Report states. The Bikis Report appears to focus only on ensuring that flows at and below the Uravan gage (located approximately 10 miles downstream of the upper terminus) meet the ISF recommendation.

I also believe that the Bikis Report analysis of flows between the Naturita and Uravan gages, and the subsequent conclusion that the reach is gaining throughout from groundwater inflows, is incomplete. Bikis Reports that average daily flow increases by 21.7 cfs between the Nucla and Uravan gages during the September through February period and that flows between the Naturita and Uravan gages increase by an average of 10.2 cfs for the same period. The report says that most irrigation return flows from the south side of the river enter via Naturita Creek[2] and that only "relatively small and dry tributaries" occur between the Naturita and Uravan gages (Bikis, 2009). To support this, one flow measurement is referenced, "The flow was estimated to be 0.2 cfs at the mouth of Tabeguache Creek on October 8, 2008. *Therefore, most of the increase in flow between the Naturita and Uravan gages during September-March is shallow groundwater inflow* [emphasis added]" (Bikis, 2009). Available data, as discussed below, suggests otherwise.

Two studies of the area completed for the BLM (Cooper & Arp, 1999, Cooper & Conovitz, 2001) found that San Miguel River stage [elevation] controls floodplain groundwater elevations in all seasons [i.e., the river is losing water to the groundwater, not gaining from groundwater inflow]. The latter of these studies (Cooper & Conovitz, 2001) was provided as an attachment to the CWCB's ISF recommendation appendices. It examined surface water and ground water interactions from April through September at two sites near the Placerville and Uravan USGS stream gages. "[Study] results demonstrate that the San Miguel River is a losing stream in most reaches and the floodplain groundwater elevation is controlled by river stage" (Cooper & Conovitz, 2001). Additionally, "Profiles of groundwater surface elevations relative to stage along [Uravan site] transects perpendicular to the river suggest that water is moving from the river into the adjacent aquifer throughout the reach in all seasons" (Cooper & Conovitz, 2001). This relationship between river stage and groundwater was very consistent in both peak and baseflow periods. The earlier Cooper study (Cooper & Arp, 1999) included the 2001 study sites (Placerville and Uravan) as well as a "Pinon" site, located between the other two sites, approximately two miles upstream from Country Road 30 bridge at Pinon. The 1999 study (Cooper & Arp, 1999) also found that floodplain groundwater elevations levels were controlled by river stage.

A likely source of at least a portion of the September through February gains between the Naturita and Uravan gages is irrigation return flows in the vicinity of the upper terminus of the ISF reach. Bikis reported an average gain of 10.2 cfs between the Naturita and Uravan gages for the September through February period. I reviewed the gage data and found that most of this occurs in September and October, towards the end of the irrigation season (average gain of approximately 21 cfs in September and 17 cfs in October). Similarly to Bikis, I believe most of the return flows from irrigation on the south side of the river likely reach the San Miguel upstream of the Naturita gage (most via Naturita Creek). Based on a review of satellite imagery and topographical maps of this area (Figures 1 and 2, respectively), I would expect additional return flows from northern irrigated areas near the town of Nucla to occur between the Nucla and Naturita gages, as well as between the Naturita gage and Turtle Draw (less than a mile below the upper terminus of the ISF reach). A small portion of irrigation return flows may also drain to Coal Canyon. Though additional field work and analysis would be required to quantify irrigation return flows, the Bikis Report neglected these in their analysis.

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[2] Naturita Creek flows into the San Miguel River about a mile upstream of the Naturita gage.

“Effects on Water Rights”

The Bikis Report included an analysis of the potential impacts of the ISF recommendation on water availability for other water users. Bikis calculated an average “lost diversion potential” of 8,667 acre-feet per year (AF/yr) if the proposed ISF recommendation is adopted. Per the Bikis Report, this was calculated as the difference between the amount of gaged flow at Uravan and the ISF recommendation. Bikis calls this volume of water “lost diversion potential” and says that it would require the curtailment of diversions junior to the ISF right. This water is not physically present in the river, so I believe it is inaccurate to portray it as “lost diversion potential” for potential future junior diversions.

Regarding water availability, I performed an analysis similar to Bikis for the 1995 through 2010 period[3] using only months and water years with complete data so as not to skew annual average results. I compared Uravan gaged flows to the ISF recommendation on a daily basis. If there was water in the river above the ISF, I consider that to be an excess. For example, if the ISF recommendation is 80 cfs and there was 100 cfs in the river, the excess for that day was 20 cfs. I then summed the daily excesses by water year[4]. I also calculated daily and annual shortages to the ISF recommendation. If the daily flow at Uravan was less than the daily ISF recommendation, the difference was considered to be a shortage. Daily shortages were then summed to total annual values by water year.

I calculated an average annual shortage of 8,583 AF to the recommended ISF values, which is similar to what Bikis reported[5]. In addition, I also calculated an average annual excess of 167,183 AF. This is water that would be physically present in the river above the ISF recommendation. Figure 1 is an exceedance curve which shows the probability of flows in excess of the ISF recommendation meeting or exceeding a given volume. For example, annual excesses of 350,000 AF are met or exceeded about 13% of the time and, looking at the other end of the graph, excesses above 50,000 AF occur in about 85% of all years. It is important to note that this curve reflects probabilities based upon the available period of record (43 water years).

Bikis also specifically focused on the potential impact of the ISF recommendation on the filling of irrigation reservoirs in the lower basin beginning in March of each year. I calculated that water in excess of the ISF recommendation is available in March in 65% of years, with an average March excess of 8,700 AF in these years.

[3] No data is available from 10/1/1963 through 9/30/1973 and 10/1/1995 through 8/29/1996. As a result of missing and incomplete data, the water years 1954, 1963 – 1973, 1996 and 2011 were not included in calculations.

[4] There were also days with shortages to the ISF recommendation. For days with shortages (for example ISF recommendation is 115 cfs but there is only 90 cfs in the river) a 0.0 cfs excess flow value was used in calculations.

[5] The difference the shortages I calculated and Bikis “lost diversion potential” is likely due to a slightly longer period of record and slight difference in methodology.

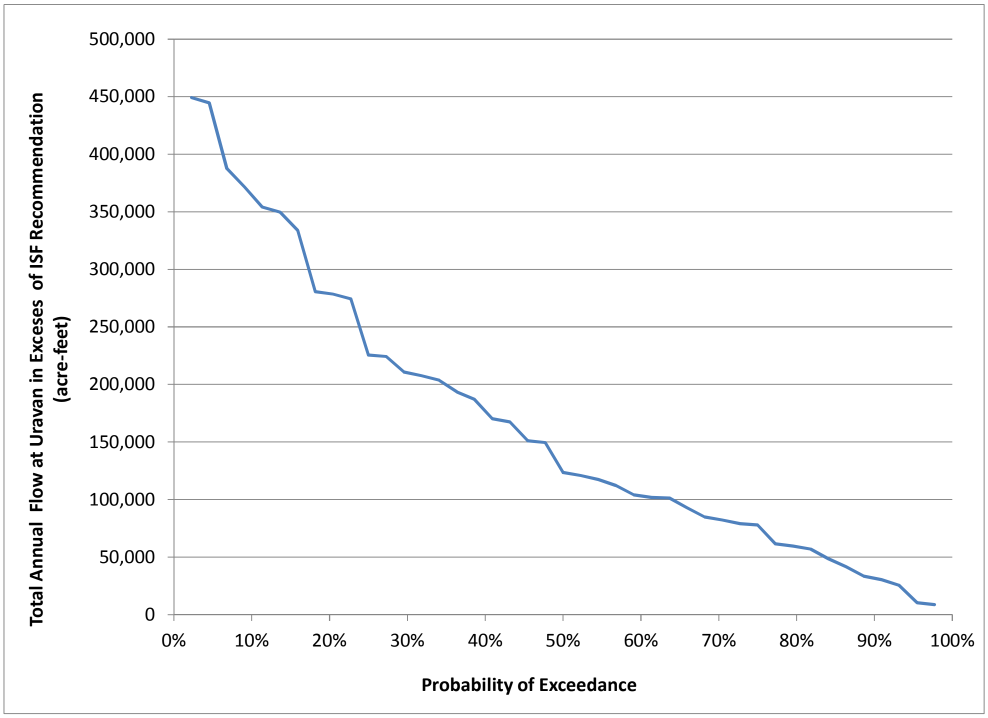

Figure 1: Probability total annual flows at Uravan (USGS gage #09177000) in excess of the ISF recommendations will occur or be exceeded in any given year (based upon period of record for water years with complete datasets – 43 years)

Conclusions

As documented above, I believe several of the Bikis Report methodologies and draft findings are incomplete or inaccurate. As such, I think it is inappropriate to adjust the September through February ISF recommendation as proposed in the Bikis Report. Rather than refer to the draft Bikis Report, any evaluation of the ISF recommendation should instead rely on the thorough analyses completed by CDOW and BLM and the materials provided in the ISF recommendation appendices.

Figure 1: Satellite imagery of the San Miguel River in vicinity of upper terminus (confluence with Calamity Draw) of the instream flow reach (source: Google Earth)

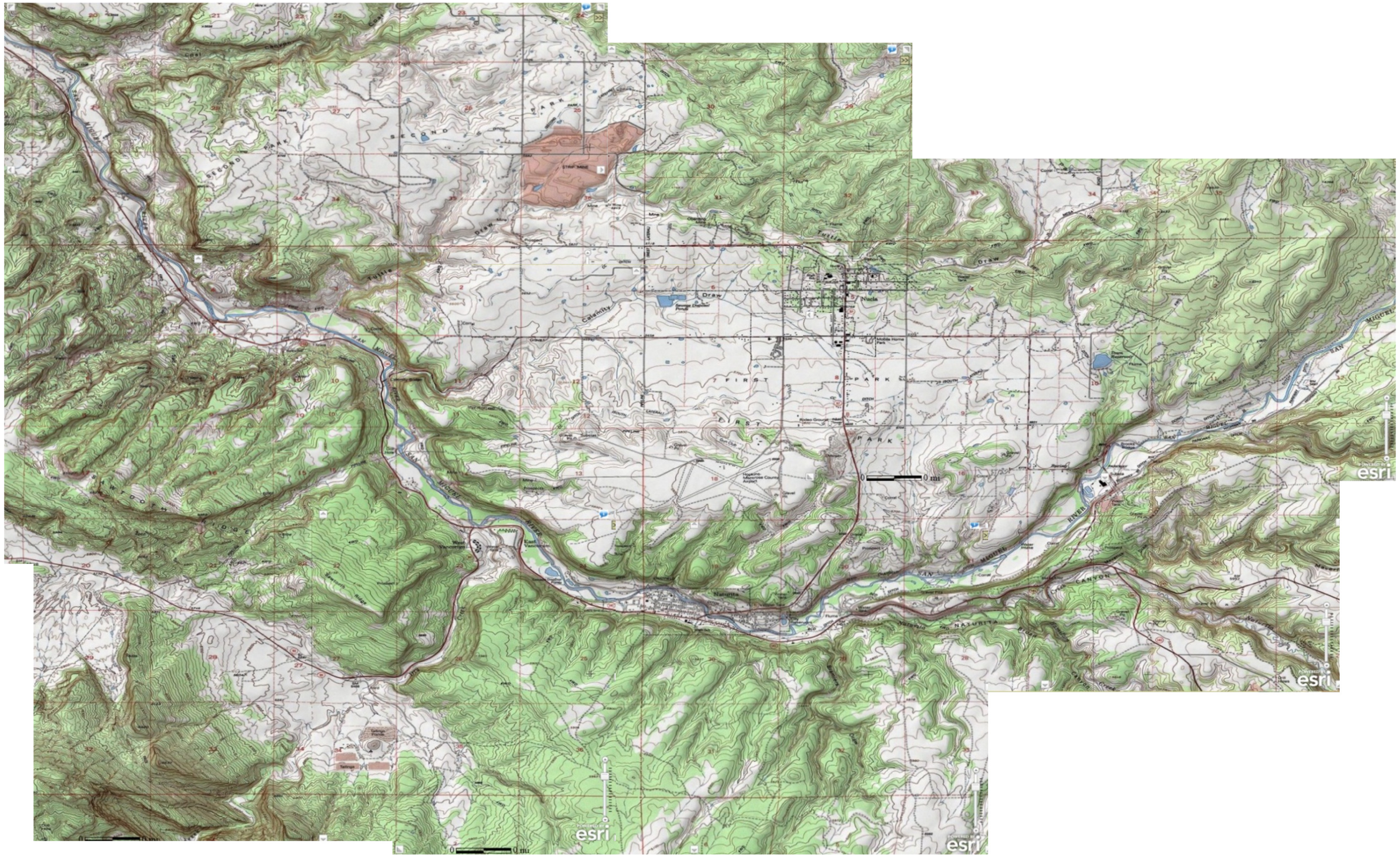

Figure 2: Topography of the San Miguel River in vicinity of upper terminus (confluence with Calamity Draw) of the instream flow reach (source: esri via BLM Geocommunicator software)

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Attachments

Cooper, D.J. and Arp, C.D. (1999).

Laura Belanger, P.E., Curriculum Vitae

Riparian Vegetation of the Middle and Lower San Miguel River: Surface and Ground Water Interactions, Plant Water Sources, Plant Water Status, and Susceptibility to Impacts from Changing River Base Flows

by:

David J. Cooper, Ph.D.
and
Christopher D. Arp, M.S.

Research Performed for:

Bureau of Land Management
Montrose District Office

February 1999

INTRODUCTION

The San Miguel River is one of the few free-flowing streams of its size remaining in the southwestern United States. It supports a nearly continuous belt of riparian vegetation from its headwaters to its confluence with the Dolores River. Riparian ecosystems typically are closely coupled with the hydrologic, geomorphic and ecological processes of their watershed. Along free-flowing streams floods of various magnitudes occur annually lead to the formation of bare bars and other floodplain features where most native riparian plants establish. During the summer peak flows slowly declining to late summer base flows.

The San Miguel River riparian forests and shrublands provide critical habitat for wildlife, fish and aquatic invertebrate communities. These habitats and wildlife provide important aesthetic value and opportunities for recreation for residents and visitors. Maintaining the integrity of the San Miguel River's riparian communities is a priority for many residents, visitors, and land management agencies. However, additional water diversions from the San Miguel River are also posed. It is essential to understand the potential impacts of lowered summer flows on riparian vegetation to evaluate the potential effects of diversion projects.

The dominant riparian trees along the San Miguel River, narrowleaf cottonwood (*P. angustifolia* James) in high and middle elevation reaches, and Fremont cottonwood (*Populus deltoides* Marshall ssp. *wislizenii* (Watson) Eckenwalder) in the lower elevation reaches, have substantial water requirements and are reported to utilize primarily floodplain ground water during the summer (Smith et al. 1991, Busch et al. 1992, Busch and Smith 1995). Thus, both species are potentially sensitive to lowering floodplain water table depths created by changes in river base flows.

Fremont cottonwood is the most sensitive tree species in North America to water stress and drought inducted xylem cavitation (Blake et al. 1996, Tyree et al. 1994). Cavitation is an unambiguous limitation to the drought tolerance of plants reducing xylem hydraulic conductivity and water delivery to leaves (Sperry et al. 1991). Embolisms (air bubbles) may develop in a plant under water stress as air penetrates into water filled vessels (Sperry and Tyree 1988, Sperry et al. 1991). Vulnerability curves, quantifying the percent loss of hydraulic conductivity for a given xylem pressure have been developed for cottonwood (Blake et al. 1996). This curve suggests that cottonwood lose most of their ability to conduct water at xylem pressures between –1.0 and –2.0 Mega-Pascals (MPa). Xylem pressures above –1.5 MPa, and even approaching –2.0 are routinely reached in both cottonwood species during dry and hot summer days. Thus, both species appear to survive on the edge of xylem dysfunction and even slight changes in the availability of water could induce severe water stress leading to leaf and branch death, and even tree death (Braatne et al. 1996).

Other important riparian tree and shrub species including blue spruce (*Picea pungens* Engelmann), thin-leaf alder (*Alnus incana* (L.) Moench ssp. *tenuifolia* (Nuttall) Breitung) and river birch (*Betula fontinalis* Sargent) are common along the upper and middle reaches of the San Miguel River. However, little is known about their water relations.

In addition, relatively little is known about the relationship of surface and groundwater in western U.S. floodplains. In certain areas ground water levels are tightly coupled with river stage (Rood and Mahoney 1995). However, in other areas rivers are "gaining" as ground water contributions from hillslope aquifers enter the stream. In these areas, hillslope processes may control floodplain ground waters. Since most riparian plants rely at some times of the year on floodplain ground water, an understanding of the relationship of the San Miguel River and floodplain ground water is essential to understanding possible threats to plants from stream flow changes.

A striking feature of the San Miguel River riparian zone is the presence of narrowleaf cottonwood trees on terraces and colluvial fans up to 7-10 meters in height above river stage. Since cottonwood are thought to establish primarily during flood events (eg. Scott et al. 1997) these trees are enigmatic. Did huge floods allow their establishment? Are they relicts of a former floodplain building episode? Have trees established and persisted based upon hillslope processes of tributary flooding and tributary ground water? Or have they established on the main floodplain, and spread to these high positions by clonal expansion. Because these trees are in such high landscape positions the question of their use of floodplain ground water must also be addressed. Thus, determining the water sources utilized by cottonwoods in various landscape positions is needed to assess the potential affects of river base flow changes.

The goals of the research presented in this report are to address the interactions and relationships of the San Miguel River with floodplain ground water in sites where cottonwoods and other riparian plants occur. In addition, we investigated the water sources utilized by cottonwoods, and began to develop an understanding of whether cottonwoods experience water stress under the existing river flow regime. We focus our research on addressing the following objectives:

(1) to determine the relationship between river-stage and groundwater level at different elevations and positions on floodplains and hillslopes,

(2) to determine the water sources utilized by narrowleaf cottonwood during peak-flow and base-flow periods,

(3) to determine if cottonwoods are undergoing water-stress under the existing flow regime, and if so where and when does water-stress occur.

STUDY AREAS

Three reaches of the San Miguel River were selected for study; these are located near the existing town of Placerville, and the relic towns of Pinon and Uravan (Figure 1). Each study site represents the major riparian vegetation types and hydrogeomorphic conditions occurring along that portion of the river. Each study area included the floodplain of at least one inside meander of the river.

Placerville. The highest elevation study site is Placerville (2,240-m elevation) located 5-km down-river from the town of Placerville, and on river-right just above the confluence with Specie Creek (Figure 2). This study area also includes a site 1.5-km down-river of the primary study area on a colluvial fan adjacent to the river floodplain. The riparian community through this river reach is dominated by narrowleaf cottonwood, blue spruce, river birch, alder, red osier dogwood (*Swida sericea* Holub), narrow-leaf willow (*Salix caudata* Nuttall), and sandbar willow (*Salix exigua* Nuttall). Willows occur primarily on low elevation portions of the floodplain, while blue spruce occurs primarily on higher elevation portions of the floodplain. Narrowleaf cottonwood occurs throughout the study area, however tree age tends to increase with floodplain elevation. Species nomenclature follow Weber and Wittmann (1996)

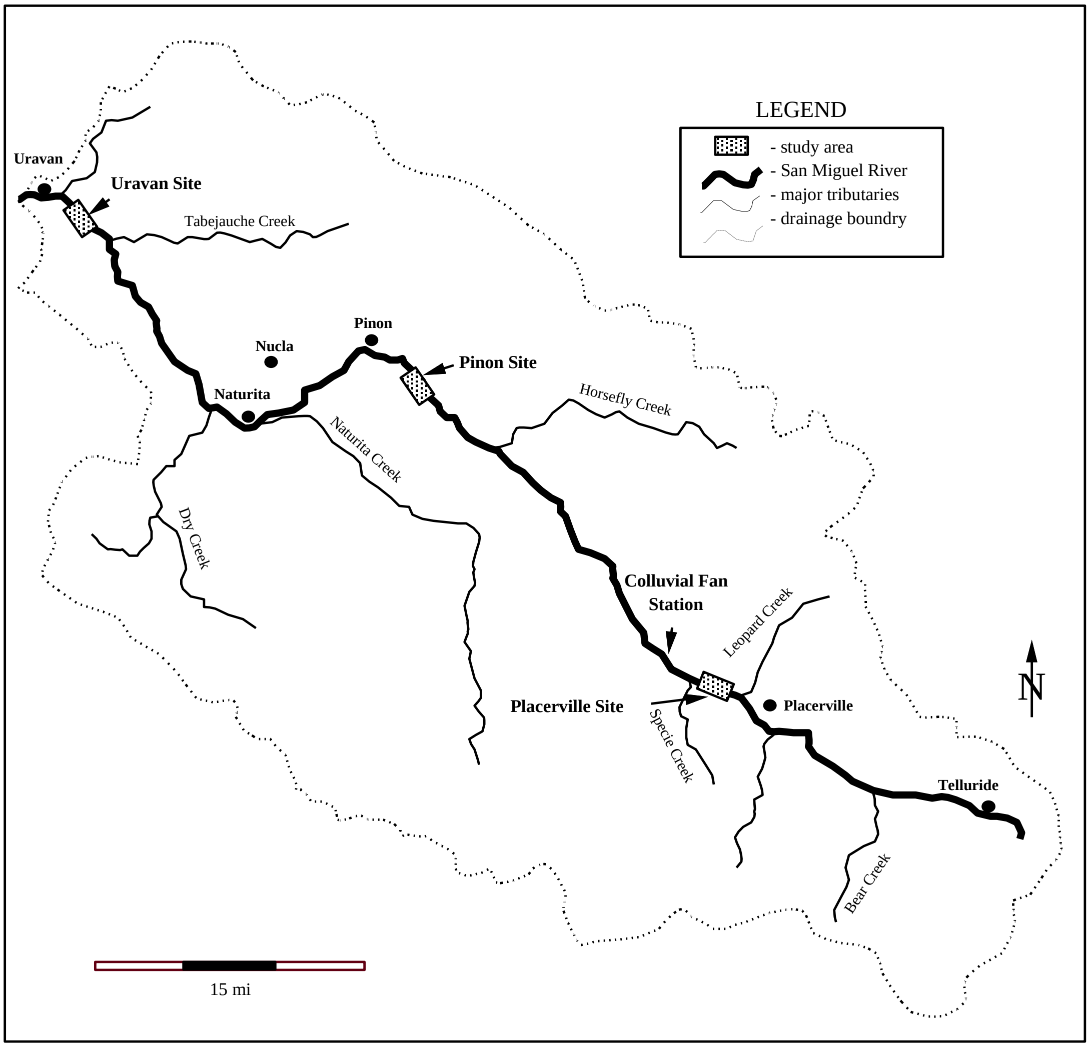

Figure 1. The San Miguel River watershed in southwestern Colorado showing location of our Placerville, Pinon and Uruvan study sites.

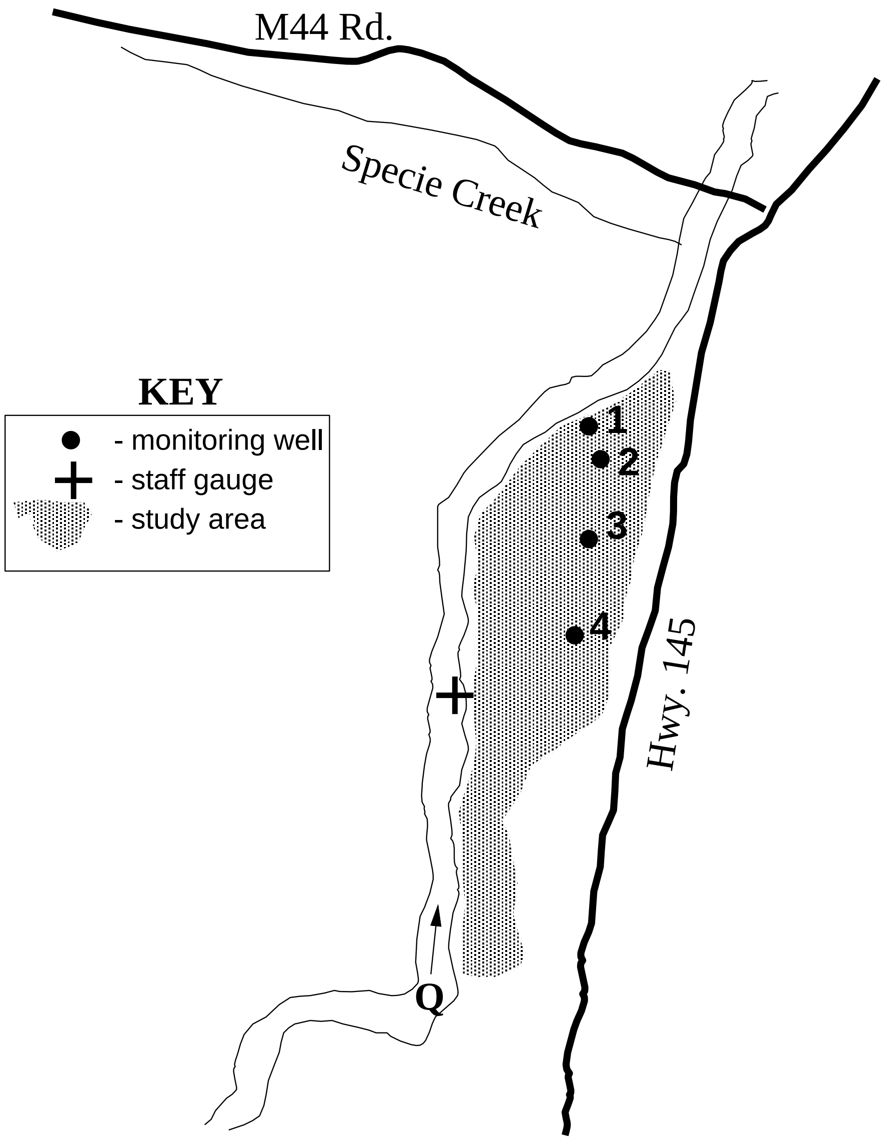

Figure 1a. Map showing the location of wells and staff gauges at the Placerville study site (the colluvial fan study site (station 5) is located 1.5 km downstream).

Along the Placerville river reach narrowleaf cottonwood populations occur not only on the main floodplain surfaces, but also on colluvial fans and high terraces well above the floodplain. Non-riparian plant species such as Gambel's Oak (*Quercus gambelii* Nuttall) and Utah Juniper (*Sabina osteosperma* Antoine) typically co-dominate these portions of the floodplain and colluvial fans.

The lower portion of the floodplain contains a number of small channels that carry flowing water during most of the summer. Beavers were active in this area and influence water elevation in channels through dam construction and deepening. The floodplain contains a distinct basal cobble-layer with bare cobble surfaces at the lowest elevations. On higher floodplain surfaces up to 1 m of fine-textured soil covers the floodplain. Floodplain soils are heterogeneous with regard to thickness and texture, ranging from coarse sand to sandy loam.

The San Miguel River has a steep gradient through this river reach with a bed of medium-size cobble and large boulders. Peak flow typically occurs in early June and averages 40 m^3/s. Base flow is typically reached by mid-August and averages 6 m^3/s (mean of 1993-1997 water years). Some water diversions occur above this river reach, however they do not remove substantial amounts of water during the growing season. Discharge data for this study area were obtained from the USGS Placerville gauge (#09172500) located 1.5-km down-river from the primary study reach. Precipitation data were obtained from a NWS station (#05-6524-02) in the town of Placerville.

Pinon. The river reach at Pinon is the middle study area, at 1,890-m elevation, located on river-left 3-km up-river from the Country Rd. 30 bridge at Pinon (Figure 1b).

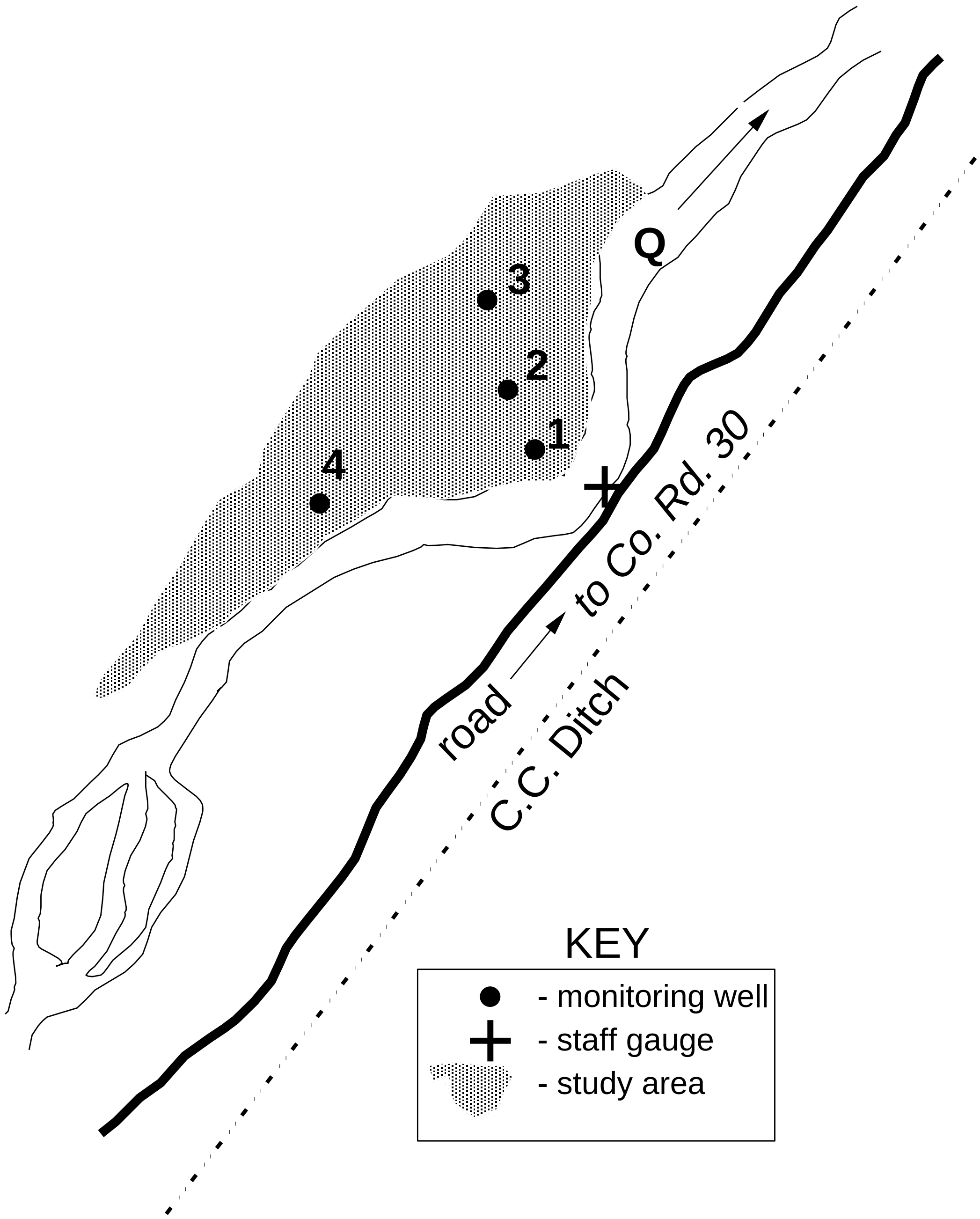

Figure 1b. Map of the Pinon study site showing the location of wells and staff gauges.

The riparian-tree community is composed of narrowleaf cottonwood, river birch, alder, red osier dogwood, narrow-leaf willow, sandbar willow and Fremont cottonwood. Narrowleaf cottonwood is the dominant tree throughout the floodplain, although a few large Fremont cottonwoods occur. A number of dryland species occur on the floodplain including piñon pine (*Pinus edulis* Engelmann) and Utah juniper. The floodplain was divided into two distinct sections based upon plant community composition, tree ages, substrate, landform complexity and position relative to the channel. One part is a low elevation, frequently flooded bar of large cobble and sand. *Salix* spp. dominates the channels while young narrowleaf cottonwoods occupy higher surfaces. The second part of the floodplain is the terrace that slopes up to the canyon wall. Mature cottonwoods and dryland plant species occur, and soils are a thin loam horizon over cobbles.

The San Miguel River has a moderate gradient through this reach with a bed of large-cobbles. The average peak-flow of 50 m^3/s typically occurs in late May and base-flow of 6 m^3/s is reached in mid-August. The CC ditch can divert up to ~4 m^3/s at a point ~2-km up-stream from this study site. Discharge data for this study area was obtained from a USGS gauge (09174600) located 8.5 km downstream near the town of Nucla and precipitation data was obtained from a remote automated weather station (RAWS) at the Nucla airport.

Uravan. The lowest elevation study reach is Uravan, located at 1,585-m elevation. It is located on river-left along Hwy. 141, 5-km upstream from the town of Uravan (Figure 1c). The riparian community is dominated by Fremont cottonwood, narrowleaf cottonwood, hybrid cottonwood (*Populus* x *acuminata* Rydberg), skunk brush (*Rhus trilobata* Weber), New Mexican privet (*Forestiera pubescens* Nuttall), and willow.

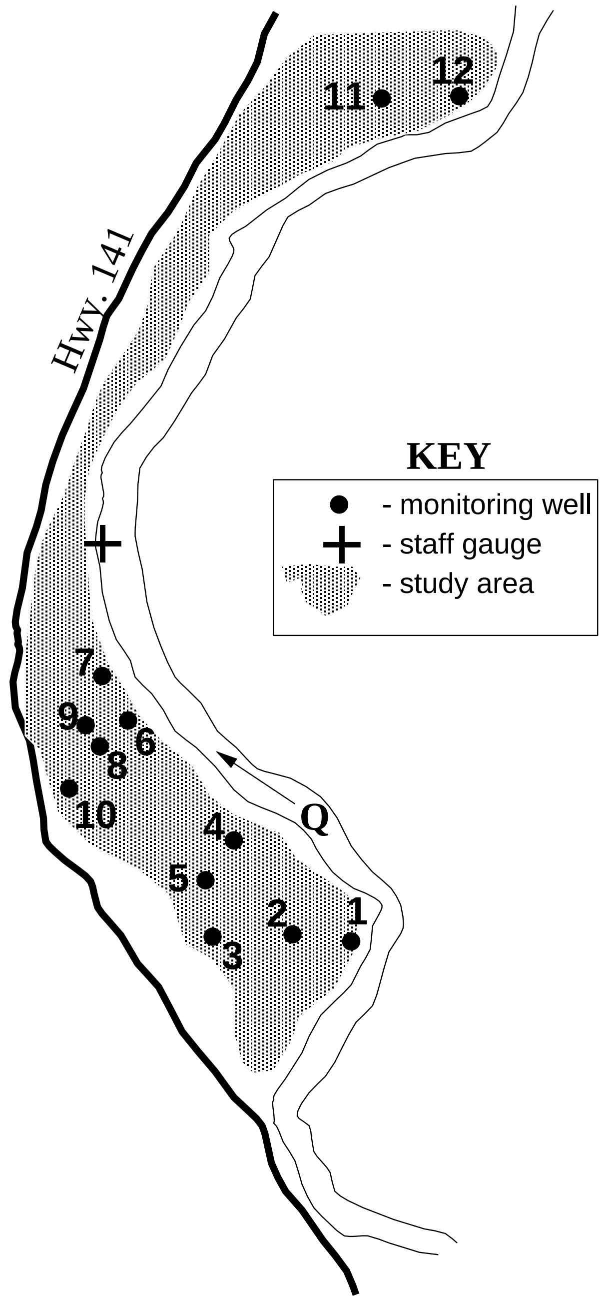

Figure 1a. Map of the Uravan study site showing the location of wells and staff gauges.

Willows, reed grass (*Phragmites australis*), and young cottonwoods occupy the lowest and most frequently flooded surfaces. Mature narrowleaf cottonwoods occur only on the mid-elevation portion of the floodplain, while mature Fremont cottonwoods occur on both middle and upper elevations. A number of dryland species occur on the higher portions of the floodplain including; big sagebrush (*Seriphidium tridentatum* (Nuttall) Weber), rabbit brush (*Chrysothamnus nauseosus* (Pallas) Britton). The floodplain gently slopes from the river up to the canyon-side with a moderate amount of topographic variability. Several intermittent tributaries from the canyon sides have formed alluvial fans onto the upper portions of the floodplain. In addition, a flood channel, and several areas of excavation by heavy machinery occur in the floodplain. Floodplain soils are heterogeneous. Typically a surface horizon of sand or loam overlays cobbles.

The San Miguel River through this study area has a moderate gradient with a bed of sand to medium cobble. The average peak-flow of ~67 m^3/s typically occurs in mid-May and base-flow of ~6 m^3/s typically occurs in mid-August. Discharge data for this study area was obtained from a USGS gauge (09177000) located 2-km up-stream from Uravan and on the lower edge of this study area. Precipitation data were obtained from a NWS station in Uravan.

METHODS

Water Level Characterization. Depth to groundwater and relative height of the river stage was measured to determine the relationship between floodplain groundwater levels and river stage. Water levels were monitored from May to August 1998 (Figure 2).

Staff gauges were constructed of 1.5-m long steel fence posts installed in a deep, relatively calm portion of the river channel adjacent to each study area. Staff gauges constructed from steel rebar were also installed in small channels within the floodplain at Placerville. Water levels in these channels were monitored from July through August. River stage was quantified as water depths above the channel bed (zero datum).

Within each study area monitoring wells were installed to represent the full range of floodplain elevations and plant communities; 5 wells at Placerville, 4 at Pinon, and 12 at Uravan. Wells were constructed using a variety of methods depending upon water table depth and soil texture. For locations with shallow water tables, holes were augured with a 10-cm diameter hand-auger or excavated by hand with a spade and post-hole digger. These wells were cased with 3.2-cm diameter, schedule 80 PVC pipe. The lower 1-m of well was machine-slotted well screen and the upper section was solid. Steel well points were driven with a fence-post installer into locations with deeper water tables or coarser textured material. Well points were constructed of machine-slotted well screen over the bottom 91 cm (3.2-cm ID PVC) and the upper portion of solid pipe (3.2-cm ID schedule 80 PVC). All well casings were permanently capped at the bottom and back-filled with native material. Water levels were recorded as depth from the native soil surface to the water table with an electronic tape.

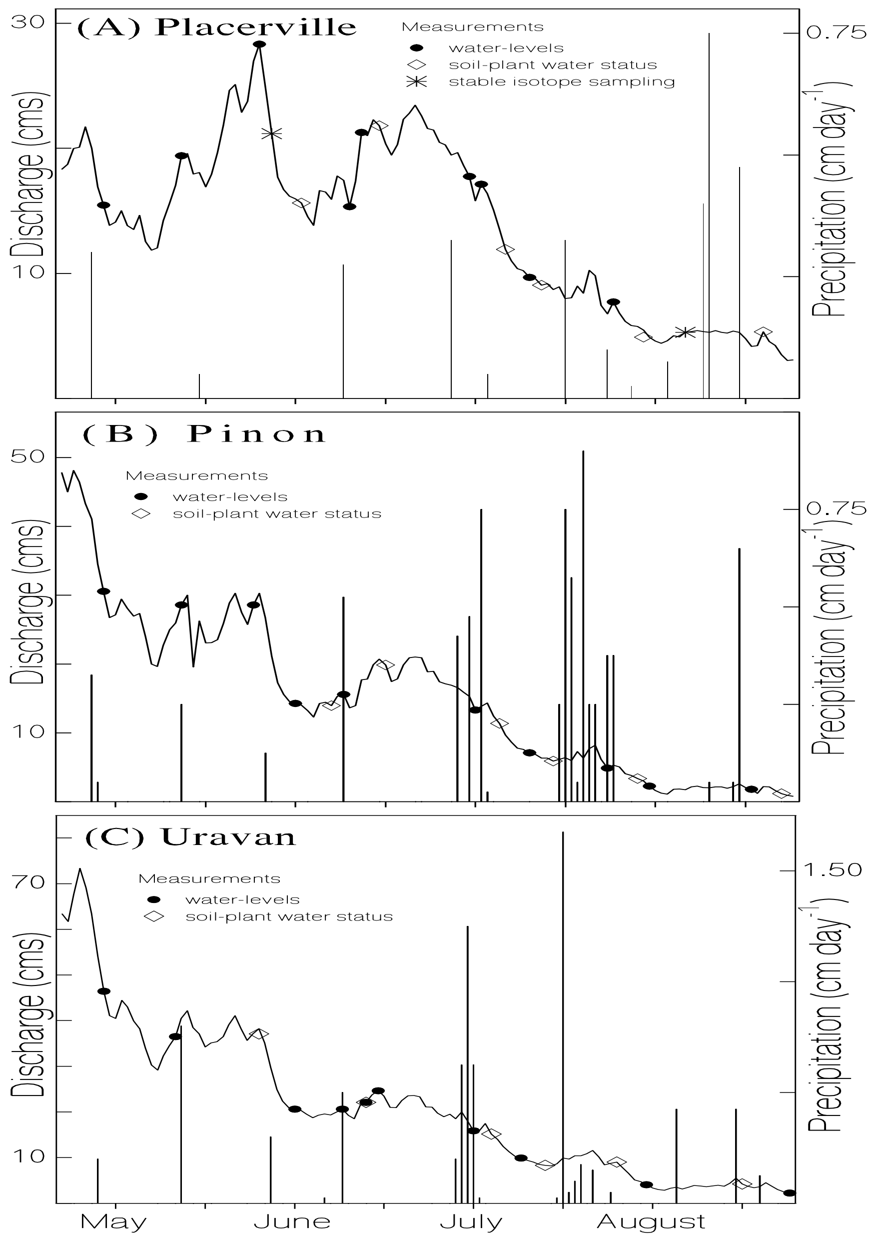

Figure 2. San Miguel River flow and daily precipitation for the three study sites during 1998. Also identified are the dates of water levels monitoring, cottonwood and soil water status measurements, and sample collection for stable isotope analysis.

Staff gauges and monitoring wells were surveyed (stadia rod and level-sight) as elevation relative to the San Miguel River. However, we do not feel that these data are reliable, and have not used them. Floodplain water levels were related to river stage using Pearson's correlation analysis (Cohort Software 1995).

Soil Water Characterization. Volumetric soil water content was quantified at selected wells (stations) in each study area. Soil cores (143 cm^3) were extracted from 18 to 30-cm soil depth using a galvanized-steel pipe (4-cm diameter) and stored in zip-seal plastic bags. Soil samples were weighed, dried at 95□C for 24 h in a gravimetric oven, and re-weighed. Volumetric soil-moisture content was determined according to the following equation:

$$\%\ \text{Soil Water by Volume} = \{(\text{Wet Soil} - \text{Dry Soil}) / \text{Soil-Volume}\} \times 100 \qquad (1),$$

where the density of water was assumed to be 1.0 g/cm^3.

Soil texture was determined from three composite samples for each sampling station using the hydrometer method. Percent sand was determined from the 40-second hydrometer reading, percent clay from the 2-hour reading, and silt was determined as the residual. Permanent wilting point was determined for each soil from standard curves based USDA soil texture classifications.

Cottonwood Water Source Analysis. The water source used by narrow leaf cottonwood was assessed at the Placerville study site in early and late summer using stable isotope analysis. Water molecules contain two hydrogen, and one oxygen atom. However, hydrogen occurs as several stable isotopes, including hydrogen (H with an atomic mass of 1), deuterium (D, atomic mass of 2), and tritium (T, atomic mass of 3). Thus, water molecules may contain an atom of D or T. When subject to evaporation, lighter water molecules containing only H ions, evaporate more readily than heavier water molecules containing an atom of D or T. Evaporative processes can produce heavier water that is enriched in D. Water sources, eg. precipitation vs. ground water, typically contain unique ratios of D/H, referred to as δD. Water acquisition patterns of cottonwood trees can be determined from the analysis of tree sap, and comparison of sap δD with the δD of all potential water sources, eg. soil water and ground water. Water

Stable isotopic analysis was conducted on water collected from narrowleaf cottonwood sap, soil at two depths, ground water, river-water, and precipitation.

Samples for isotopic analysis were collected during peak flow (early-June) and again during the base-flow period (mid-August) (Figure 2). Isotopic analyses were performed at three stations at the Placerville study site: W-3, a low elevation floodplain area, W-4, a higher elevation floodplain area, and W-5, the colluvial fan area. At each station, three trees were sampled by extracting cores from the tree trunk with a standard increment borer. Cores were placed in HDPE scintillation vials. Soil samples were collected from two depths, 0 - 20 cm and 20 - 50 cm to represent soil horizons recharged by precipitation. Soil samples were placed within two individual zip-seal bags (double bagged). Ground water monitoring wells at each station were purged three times with a bailer and one water sample was collected in a 60-mL polyethylene bottle. One sample of river water was collected into a 60-mL polyethylene bottle. Precipitation was collected from the nearest preceding rain event using a funnel mounted onto a bottle buried in the soil. A layer of mineral oil in the bottle prevented evaporation. Water was extracted from the sample using a sterile syringe and placed in a 60-mL polyethylene bottle. All water sample bottles were sealed with plastic tape. All samples for isotopic analysis were frozen until analysis.

Water was extracted from soils and xylem using cryogenic distillation methods (Ehleringer and Osmond 1989). Analysis was performed on a mass spectrometer by Matt Emmons of Mountain Mass Spectrometry, Evergreen, Colorado. He calculated the isotope ratio relative to that of a standard, δD, as:

$$\delta D\ (\%) = [(D/H)_{sample}/(D/H)_{SMOW} - 1] \times 1000,$$

using Standard Mean Ocean Water (SMOW) as the standard (Dawson 1992).

Cottonwood Water Status Characterization. The water status of cottonwoods was assessed by measuring stem xylem pressure (negative pressure or suction reported in Mega Pascal's (MPa) at mid-day and pre-dawn using a Scholander-type pressure bomb (PMS®). Mid-day measurements (1300 - 1600 h) were taken when plants are undergoing maximum water-stress to determine if plants were approaching the point of cavitation (-1.8 to -2.0 MPa). Pre-dawn measurements (0200 - 0500 h) were taken to determine if plants are able to recover their water balance at night when stomates are closed. We have found (Cooper and D'Amico unpublished data) that cottonwoods with pre-dawn water potentials < -0.5 MPa are not recovering, and are highly susceptible to drought induced cavitation. Sampling stations were selected to assess the importance of floodplain position on cottonwood water-stress and the corresponding influences of groundwater levels, soil moisture, and precipitation.

Mid-day and pre-dawn measurements were taken during six periods at each study area from June to August (Figure 2). Narrowleaf cottonwood was assessed at 3 stations per study area. Fremont cottonwood was assessed at 6 stations at Uravan. For the first four periods of measurement (June - July), a minimum of 2 twigs per station was measured at mid-day and pre-dawn. For the last 2 periods of measurement (August), 3 trees were measured per station at mid-day and pre-dawn.

RESULTS

PLACERVILLE - *Groundwater Relationships*

San Miguel River flow peaked at the Placerville gauge in early June 1998 at 29 m^3/s. From peak flow, river stage dropped 46 cm to a base flow in August of ~6 m^3/s (Figure 3).

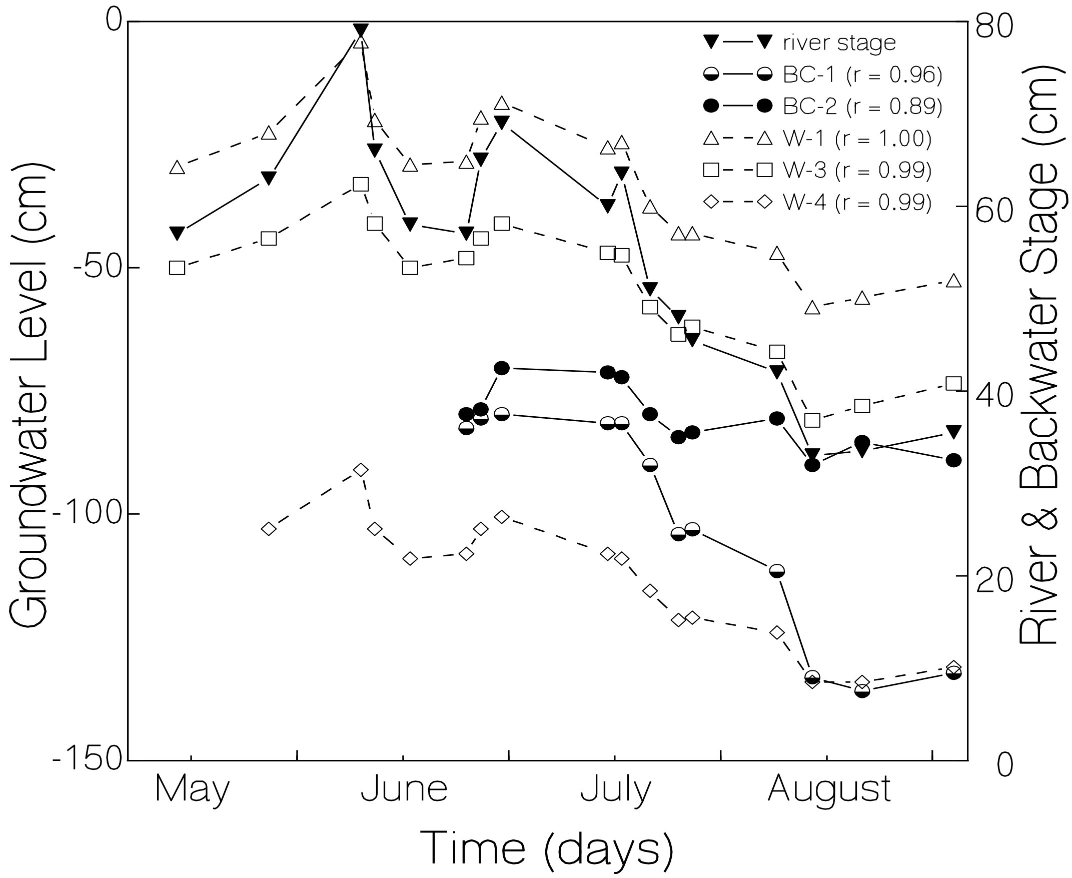

Figure 3. Water table depth (W), and backwater stage (BC) and San Miguel River stage at Placerville. Correlation coefficients for river stage vs. groundwater depth and backwater stage, are in parentheses.

Groundwater levels in all wells were highly correlated with river stage (Figure 3). The lowest elevation well (W-1) was completely correlated with river stage ($r = 1.00$, $p < 0.0001$) while the highest elevation well (W-4) still had a very strong correlation with river stage ($r = 0.99$, $p < 0.0001$). In early June the δD of groundwater in the low and high floodplain wells was very similar to river water, which had a δD of –102. This indicates that the river most likely was supplying water to these floodplain areas. At this same time ground water at the colluvial fan site was more negative than river water.

In mid-August, river water had a δD of -104 while the three groundwater sites had a δD of -112 (Figure 6). This suggests that the isotopic ratio of river water changed little during the summer, while the chemistry of ground water in the low and high elevation wells changes substantially. The δD of the colluvial fan ground water changed little from its early summer measurement. It indicates that in late summer water sources other than the San Miguel River contribute significantly to floodplain groundwater. The additional water source most likely is ground water from the adjacent hillslopes.

Water tables at wells W-1 and W-2 dropped by 54 cm and 53 cm, respectively, during the summer. The water table at the middle elevation well W-3 and higher elevation well W-4, changed 48 and 43 cm, respectively. River stage during this same period changed by 46 cm (Figure 3). Water stage in one of the backwater sites changed by only 30 cm during the study period, and was highly correlated with river stage ($r = 0.96$, $p < 0.01$) (Figure 3). Another back-channel was less correlated with river stage ($r = 0.89$, $p < 0.04$) and fluctuated only 11 cm during the same period, due apparently to beaver regulation of water levels.

Ground water levels in the colluvial fan well (W-5) were significantly correlated with river stage ($r = 0.89$, $p < 0.04$). Well W-5 is located ~5.4 m above the river at base flow stage, and the water table was -546 cm and -603 cm, below the soil surface in late May in late August, respectively (Figure 4). During this same time period, the San Miguel River dropped approximately 37 cm.

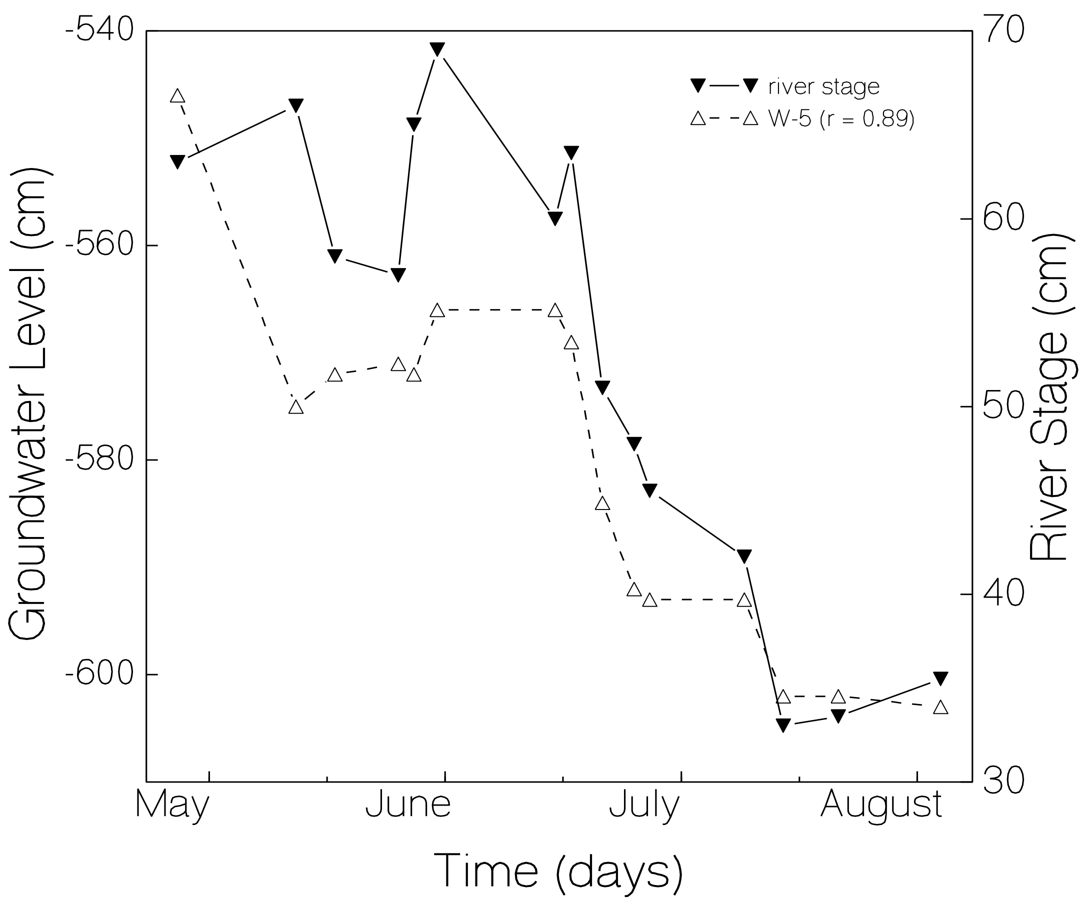

Figure 4. San Miguel River stage and ground water depth at well W-5. Pearson's Correlation Coefficient is shown in parenthesis

Groundwater in well W-5 had a δD of –108 in June and –115 in August, while river water had a δD of -102 in June and –104 in August (Figure 6). This indicates that hillslope ground water more depleted in D (more negative δD) contributed to this sites ground water throughout the summer. It is unclear whether the San Miguel River contributed any ground water to W-5. However, river stage controls ground water levels at this site through the summer (Figure 4).

PLACERVILLE - *Soil Moisture Regime*

Mean volumetric soil water content at 18 to 30 cm depth ranged from 41 % in early-June to 30 % in late-July, although water content varied across the floodplain (Figure 5). At the Colluvial fan site (W-5) soil water content was highest in late May and lowest in late-June.

It was not possible to directly relate soil moisture content to precipitation as our samples were too widely spaced during the summer. However, soil water content was fairly stable through the summer indicating that rain did replenish soil water.

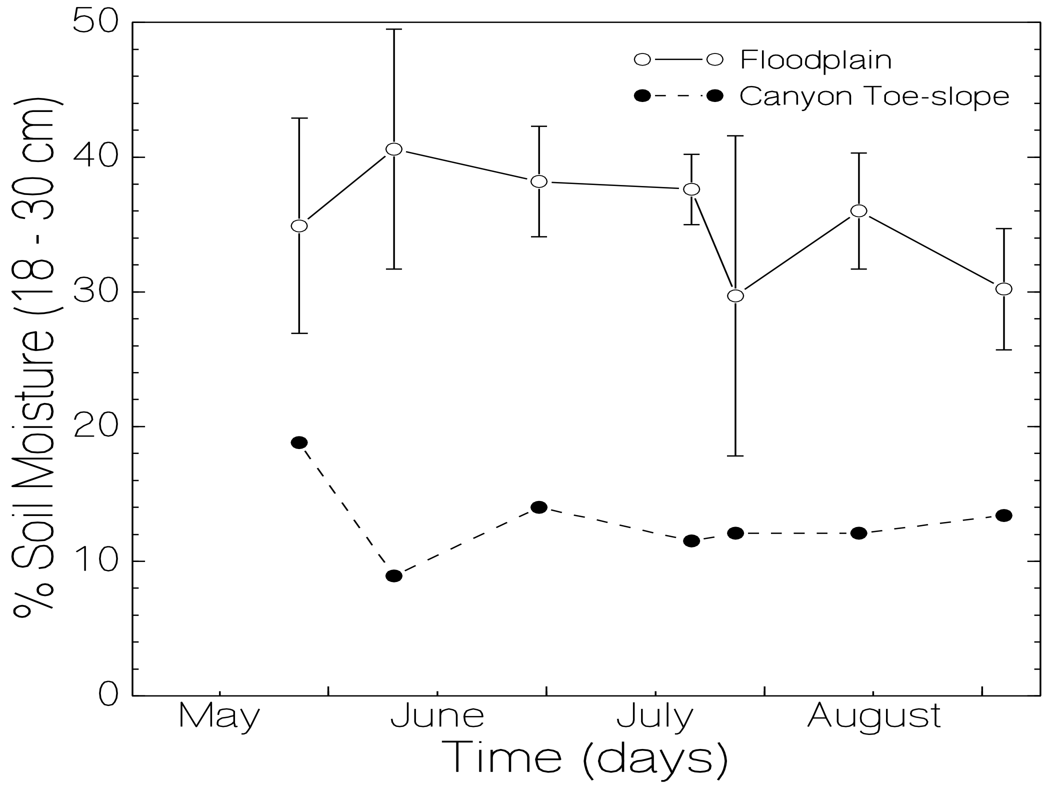

Figure 5. Mean volumetric soil water content for floodplain sites (mean ±1SE) and the colluvial fan site.

The water table at W-3 ranged from 33 to 50 cm below the soil surface in the early summer and capillary water most likely wetted soils to the surface. This site had the highest soil water content in early summer, 48 %, which coincided with river stage and groundwater level peaks. Soil water at 20 - 50 cm depth had a δD of -102 in early June at this site that was nearly identical to groundwater with a δD of -102. By late summer soil water at 0 - 20 cm depth was slightly enriched due to evaporation and had a δD of -99 (Figure 6). At station W-4 soil at 0 -20 cm and 20 - 50 cm depths had δD of -76 and –78, respectively during June, indicating no connection with the ground water.

In August when the water table at W-3 had dropped well below the soil surface, soil water δD was -98 at for both soil depths, while groundwater in well W-3 had a δD of -112 (Figure 6). This indicated that during the summer soils were no longer connected to the water table by capillary action.

Placerville – *Narrowleaf Cottonwood Water Sources*

The δD of narrowleaf cottonwood sap was quite similar at the three sampling stations in June, with a δD of approximately -90 (Figure 6a). For the low floodplain site, the isotopic ratio of soil-water, groundwater, and river water were similar, but tree sap was different. This indicates the connection between river water, ground water and soil water in the horizons sampled. However, trees must have been acquiring water from very shallow soil depths, which were more enriched in D (a less negative δD).

For the high floodplain site soil water δD was similar to rain water during our early June sample period, indicating its probable source. Tree sap appears to be a mixture of soil water and ground water, which was similar to river water. Trees on the colluvial fan site had sap with a δD identical to soil water but distinct from river water and ground water, indicating that trees were acquiring largely soil water. In addition, groundwater had a more negative δD than river water, a signature that persists to the August sample period.

River water had a similar δD on the two sample dates, August and June (Figure 6b). However, all ground water samples in August were more depleted in D (more negative δD) than river water. In addition, the δD of all three groundwater well sites was similar, between –110 to –115. It indicates that hillslope groundwater may be the source of water for the floodplain during late summer when river stage is low. Cottonwood tree sap in August had similar δD at all sites, near –115 and with the variance taken into account was nearly identical to groundwater. It indicates that trees throughout the floodplain rely on groundwater or very deep soil water in late summer, and the source of water does not appear to be the San Miguel River. However, as stated earlier, San Miguel River stage controls groundwater levels.

The isotopic signature of soil water varied in August. At the low floodplain site soil water was similar to river water, while at the higher elevation sites soil water was much more enriched with D (less negative δD). The isotopic signatures of soil water at the high floodplain site were relatively similar in June and August, while the signature of the colluvial fan soils was more enriched in D in August indicating the input of enriched rainwater.

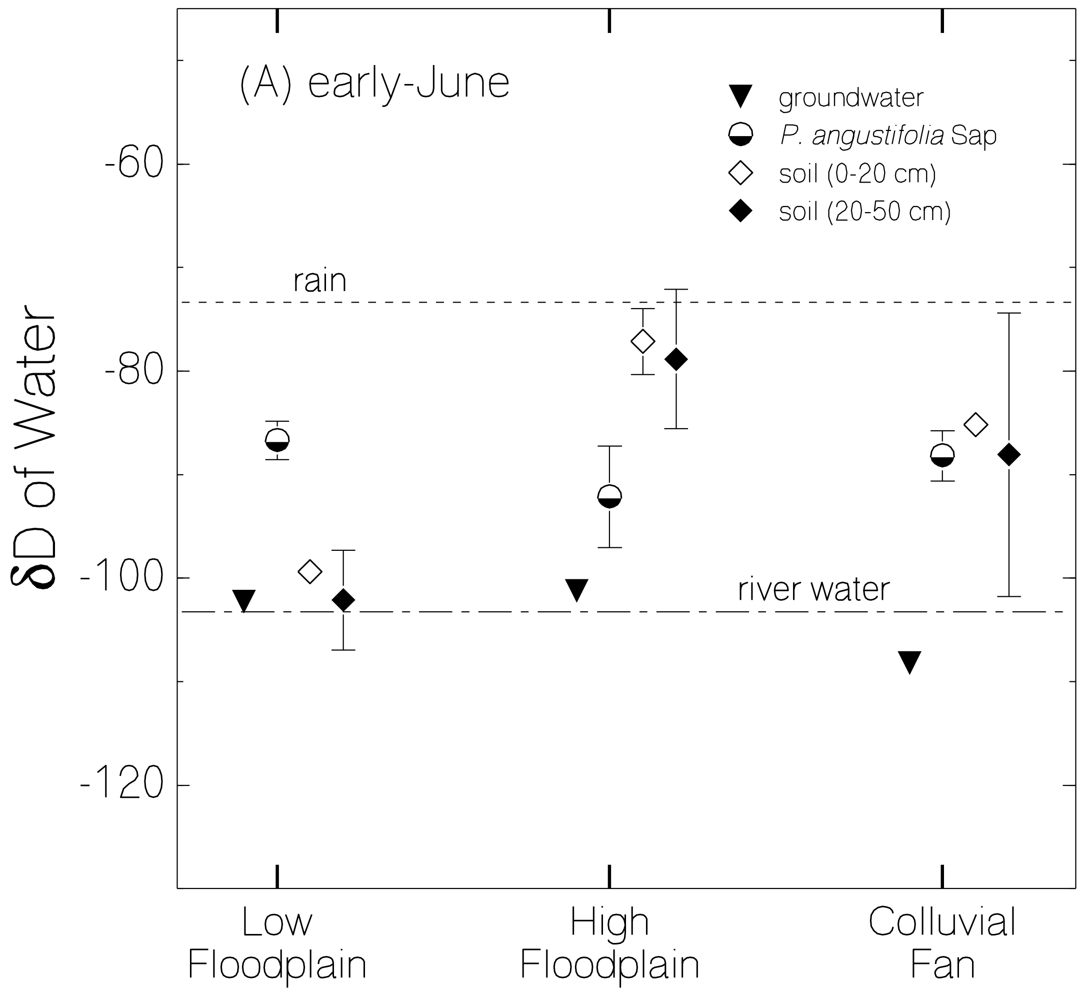

Figure 6a. Stable hydrogen isotope ratios (relative to SMOW) of narrowleaf cottonwood sap, soil water (0 - 20 cm and 20 - 50 cm depths) groundwater, river water, and rain at the Placerville study site in early-June (error bars are ±1 SE for soil and tree sap samples, however groundwater, river-water, and rain are from one sample each). Rain and river water are represented as horizontal lines.

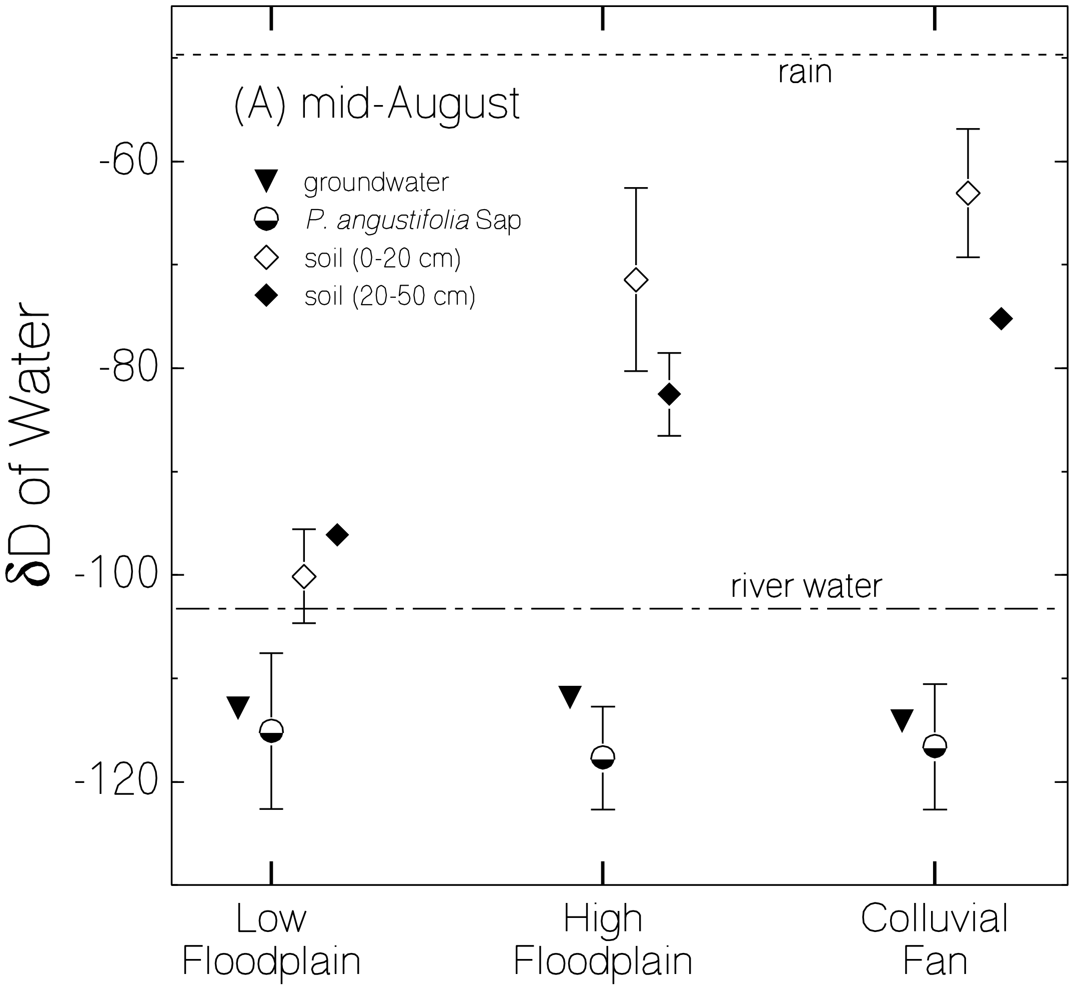

Figure 6b. Stable hydrogen isotope ratios (relative to SMOW) of narrowleaf cottonwood sap, soil water (0 - 20 cm and 20 - 50 cm depths), groundwater, river water, and rain at Placerville on the San Miguel River in mid-August (error bars are ±1 SE for soil and tree sap samples, while groundwater, river-water, and rain are from one sample each). Rain and river water are represented as horizontal lines.

PLACERVILLE - ***Tree Water Status***

Mean xylem water potentials (Ψ_{xp}) for narrowleaf cottonwood at the low and high floodplain study areas averaged -1.3 MPa at mid-day and -0.28 MPa at pre-dawn. These xylem pressures do not indicate significant water stress (Figure 7 and 8). However, mid-day and to some extent pre-dawn xylem potentials appeared to vary with local soil moisture content.

Trees on the colluvial fan had lower mean water potentials than the other floodplain locations, -1.6 MPa at mid-day and -0.5 MPa at pre-dawn (Figure 9). Mid-day xylem potentials of trees were often near levels for severe water stress during July and August, and pre-dawn xylem potentials indicated that the trees were not recovering well (Ψ_{xp} < -0.5 MPa). Soil water content was always low at this site and the water table was extremely deep (~6 m). Isotope analysis of these trees indicated that they relied on soil water in early summer and ground water in late summer. Thus, a deeper water table could severely affect these trees.

The lowest water potentials occurred between late July and early August. Mean Ψ_{xp} was -1.50 MPa during this period, compared to mean of -1.35 MPa in June, early July and late August. This period corresponded to the onset of base flow conditions, the hottest daytime temperatures, and a rainless period (Figs. 7, 8, and 9).

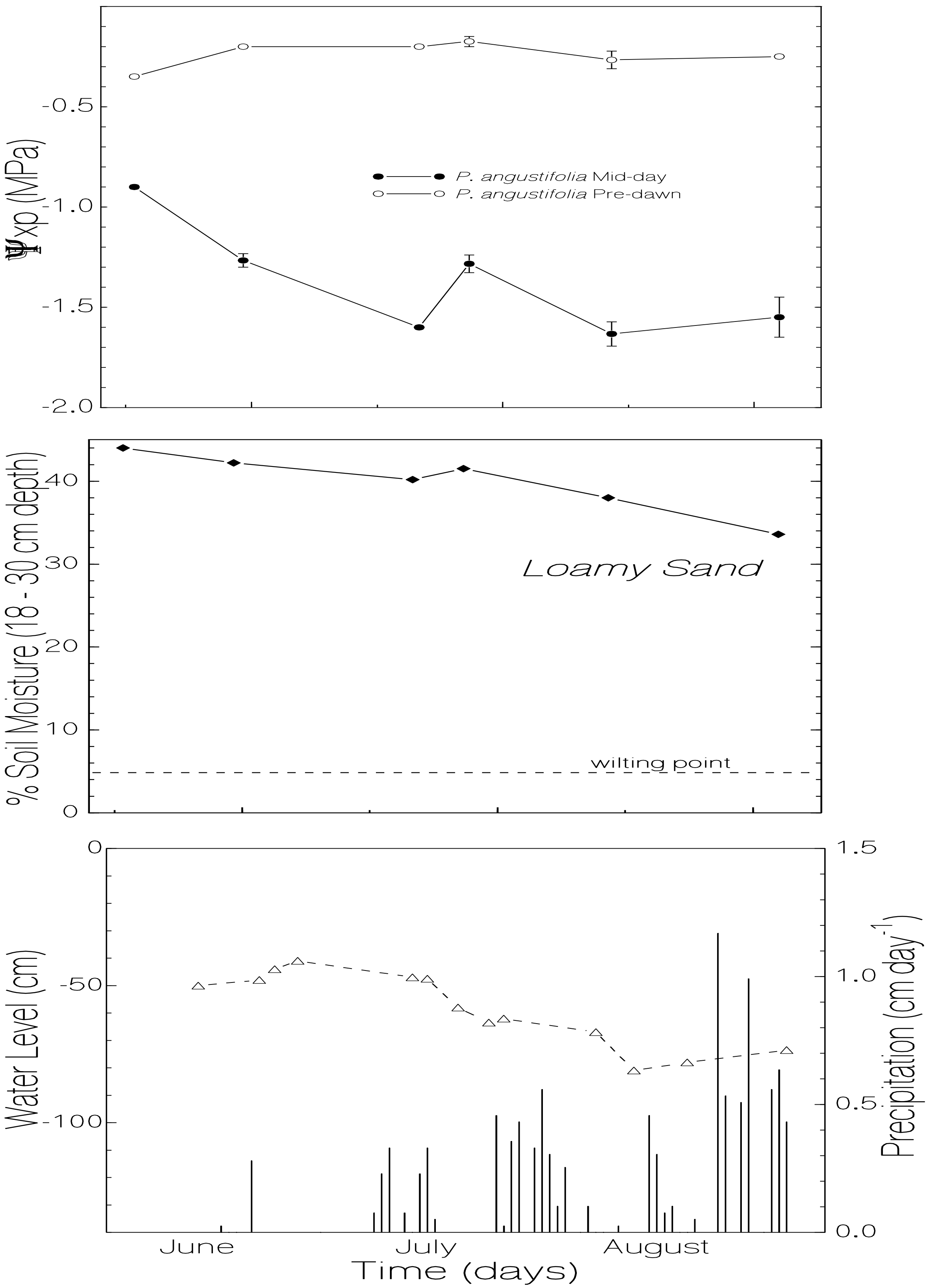

Figure 7. Low floodplain area (Station 3) at Placerville on the San Miguel River.

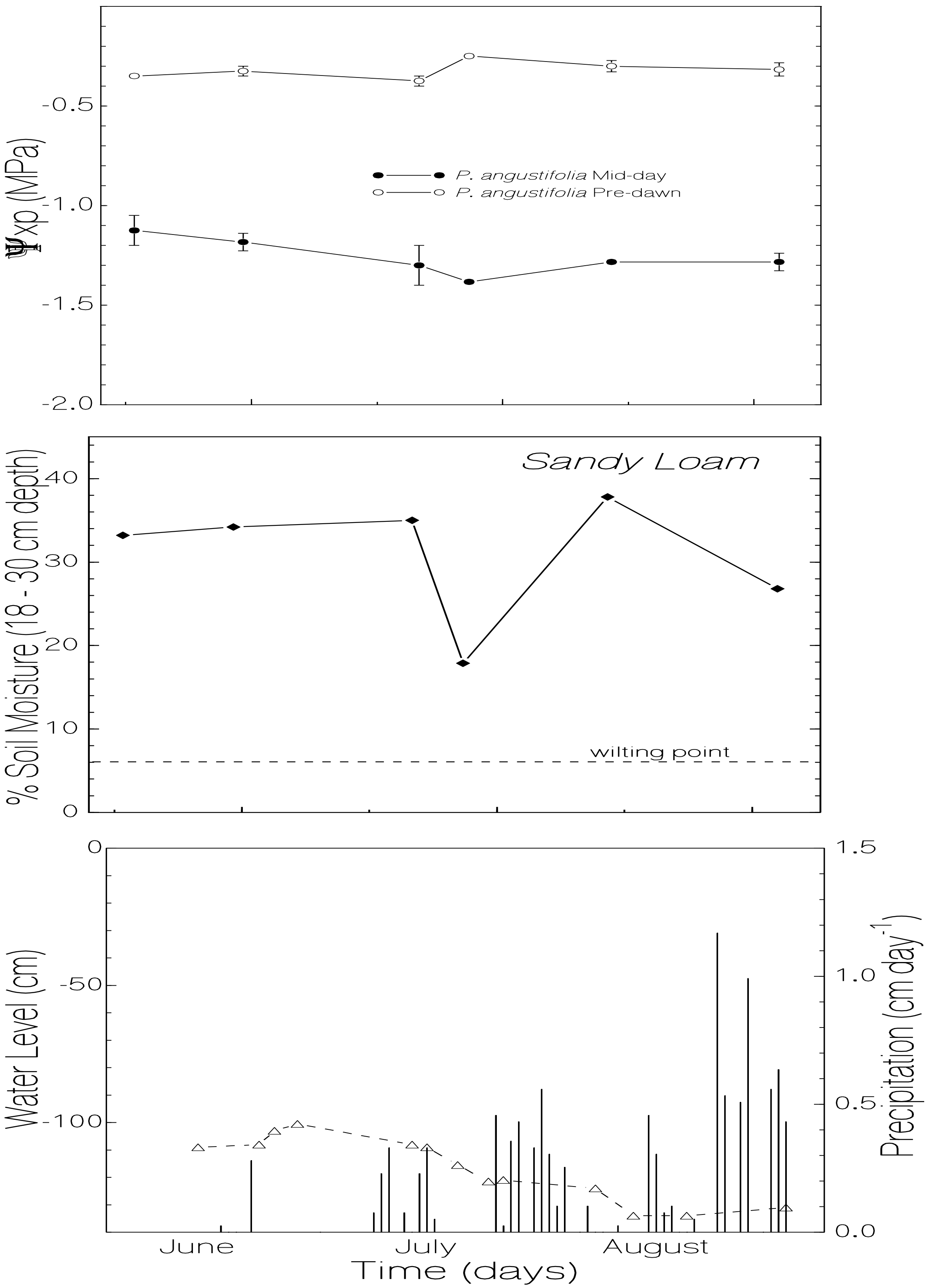

Figure 8. High floodplain area (Station 4) at Placerville on the San Miguel River.

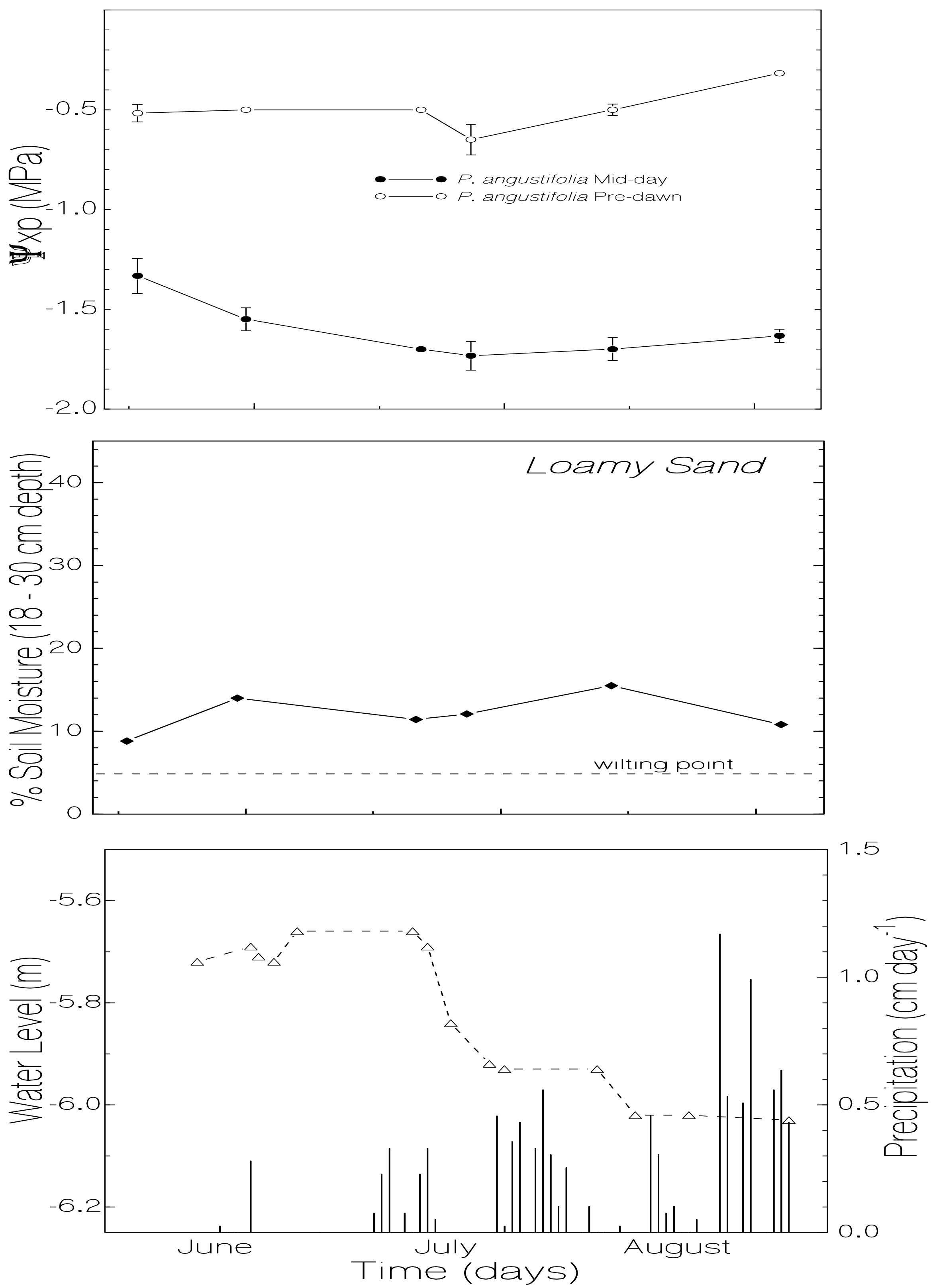

Figure 9. Colluvial fan area (Station 5) at Placerville on the San Miguel River.

PINON - *Groundwater Relationships*

The San Miguel River peak flow at Pinon occurred in late April, at >48 m^3/s. Base flow conditions occurred by early August (< 6 m^3/s) and decreased to < 1 m^3/s in late August. Seventeen August days had flows <2 m^3/s. The change in river stage from peak to base flow was 66 cm (Figure 10).

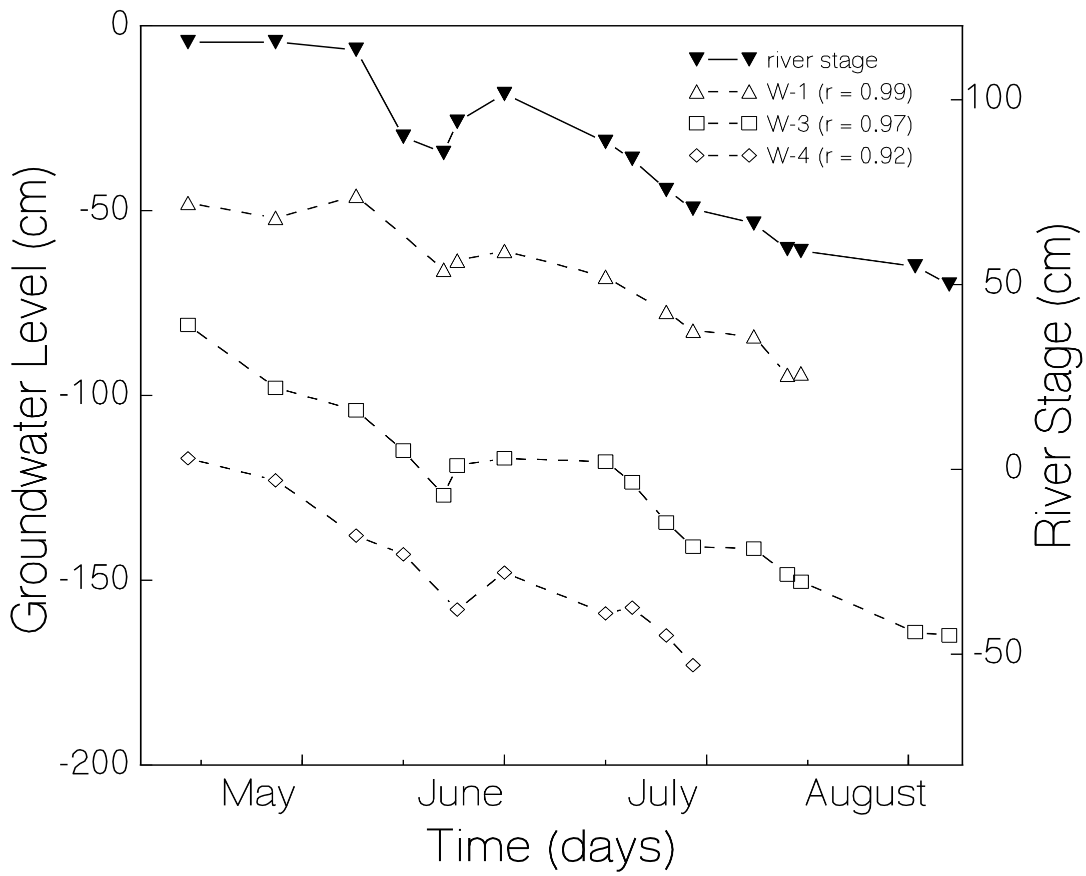

Figure 10. River stage and depth to groundwater during the study period at Pinon. The relationship of groundwater to river stage is presented as Pearson's Correlation Coefficient (parenthesis).

Groundwater levels were strongly related to river stage on the Pinon floodplain. The correlation was strongest at low elevations wells ($r = 0.99$, $p < 0.0001$ at W-1 and W-2) (Figure 10). Ground water leves in higher floodplain sites were also highly correlated with river stage ($r = 0.97$, $p < 0.01$; at well W-3), while this relationship was less strong at the higher site ($r = 0.92$, $p < 0.03$; at well W-4). Interestingly, the highest well, W-4, is closer to the river than either well W-3 or W-2. The water table dropped > 80 cm at all wells, while the river stage changed 66 cm during the same period.

PINON - *Soil Water Regime*

Volumetric soil water content at 18 - 30 cm soil depth was highest in May and decreased to a mean of 8 - 16 % for most of the summer (Figure 11). Soil water content increased in early September in response to a large rain event. Soil water content varied among sites and may be related to differences in soil texture between sites. Mean soil water content from late July to early August was 5 % at Station 2 (sandy soil), 14 % at Station 3 (loamy sand soil), and 17 % at Station 4 (sandy loam soil). However, soil moisture also varied due to precipitation. For example, the June sample collected at W-3 may have high water content due to a coincident rain event.

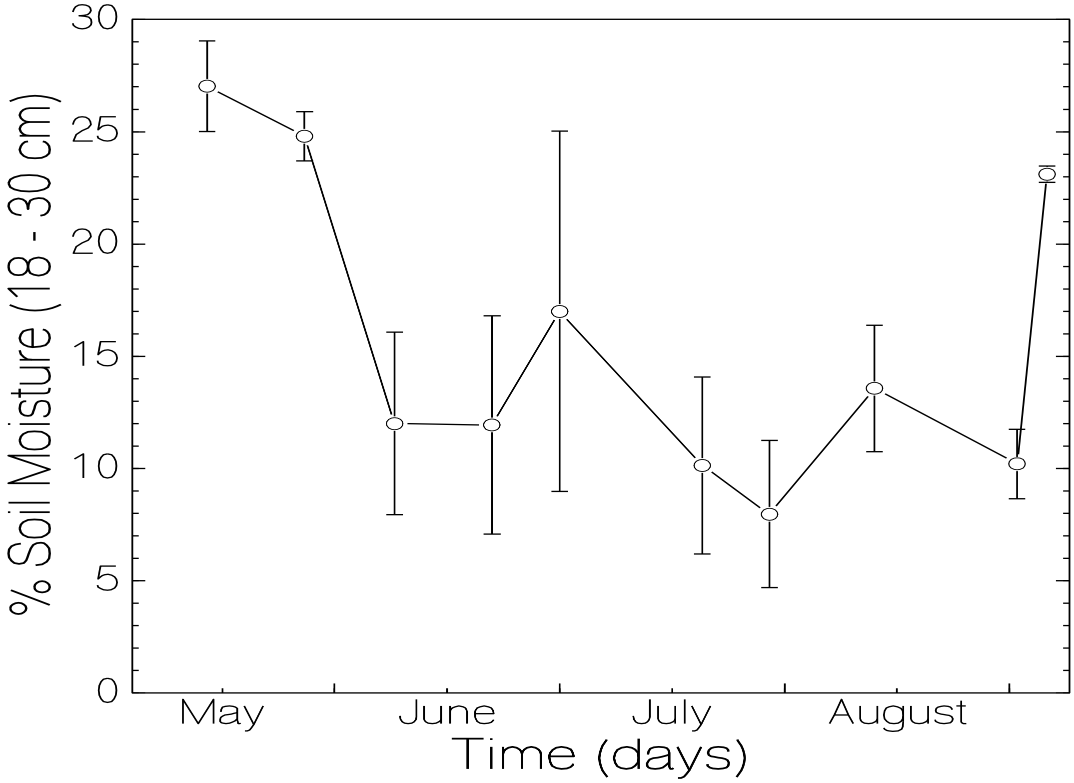

Figure 11. Volumetric soil water content at the Pinon study site (error bars are ±1 SE).

PINON - ***Tree Water Stress***

Mid-day and pre-dawn xylem potentials changed simultaneously, as would be expected. The lowest water potentials occurred in early summer and late summer, most likely during periods with low rainfall and high daytime temperatures. Average mid-day and pre-dawn xylem potentials during these periods were -1.65 MPa and -0.55 MPa, respectively. Several trees had mid-day water potentials lower than -1.8 MPa indicating severe water stress (Figure 12, 13, and 14). The lowest xylem potentials were measured in late June at Station 3, with mid-day values < -1.8 MPa and pre-dawn values < -0.65 MPa (Figure 13).

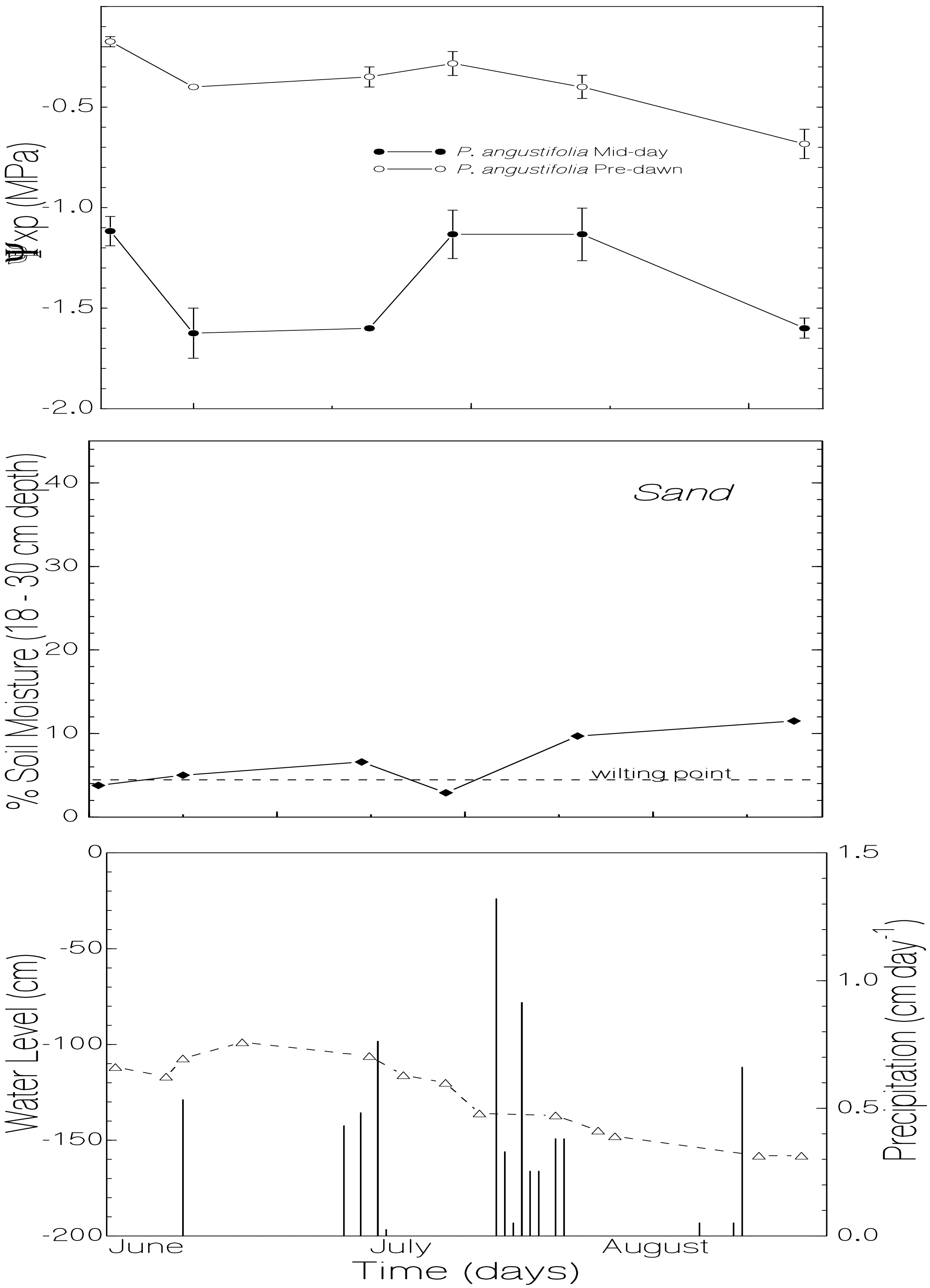

Figure 12. Tree xylem pressures, soil moisture, ground water levels and precipitation at the low floodplain area (W-2) at Pinon.

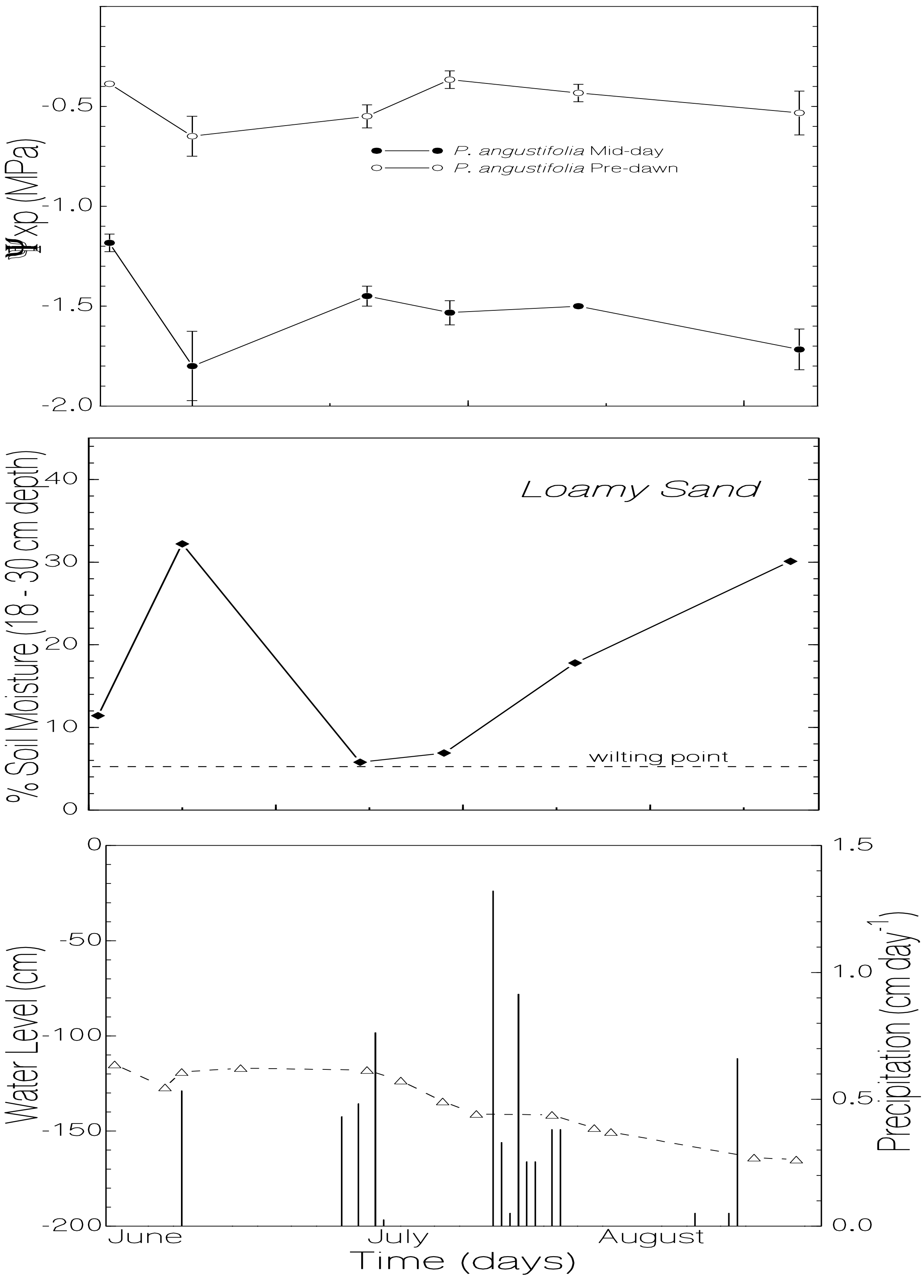

Figure 13. Tree xylem pressures, soil moisture, ground water levels and precipitation at the high-downstream floodplain area (W-3) at Pinon.

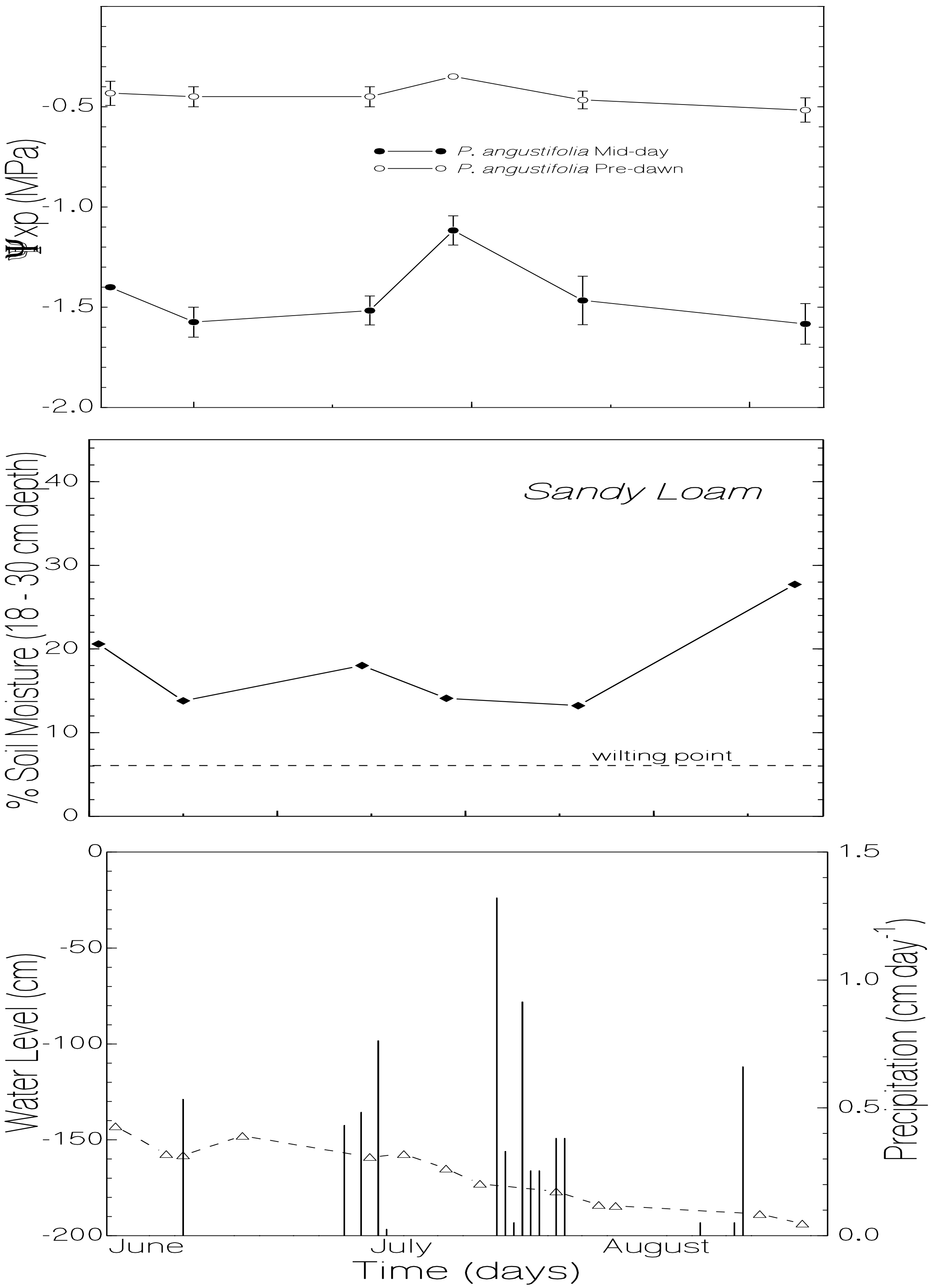

Figure 14. Tree xylem pressures, soil moisture, ground water levels and precipitation at high-upstream floodplain area (W-4) at Pinon.

Soil water content was often near or below wilting point at Pinon Stations 2 and 3. However, xylem pressures at this time did not reflect serious water stress (Figure 12 and 13). Interestingly, low water potentials occurred in early summer even though water tables were still relatively high (Figs. 12, 13, and 14).

URAVAN - *Groundwater Relationships*

The San Miguel River peaked at Uravan in April, long before peak flows occurred at the Placerville site. The highest mean daily flow of 73 m^3/s occurred on 3 May. Base flows <6 m^3/s occurred in early-August and diminished to ~2 m^3/s by late August.

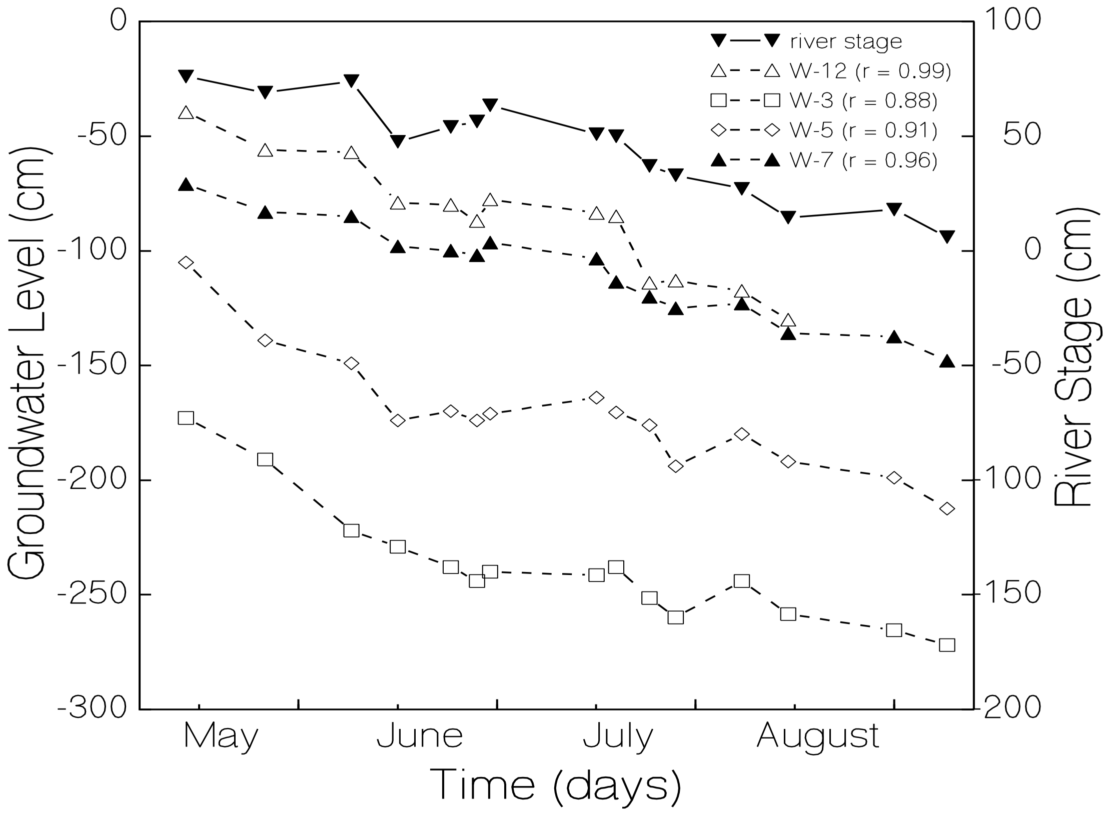

Figure 15. River stage and depth to groundwater during the study period at the Uruvan study site. The relationship of groundwater to river stage for each well is presented as Pearson's Correlation Coefficient (parenthesis).

The water table throughout the Uravan study site floodplain was highly correlated with San Miguel River stage. The strength of this relationship generally decreased with increased height above and distance from the river (Figure 15). The correlation of river-stage to groundwater level ranged from $r = 0.99$ ($p < 0.0001$) at W-2 (1.9 m above the river), W-11 (1.6 m), and W-12 (1.7 m), to a correlation of $r = 0.88$ ($p < 0.04$) at W-3 (2.8 m). Position on the floodplain, other than with elevation above the river, did not appear to influence this relationship.

San Miguel River stage declined 70 cm from the May peak to the August base flow. However, mean difference between groundwater highs and lows for wells was 82 cm at downstream meander locations, while on some middle and upstream-meander locations ground water levels changed by up to 101 cm.

URAVAN - *Soil Water Regime*

Volumetric soil water content at 18 - 30 cm depth ranged from a mean of 24 % in late May to a mean of 12 % in late June. Soil moisture generally decreased during the early part of the summer, yet increased at many sites in July and August (Figure 16). Soil water content at low elevation floodplain sites averaged 35 % in early May compared to 22 % at upper floodplain sites. In late July upper and lower floodplain sites had similar soil water content, ~14 % and ~13 % respectively. From May to August middle elevation areas had the highest mean soil moisture, 22 %, with low variance among sites. A single day rain of 0.8 cm/day on 21 May could have led to higher soil moisture at all stations in late May, as late July precipitation did.

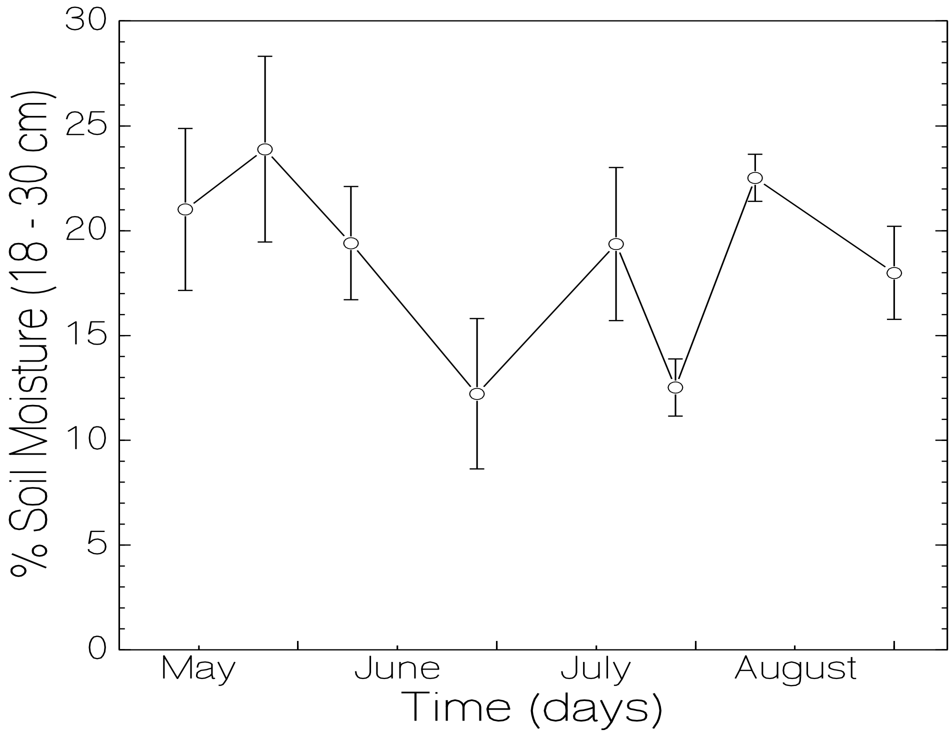

Figure 16. Volumetric soil water content at the Uravan study site (±1 SE).

URAVAN - *Tree Water Status*

Mid-day water potentials lower than -1.8 MPa occurred for Fremont cottonwood at several stations and several times during 1998. These conditions occurred during mid-July for trees adjacent to the San Miguel River (Station 1, Figure 17), during late June to mid-July at the highest floodplain location (Station 3, Figure 19), and during late August at a middle floodplain location (Station 9, Figure 21). Pre-dawn water potentials lower than -0.5 MPa also occurred in trees at all upstream meander locations in late August (Figure 17, 18, and 19) and at lower and middle elevations locations in early-June and late August (Figure 20 and 21).

In general narrowleaf cottonwood trees experienced their lowest mid-day xylem pressure potentials in late June and early July, while Fremont cottonwood experienced their lowest water potentials in August. Pre-dawn xylem potentials for both cottonwood species were lowest in early June and again in late August. At sites supporting both Fremont and narrowleaf cottonwood xylem pressures were typically similar for both species (Figure 17, 18, and 20).

Pre-dawn xylem potentials appeared to be related to soil moisture content, particularly at Stations 1, 2, 6, and 9 (Figure 17, 18, 20, and 21). Higher mid-day xylem pressure potentials in late July may have been due to a 2.7-cm rain event. A general decrease in Fremont cottonwood mid-day xylem pressures appeared to relate to declining groundwater levels and increasing air temperatures during mid-summer.

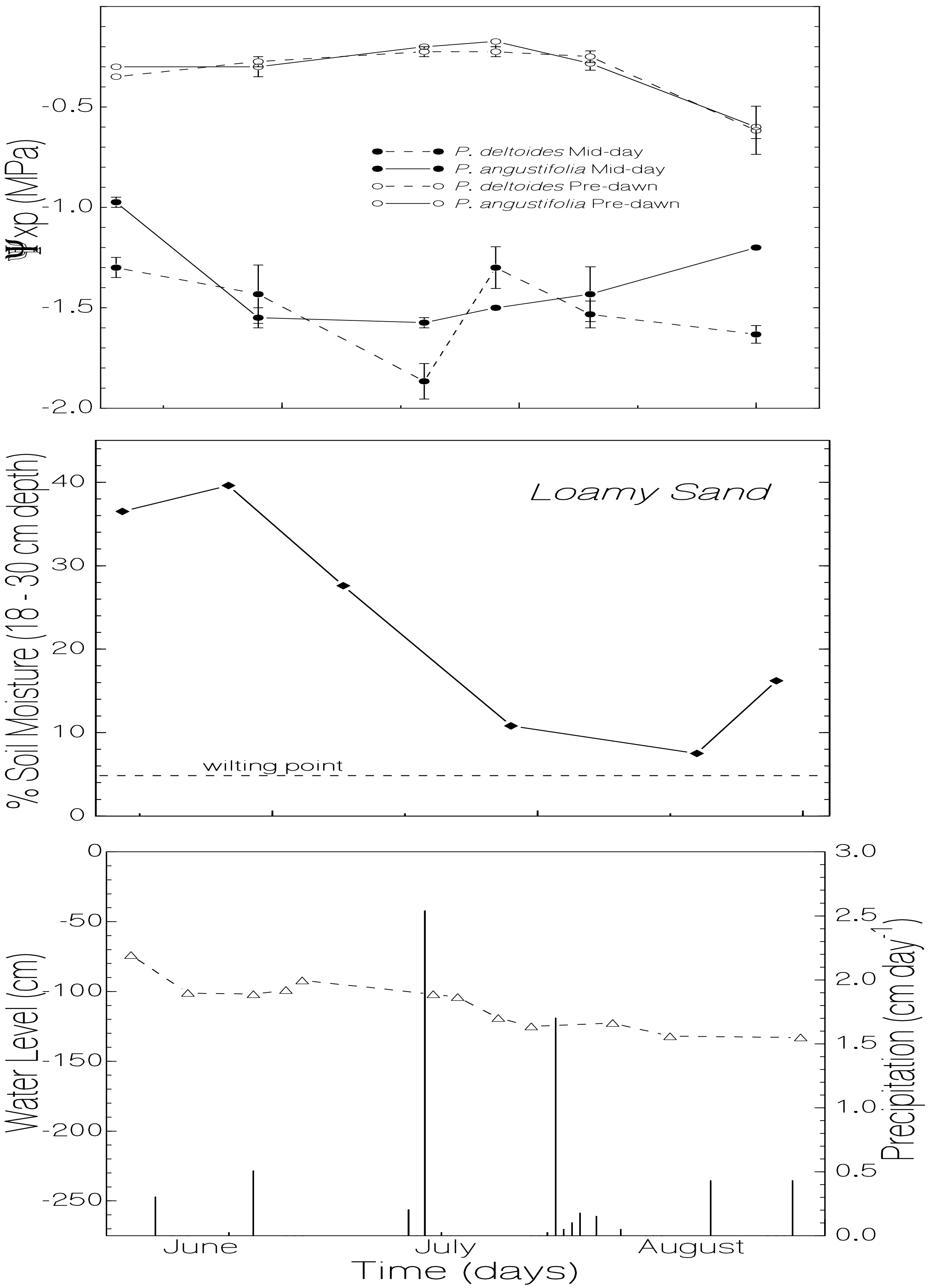

Figure 17. Low elevation upstream floodplain area (Station 1) at Uravan.

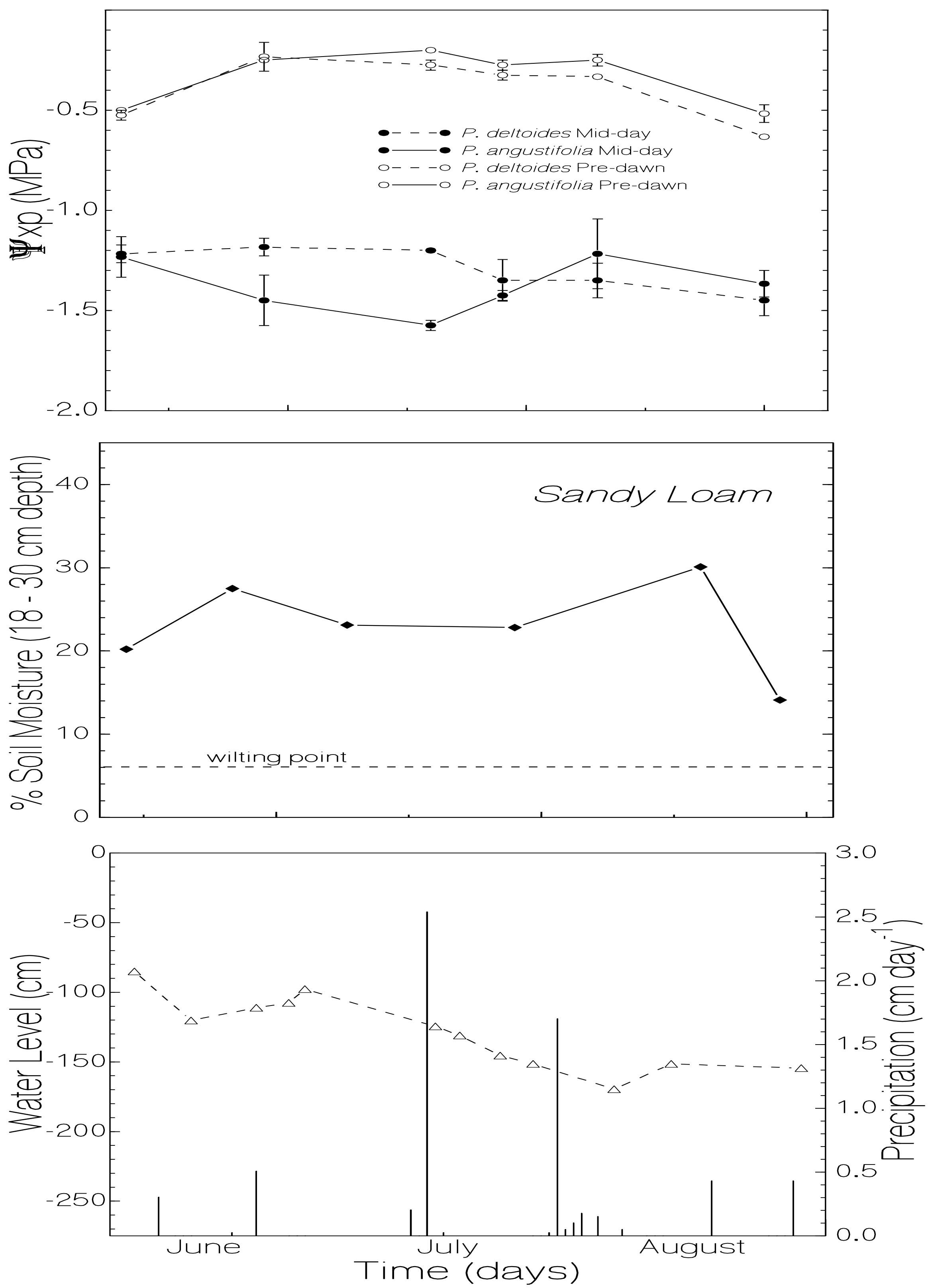

Figure 18. Middle elevation upstream floodplain area (Station 2) at Uravan.

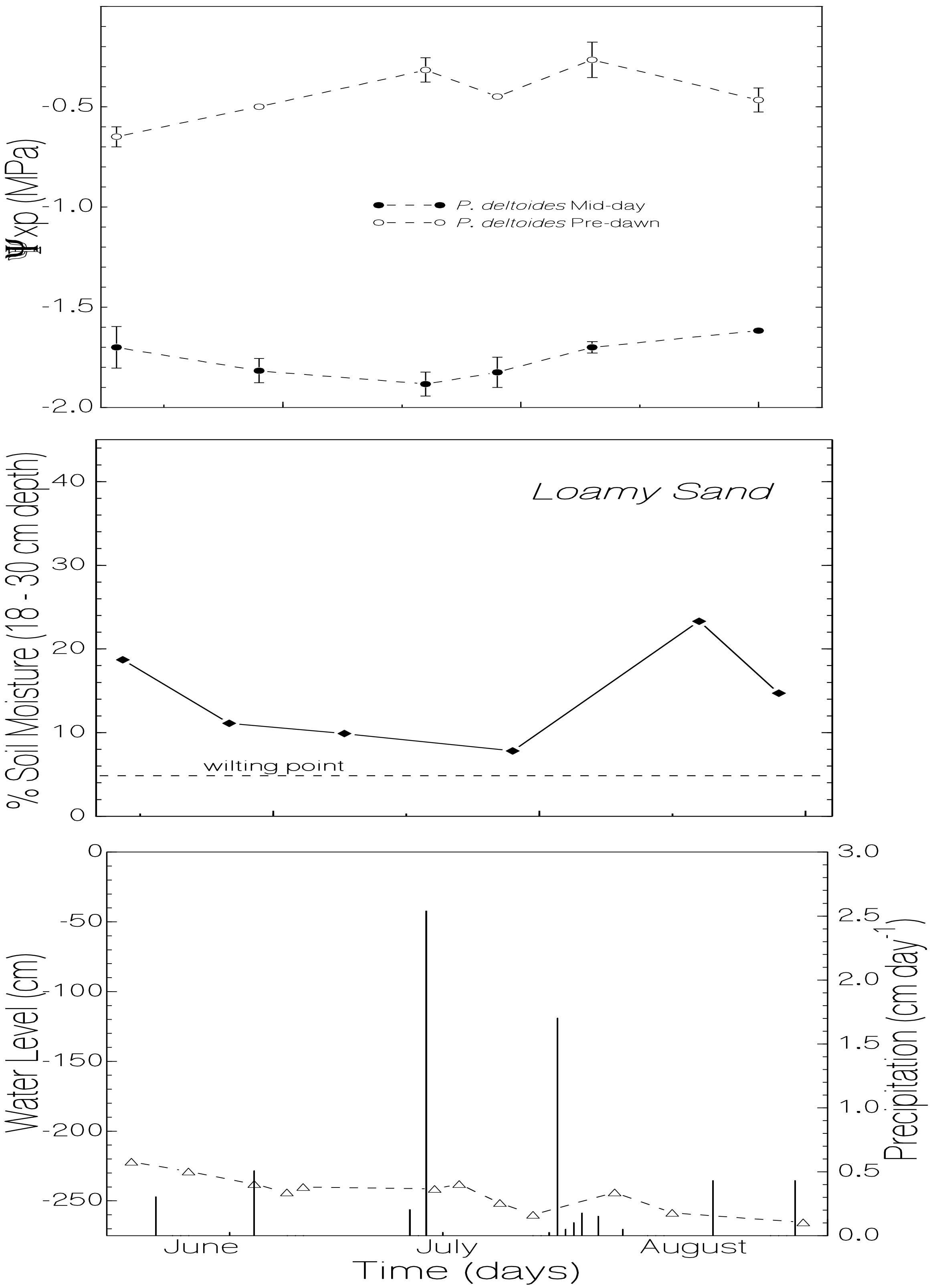

Figure 19. High elevation upstream floodplain (Station 3) at Uravan.

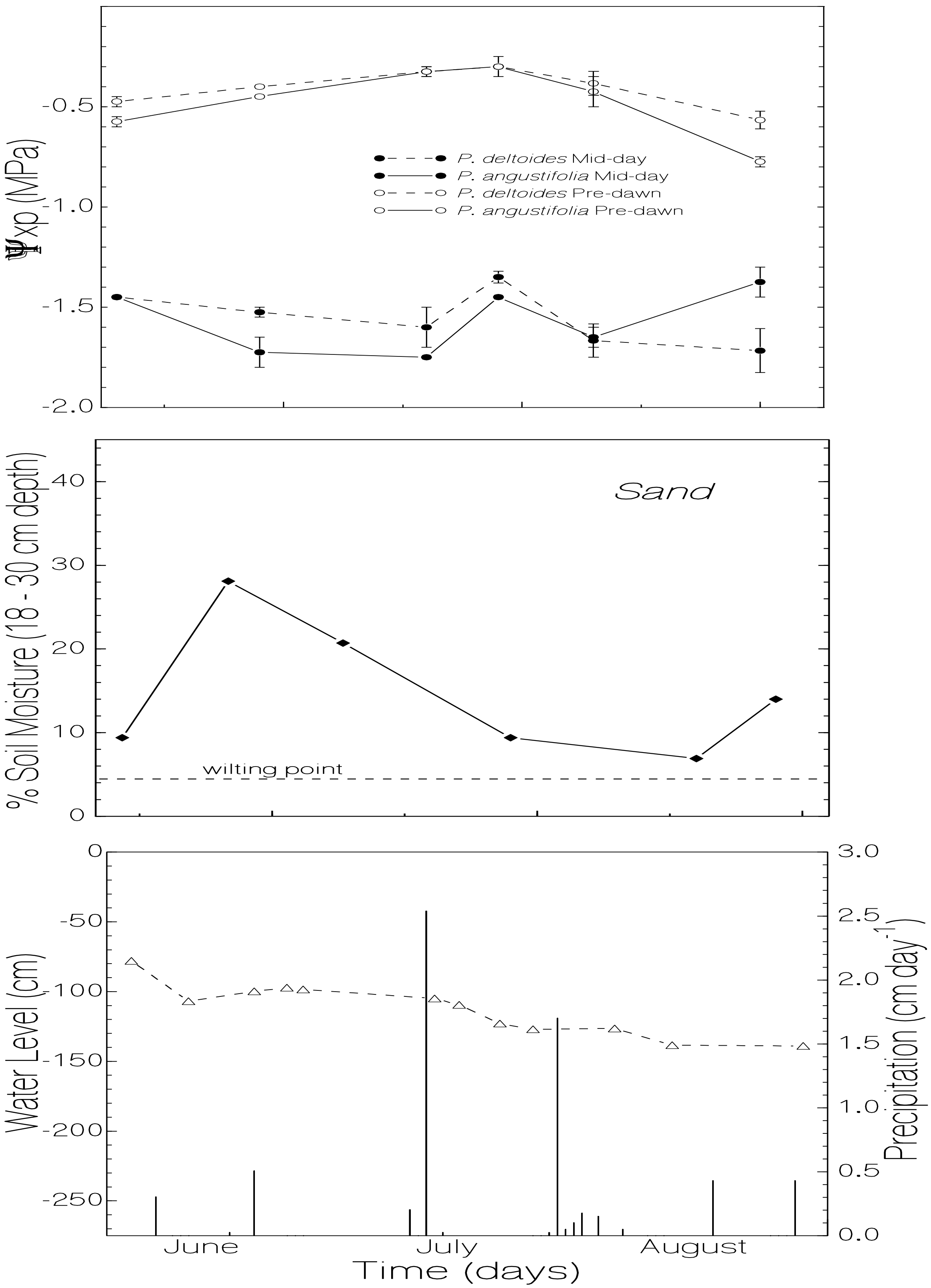

Figure 20. Low elevation downstream floodplain area (Station 6) at Uravan.

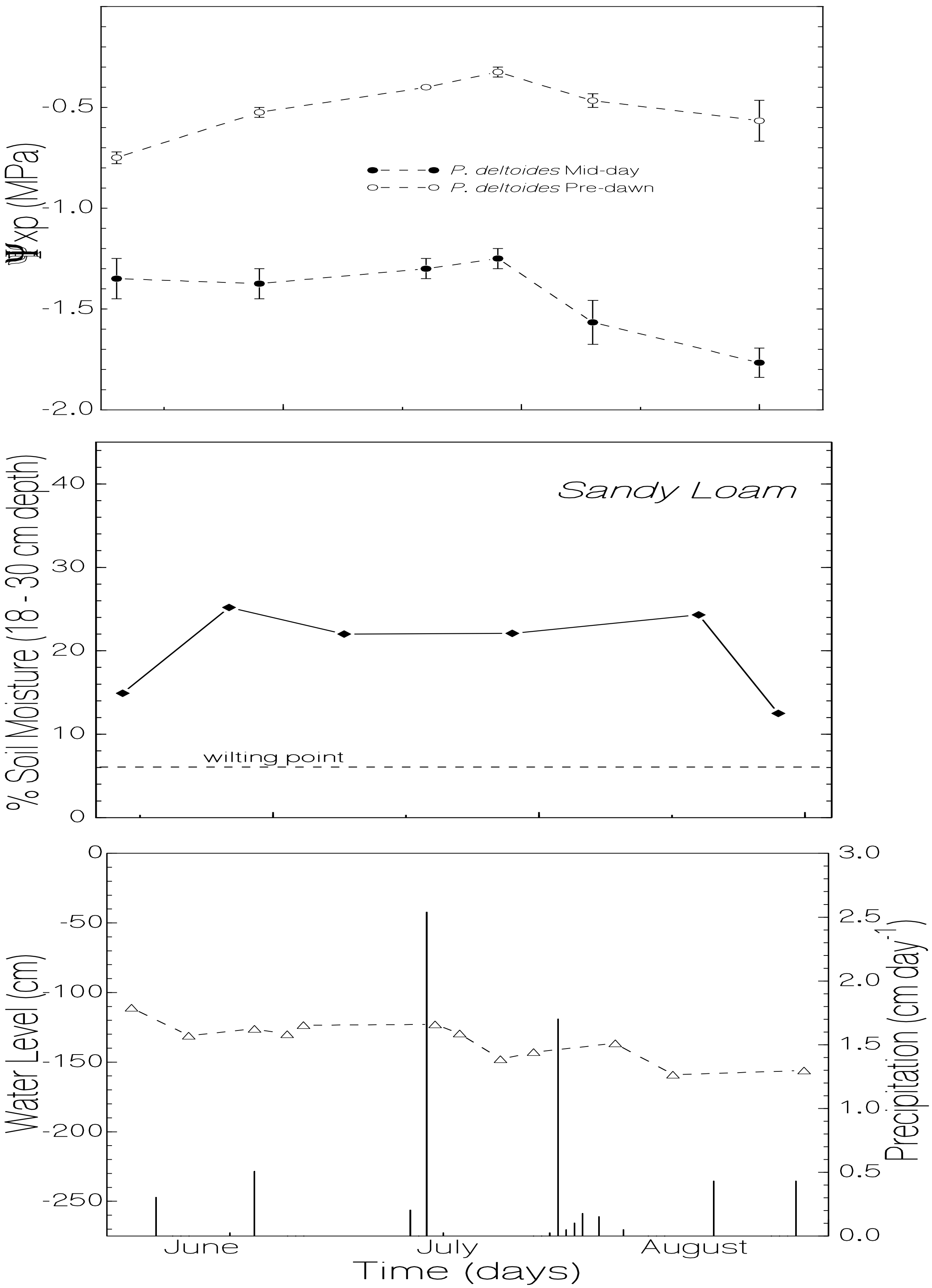

Figure 21. Middle elevation downstream floodplain area (Station 9) at Uravan.

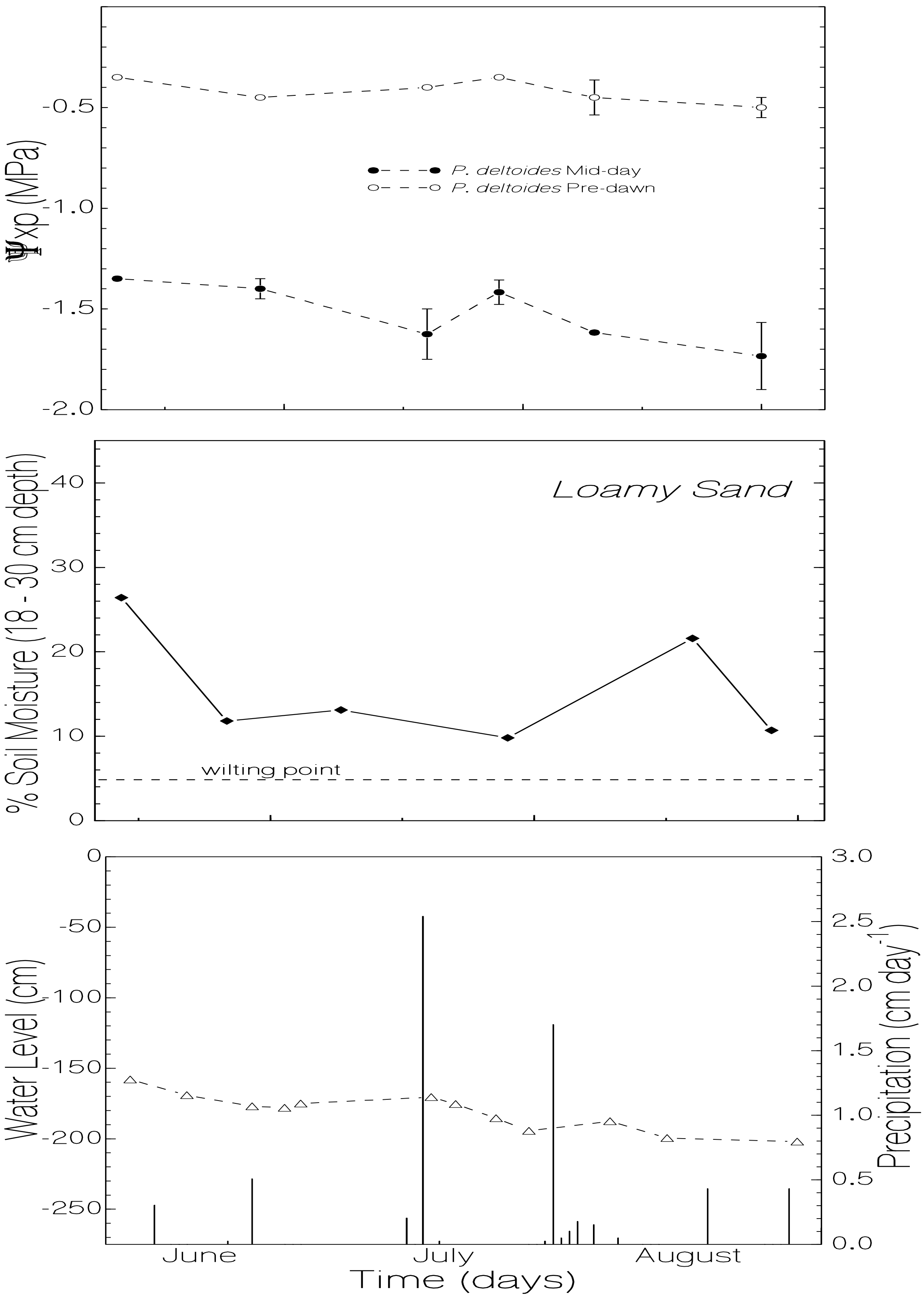

Figure 22. High elevation downstream floodplain area (Station 10) at Uravan.

DISCUSSION

Groundwater and Surface Water Relationships

Our data on river stage and groundwater level from peak flow through base flow conditions clearly indicate that floodplain groundwater tables are strongly controlled by the river (see Figures 3, 10, 15). This relationship is strongest in low elevation sites, however even at the colluvial fan site located more than 5 m above the river, depth to the water table are controlled by San Miguel River stage. Pearson correlation coefficients are between 0.90 and 1.00 for most sites, and the weakest correlation we found was 0.88, a statistically significant correlation ($P < 0.05$).

The source of water recharging floodplain aquifers was investigated using stable isotopes of hydrogen at the Placerville site on two dates during 1998. Our data indicate that during high San Miguel River flows in early June river water recharges alluvial groundwater aquifers, especially at sites close to the river (Figure 6a). However, at this time, the isotopic signature of ground water at the colluvial fan site did not match river. This suggests that a source of hillslope water is tributary to the San Miguel River and contributes significant amounts of ground water even in early summer.

On our late summer base flow sample date the isotopic signature of river water did not match any of the three ground water sites, and the three sites were very similar to each other (Figure 6b). Since ground water in late summer is isotopically depleted, compared with river water and rainwater, it cannot be inferred that evaporative processes contributed to create the unique groundwater signature. It suggests that hillslope groundwater from moving through colluvial fans dominates the floodplain ground water in late summer. This suggests that the late summer water source under floodplains is supplied largely by hillslope groundwater.

This hypothesis should be researched more completely in the future. It suggests that although riparian plants are utilizing ground water through the summer, the contribution of the San Miguel River to the groundwater system may be limited. However, because San Miguel River stage controls ground water levels, any change in late summer river stage will change groundwater levels under the floodplain.

Narrowleaf Cottonwood Water Sources

Our results isotopic analyses (Figures 6a and 6b) suggest that narrowleaf cottonwood trees along middle elevation reaches of the San Miguel River acquire largely soil water or a mix of soil water and groundwater in early summer. In late summer they acquire largely groundwater. Because soil water typically is aerobic and may contain nutrient concentrations higher than concentrations in groundwater, it is a more desirable water source for trees. When soil water is available, such as in early summer or during periods of heavy monsoon rain, trees appear to preferentially acquire soil water. Most interesting was the isotopic signature of cottonwood trees on the low floodplain in early June. Even though the water table was close to the soil surface the δD of tree sap indicated that trees were acquiring water from the most shallow soil depths. Thus, at a time when ground water is at its most shallow depth, and readily available, plants preferentially acquire soil water.

Our isotopic data indicate that trees rely on groundwater in late summer. This is most likely due to the reduced availability of soil water in soil horizons where roots are most abundant. These data indicate that changes in the depth of the late summer water table could affect trees throughout the floodplain.

Our analyses indicate that narrow-leaf cottonwood trees on the colluvial fan site root more than 6 m to the water table, and acquire soil water and ground water in patterns similar to trees in lower floodplain positions. We wonder, how did these trees establish in landscape positions so high above the water table. There appear to be three possible methods of tree establishment on these fans. 1) Trees germinated on the site they currently occupy during a flood from a hillslope stream tributary to the San Miguel River. These trees could have established a root system and persisted. This scenario of establishment is possible, but it does not answer the question of how the trees could have survived long enough in this semi-arid climate to grow roots 6 m deep. 2) Rhizomes of narrowleaf cottonwood trees established on the main portion of the floodplain spread up-slope and produced sucker shoots that are the trees we see today. These trees would have been supported by the parent plant, as are the asexual shoots of many clonal plants (Bazzaz 1996). With this parental support the trees may have been able to eventually grow roots to the water table. A parental connection is not possible today as the Highway cuts between this colluvial fan population of plants and the lower floodplain population of trees. 3) Narrowleaf cottonwood trees could have established on this site prior to the formation of the fan. As they were buried during fan construction, trees could have developed adventitious root systems (roots emerging from the buried trunk). If this is the case, cottonwood clones may be thousands of years old. Only the root system would be this old, and individual trunks would be produced asexually, and last no more than a couple of hundred years.

The mechanism of cottonwood establishment is critical to understand because it could provide clues to the susceptibility of these populations to local extinction. If hillslope tributary processes led to the establishment of these populations, then they are relatively immune to San Miguel River changes. However, this method of establishment seems unlikely because it is not feasible for trees to grow a taproot 6-m long to reach the water table under the dry regional climate conditions. If trees established by clonal spread from lower floodplain positions then they are vulnerable to local extinction. This would occur in a situation where the clonal ramets are killed or die could not be replenished because the Highway has permanently severed the connection with the parent plants. If the trees established during the colluvial fan building then they are ancient plants and the processes that led to the development cannot be replicated.

Narrowleaf and Fremont Cottonwood Tree Water Stress

Severe water-stress, as measured by twig xylem pressures, occurred in cottonwood trees at all sites during certain times of the year. Water stress (defined by us as mid-day xylem pressure potentials lower than –1.8 MPa, and pre-dawn xylem pressure potentials lower than –0.5 MPa) were most common at the Pinon and Uravan sites, particularly in stands with the most coarse-textured soils and those highest above the water table. Few trees at the Placerville floodplain showed signs of water-stress. However, trees on the colluvial fan were stressed for much of the study period.

Water-stress developed as river flows decreased and water tables dropped, and little rain fell. At Placerville, this occurred between late July and early August. At Pinon, the early peak river flow coupled with little summer precipitation and very coarse textured soils may have caused stressful condition in late June through mid-July. Trees were also water-stressed at Pinon in late August when river flow declined to less than 1 m^3/s, even though several rain events occurred. At Uravan, water-stress was most pronounced in cottonwoods during periods when rainfall was low. Water-stress generally increased in Fremont cottonwood as groundwater levels dropped and temperatures rose throughout the summer.

The presence of both *P. angustifolia* and *P. deltoides* at Pinon and Uravan creates interesting and unusual riparian communities. Factors controlling the distribution of these two tree species are not clearly understood. Fremont cottonwood occurs at lower elevations than narrowleaf cottonwood, but the reasons for this are unknown. Fremont cottonwood appears better suited for rivers with fine-textured alluvial floodplains, while narrowleaf cottonwood typically occupies higher gradient, and more coarse-textured floodplains. The niche of these species may relate to the water-sources utilized, mechanisms of reproduction, and temperature requirements for maximum photosynthetic rates. Because the distribution of these cottonwoods overlaps at Pinon and Uravan, it might be considered that neither species is occurring in its optimum environment.

While our xylem pressure data indicate that cottonwood trees throughout the study area are experiencing water stress during the summer, we did not observe leaf yellowing or leaf-loss due to xylem cavitation, or twig or branch death. We did observe that many trees had dead branches in their canopies, most likely due to drought induced xylem cavitation. This indicates that during dry years when monsoon rains do not develop, more severe drought conditions develop which exceed the drought tolerance of cottonwood. On dry years any lowering of the water table could disconnect tree roots from the water table.

Cottonwood trees do not have the ability to avoid uncontrolled drought induced xylem cavitation through stomatal closure. Even though trees may close their stomates, leaves and twigs can still desiccate, resulting in leaf, twig, and branch death.

CONCLUSIONS

Our research indicates that floodplain groundwater levels are controlled by river stage. High river stages in early summer recharge floodplain groundwater. However, as river stage declines hillslope groundwater appears to become the most important source of floodplain groundwater. Narrowleaf cottonwood can acquire both soil water and groundwater in early summer, and preferentially acquires soil water. However, as soil water is depleted, groundwater becomes its primary water source. In dry climate periods, trees may depend primarily on ground water at all times. The shift of tree water sources to ground water coincides with the period of late summer base flow conditions.

Cottonwood trees throughout the study area develop relatively low twig xylem pressure potentials in mid-summer. Trees open stomates as much as possible each day to maximize their photosynthetic rate. This however results in water loss subjecting trees to dangerously low xylem pressures. Cottonwood trees most likely operate near the edge of uncontrolled cavitation and any additional water stress created by either low summer rainfall or a partial or total disconnection of its roots from the water table could results in tree leaf and branch death, and if the situation persists, tree death. In-stream flows to maintain water tables are essential to protect cottonwood and other riparian plants that depend require ground water during the late summer.

RECOMMENDATIONS

Several issues raised by this research should be further investigated. These include:

1. Expanding the water source investigations to expand our understanding of the importance of river water for recharging ground water systems in early summer, and hillslope or other water sources for recharging soils and floodplain groundwater in late summer.
2. Accurately survey each well and floodplain area so that groundwater elevations and flow gradients can be established to corroborate other data.
3. Investigate tree water sources in study areas other than Placerville, and for tree species other than narrowleaf cottonwood. We suggest that Fremont cottonwood, blue spruce, and river birch need study as they may be just as dependent upon ground water in late summer as is narrowleaf cottonwood.
4. Water stress analyses should be expanded to species other than cottonwood, and to investigations other than xylem pressure potential. We suggest that by investigating tree stomatal behavior and photosynthetic rates in response to water availability would provide a more in depth functional understanding of the effects of drought on trees. This information would provide a more solid tie between tree water balance, tree physiology, and tree requirements for ground water.
5. Our investigations examined adult plants. Seedlings and saplings may be most susceptible to drought stress as their root systems are poorly developed. While adults may survive certain drought or water level changes, seedlings and saplings may not. Without high seedling and saplings survival rates, riparian forests cannot persist.

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EDUCATION

M.S. Civil Engineering, Water Resources/Environmental, University of Colorado, 2002

B.A. Social Thought and Political Economy, Minor in Political Science, University of Massachusetts, 1991. Exchange Program, 1989 - 1990, University of Nairobi, Kenya

PROFESSIONAL LICENSURE AND MEMBERSHIPS

Registered Professional Engineer, State of Colorado

American Water Resources Association

American Water Works Association

Colorado Lake and Reservoir Management Association

EMPLOYMENT HISTORY

2011 – Present Water Resources and Environmental Engineer, Western Resource Advocates, CO
Engineer for a regional non-profit environmental law and policy organization with a mission to protect the West's land, air, and water. Complete hydrologic analyses to evaluate proposed water supply projects for environmental and related impacts. Develop alternative supply options that balance human needs with protecting healthy rivers. Provide technical analyses related to instream flow filings, energy development water needs, and other issues.

2008 – 2010 Water Resources Engineer, Headwaters Corporation, CO Engineer for the Platte River Recovery Implementation Program (PRRIP), an agreement between three states (WY, CO and NE), the federal government, water users, and environmental groups to improve habitats for four threatened and endangered species. Evaluated and advanced a variety of water projects to provide species flows and create and maintain habitat. Provided technical, managerial and administrative support to the PRRIP's Executive Director and Water Advisory Committee. Assisted other clients in developing and implementing comprehensive water conservation plans and compiling drought planning resources.

2002 – 2008 Water Resources and Environmental Engineer, Hydrosphere Resource Consultants, CO (firm acquired by AMEC in 2007) Engineer and project manager for a variety of projects including water quality and biological field studies, environmental permitting and regulatory work, RiverWare surface water modeling, water conservation planning, and database development and management.

2000 – 2002 Graduate Research Assistant, Institute of Arctic and Alpine Research, CO. Examined spatial, temporal and ecological impacts of acid rock drainage in collaboration with a local stakeholders group. Planned and implemented water quality and biological sampling events. Performed laboratory analysis of samples.

1999 – 2000 Graduate Research Assistant, Center for Advanced Decision Support in Water and Environmental Systems (CADSWES), CO. Developed engineering object code for RiverWare modeling software in response to client requirements. Documented, tested, debugged and integrated new code. Provided bilingual (English and Spanish) RiverWare user training.

1996 – 1998 Development/Marketing Coordinator, Alexandria Child and Family Network, VA. Secured $900,000 annual budget for non-profit which provided a free fully accredited preschool education to at-risk children and education and job training for parents. Expanded donor base, created agency's first fundraising special event, directed board and volunteer committees, and assisted in the preparation of proposals and financial reports.

1993 – 1995 Agricultural Diversification Volunteer, United States Peace Corps, Guatemala. Collaborated with governmental and non-governmental organizations to educate and encourage women's groups, farmers, families, and school children to improve nutrition while using safe and sustainable agricultural practices.

1991 – 1993 Development Assistant, Big Sister Association of Greater Boston, MA. Member of a two person fundraising team responsible for $500,000 annual budget. Organized annual fundraising events, generated direct mailings, assisted with grant applications, and created public relations materials.

DETAILED SKILLS BY PROJECT

RiverWare Modeling and Decision Support Systems

Pecos River Decision Support System (PRDSS) Development, NM: Implemented numerous enhancements to the Pecos River RiverWare model, rulesets, database, and data analysis components of the PRDSS suite of models. Developed and provided PRDSS user trainings and accompanying documentation and user guides.

Pecos River Adjudication Settlement Negotiations and Litigation Support, NM: Provided technical support to the New Mexico Interstate Stream Commission (NMISC) as part of Adjudication Settlement negotiations and implementation. This included developing rules to represent Settlement Terms in the RiverWare model, scenario development, simulation, and analysis of model results for technical and non-technical stakeholders.

Carlsbad Project Water Operations and Water Supply Conservation EIS, NM: Assisted in the development of a daily rule-based model to simulate reservoir operations for irrigation, flood control, interstate compact deliveries and instream flows for the endangered Pecos Bluntnose Shiner (PBNS). Simulated Environmental Impact Statement (EIS) alternatives, reviewed technical data, developed and managed a processing and results database, participated in work groups, and prepared EIS documentation.

Pecos River Annual Accounting for PBNS Operations, NM: Designed an Excel-based tool to measure water depletions and exchanges resulting from U.S. Bureau of Reclamation operations to meet the constraints of the U.S. Fish and Wildlife Service Biological Opinion on the PBNS.

Simulation of Priority Administration in the Pecos River Basin, NM: Developed and implemented enhancements to the PRDSS to simulate impacts of priority administration on primary and supplemental groundwater pumping in the Carlsbad, NM area and on NM/TX Stateline flows.

Lower Colorado River Authority (LCRA) RiverWare Model Documentation and Training, TX: Developed ruleset documentation and user training materials for the Lower Colorado River RiverWare model and rulesets.

Pecos River Carlsbad Project Operations Long-Term Miscellaneous Purposes EIS, NM: Provided technical services to the NMISC including developing resource indicators for alternatives analysis, generating technical work plans, and reviewing and editing EIS documentation.

Water Conservation/Drought Planning and Water Supply/Water Rights Analysis

PRRIP Water Action Plan Water Supply and Project Evaluation, NE: Developed Excel-based operational models to estimate potential water supplies and projects' ability to release/retime return flows during periods of shortages to species target flows. Evaluated a variety of potential water projects including new off-channel reservoirs, leased water, conserved water, and groundwater recharge. Developed technical information for use in project selection, working closely with the PRRIP's Executive Director, Water Advisory Committee, and project workgroups.

Sterling Ranch Water Conservation Planning, CO: Worked with project manager to develop an extremely comprehensive and forward thinking water conservation plan for a proposed development in a water-limited area. 100% of new homes and landscaping would be water efficient under the plan, resulting in significantly less water use than traditional new developments.

Drought Toolbox Report, CO: Researched, compiled and summarized existing drought planning resources and regulations from across the United States for the Colorado Water Conservation Board for use in develop similar requirements and guidance materials for Colorado.

Eagle River Water and Sanitation District Water Conservation Plan, CO: Initiated the development of a water conservation plan for the Vail area to address unique challenges associated with mountain resort communities.

North Table Mountain Water and Sanitation District Water Conservation Plan, CO: Project manager for an ongoing project to develop and implement a water conservation plan for a medium-sized utility in the metro Denver area. Though the utility currently has sufficient water to meet demands, the plan will ensure that water supplies are used wisely and are sufficient to meet future demands.

Northglenn Water Conservation Plan, CO: Project manager for the development of the City of Northglenn's water conservation plan. Inventoried water supplies, water and wastewater systems, water use patterns and existing conservation measures. Worked closely with City staff to evaluate and select a variety of conservation measures and programs. Estimated water and financial savings and costs, and developed an implementation plan.

Citizens for Dixie, UT: Worked for a citizens group to evaluate the need for a proposed pipeline. Reviewed existing resources for information on current and projected local water supplies, projected population growth, water quality, and per capita water use. Evaluation included converted agricultural and non-potable water supplies. Formulated alternative supply scenarios.

Wolf Creek Ski Area, CO: Evaluated hydrologic data to assess build out demand and supply projections for small ski area. Collected and reviewed water use, skier and snowmaking data. Determined existing and build out monthly and seasonal water use. Calculated available supplies at diversion points using flume, gage, and drainage area data.

AB Lateral Hydropower Facility Conditional Water Rights Evaluation, CO: Evaluated conditional water rights for water availability to assess the economic feasibility of a proposed hydropower facility in the Gunnison River Basin. Reviewed technical documentation, historical data, and an Excel-based model to determine probable impacts of hydropower diversions on upstream water rights.

Review of Eldora Enterprises' Proposed Augmentation and Substitute Supply Plan, CO: Reviewed and analyzed methodologies used in the 1986 Colorado Ski Country USA Water Management Research Project Final Report to determine consumptive use during snowmaking. Assessed the reliability of applying Ski Country USA consumptive use values to the 2002 ski season at Eldora Mountain Resort.

Regulatory Processes and Environmental Permitting

Severy Creek Wetland and Ski Creek Restoration Project Environmental Assessment (EA), Pikes Peak National Forest CO: Prepared environmental documentation for the U.S. Forest Service to determine whether to prepare an EIS or a Finding of No Significant Impact for a restoration project. Responsibilities included EA scoping, data collection, biological and hydrologic evaluations, alternative development, and identification of mitigation measures to avoid and/or minimize environmental impacts.

Keystone Ski Area 2003 and 2008 Regulation 33 Rulemaking Hearings, CO: Assessed the scientific basis for, and potential impacts of, proposed changes in water-quality standards for tributary streams located within the Keystone Resort ski area. Developed a Use Attainability Analysis (UAA) for the 2008 process. Worked with the Colorado Water Quality Control Division and other agencies to create consensus on standards proposals.

Keystone Ski Area 2004 and 2008 Regulation 93 303(d) Listing Rulemaking Hearing, CO: Analyzed water quality data and factors influencing pH levels in ski area and other high elevation Colorado streams in response to a proposed listing of streams on Colorado's 303(d) list of impaired water bodies for pH. Prepared hearing documentation summarizing findings on behalf of Keystone Ski Area.

Windy Gap Firming Project EIS, CO: Assembled existing reservoir water quality data from numerous sources, reviewed and formatted data for errors and consistency, and developed a water quality database. Evaluated water quality data against existing and proposed Colorado water quality standards. Prepared data for use in modeling water quality conditions in several reservoirs for possible future alternatives for the Windy Gap Firming Project EIS.

Eagle Mine Superfund Site Surface Water Quality Standards Development, CO: Evaluated hydrologic and water quality data for several stream segments of the Eagle River in Eagle County, Colorado. Assessed temporary and proposed water quality standards for their ability to protect aquatic life. Worked with client and a stakeholders group to develop standards proposals.

Eagle Park Reservoir Pump Back Operation and Reservoir Enlargement Assessment, CO: Developed a daily Excel-based model to evaluate river flows below the Eagle Park Reservoir for various hydrologic scenarios including a reservoir expansion and a pump back to divert water to the reservoir. Completed 1041 Permit amendment application.

Black Lake No. 1 Second Enlargement 1041 Permit Application, CO: Developed a 1041 Permit amendment application for a second Black Lake No. 1 enlargement to provide additional water to augment domestic, golf course, and snowmaking diversions.

Beard Creek Water Storage Tank 1041 Permit Application, CO: Developed a comprehensive assessment of the impacts of a proposed treated water storage tank to be located in Edwards, Colorado. Assisted the Upper Eagle Regional Water Authority with the preparation of necessary environmental permit applications including a 1041 application.

Vail Wastewater Treatment Plant Expansion and Upgrade, CO: Prepared an Environmental Impact Report for an upgrade and expansion to the Eagle River Water and Sanitation District's Vail wastewater facility and proposed co-located drinking water facility. Potential impacts to riparian areas, instream flows, and water quality were examined.

Vail Resorts Environmental Permitting, CO: Prepared Army Corps of Engineers 404 permit notification for the placement of fill to raise and flatten existing contours in the Golden Peak Terrain Park at Vail Ski Area. Prepared a request to amend an existing Minimal Industrial Discharge (MINDI) permit to include an additional wastewater source at the Vail Shop Yard.

Pueblo Reservoir Water Quality Model, CO: Ran multiple water quality simulations of Pueblo reservoir for a variety of alternatives being considered for an EA using LAKE2K.

Field Sampling and Data Analysis

Lake DeSmet Baseline Water Quality Study, WY: Planned and managed a baseline water quality field study for a lake located near Buffalo, WY. The lake is a potential source of drinking water supplies and may be impacted by future development and coalbed methane production.

Study of Algal Communities and Water Quality in Gore Creek, CO: Planned and managed a multi-year algae and water quality study in response to concerns about a visible shift in algae species composition and abundance in a high altitude stream with a high recreational value.

Keystone Ski Area Water Quality Monitoring, CO: Responsible for monthly water quality monitoring and data analysis to assess the impacts of snowmaking, drainage improvements, and other activities on ski area streams.

Vail Resort Water Quality Monitoring, CO: Provided water quality monitoring and data analysis to assess the impacts of drainage improvements, snowmaking, and other activities on ski area streams.

Mariano Exchange Ditch System Assessment, CO: Designed and implemented a multi-year field study to assess a reservoir and exchange ditch system that contributes sediment and nutrients to the Big Thompson River. Project involved monitoring, data analysis, and mitigation recommendations.

International

E-Tech International *Aguinda v. ChevronTexaco* Litigation Support, Ecuador: Managed the development of a database for use by Amazon residents in litigation against Chevron for damages relating to a former concession in the Amazon rainforest. Gathered and reviewed existing reports and documents, designed and developed a Microsoft Access database to house environmental and related data, and ensured quality control of data. Managed Ecuadorian and U.S. staff.

Jalapa, Nicaragua Engineers Without Borders (EWB) Project, Nicaragua: Volunteer project manager for EWB-USA's Nicaragua program. Led an evaluation team in Nicaragua to assess several potential projects. Met with community members, local government officials, and non-governmental organizations to gather data and secure community cooperation. Completed site reports and performed initial engineering calculations for projects including a gray water drainage system for 300 homes, two gravity driven potable water systems, and water storage tanks for a hospital and an elementary school.

Foutaka, Mali Engineers Without Borders Water and Sanitation Project, Mali: Member of a team that designed and implemented a rainwater catchment and drip irrigation system for the village of Foutaka Zambougou, Mali.

United States Peace Corps, Santa Lucía Utatlán, Sololá, Guatemala: Served as a Peace Corps volunteer working with governmental and non-governmental organizations, women's groups, farmers, families and school children. Encouraged sustainable agricultural practices and improved nutrition. Planted school and family gardens and small commercial plots. Developed nutrition and health workshops for women's groups and school children. Created an environmental education and reforestation project at a local middle school.

United Nations Centre for Human Settlements Intern, Nairobi, Kenya: Wrote and edited articles for several monthly shelter-related journals.

PUBLICATIONS AND PRESENTATIONS

Courtney, B., Belanger, L., 2010. "Adapting Water Conservation Programs, Examples from Two Different Water Providers: Sterling Ranch & North Table Mountain WSD", Colorado Waterwise Annual Meeting, September 24, 2010, Denver, CO

Maest, A., Weaver, B., Belanger, L., 2009. "Elution and Transport of Contaminants from Metal-Rich Artificial Snow in Colorado" Poster. Geological Society of America Annual Meeting, October 18 - 21, 2009, Portland, OR

Barroll, P., Burke, P., Carron, J., Belanger, L., 2003. "Ft. Sumner Irrigation District Return Flow Calculations" Poster. New Mexico Symposium on Hydrologic Modeling, August 12, 2003, Socorro, NM

Boroughs, C., Carron, J., Belanger, L., Liu, B., 2003. "The Fish Rule: Modeling Pecos River Operational Policy to Achieve Target Flows for the Endangered Pecos Bluntnose Shiner. New Mexico Symposium on Hydrologic Modeling", August 12, 2003, Socorro, NM