Rocky Mountain Hydrologic Research Center

Meeting Program and Abstracts

55th Annual Meeting

October 14, 2000

Wild Basin Lodge

Schedule of Presentations

8:30 **Nel Caine**, University of Colorado
Ice thickness on an alpine lake: An amplified response to changes in precipitation

8:50 **Robert T. Milhous**, U.S. Geological Survey
When a year is not a year: Selecting an annual period for hydrologic analysis

9:10 **Connie A. Woodhouse**, NOAA Paleoclimatology Program, and Jeffrey J. Lukas, Univ. of Colorado
Clear Creek streamflow reconstructions from tree rings and applications to water resource management

9:30 **Martyn P. Clark**, University of Colorado, and Lauren E. Hay, U.S. Geological Survey
Is it possible to predict streamflow?

9:50 **BREAK**

10:30 **Peter D. Blanken**, University of Colorado
The Surface Energy Balance of a High Altitude Wetland

10:50 **Jonathan W. Godt**, E.K. Larson and D.A. Kile, University of Colorado
Field mapping and survey observations of debris flows, Ruby Creek basin, Mount Parnassus, Clear Creek County, Colorado

11:10 John A. Moody and **Deborah Martin**, U.S. Geological Survey
Infiltration rates for volcanic and granitic soils in burned mountainous watersheds

11:30 **Claire C. McGrath** and William M. Lewis, Jr., University of Colorado
Displacement of greenback cutthroat trout by brook trout in Rocky Mountain streams

12:00 **BREAK**

1:30 **Hillary B. Hamann**, University of Colorado
Temporal and Spatial Variation in Chemical Transformations of Snowmelt Runoff at Niwot Ridge, Colorado.

1:50 **Sujay Kaushal** and William M. Lewis, Jr., University of Colorado
Effect of environmental variables on export of nitrogen from undisturbed watersheds in the Colorado Rockies

2:10 **BREAK**

2:30 **James F. Saunders, III** and William M. Lewis, Jr., University of Colorado
Implications of climate variability for low flows and dilution of discharges from point sources in the South Platte River basin

2:50 **Gigi A. Richard**, Colorado State University
Historic Geomorphic Analysis on the Middle Rio Grande, New Mexico

3:10 **John Pitlick**, University of Colorado
Longitudinal trends in channel characteristics of the Colorado River: Implications for food web dynamics

ICE THICKNESS ON AN ALPINE LAKE: AN AMPLIFIED RESPONSE TO CHANGES IN PRECIPITATION

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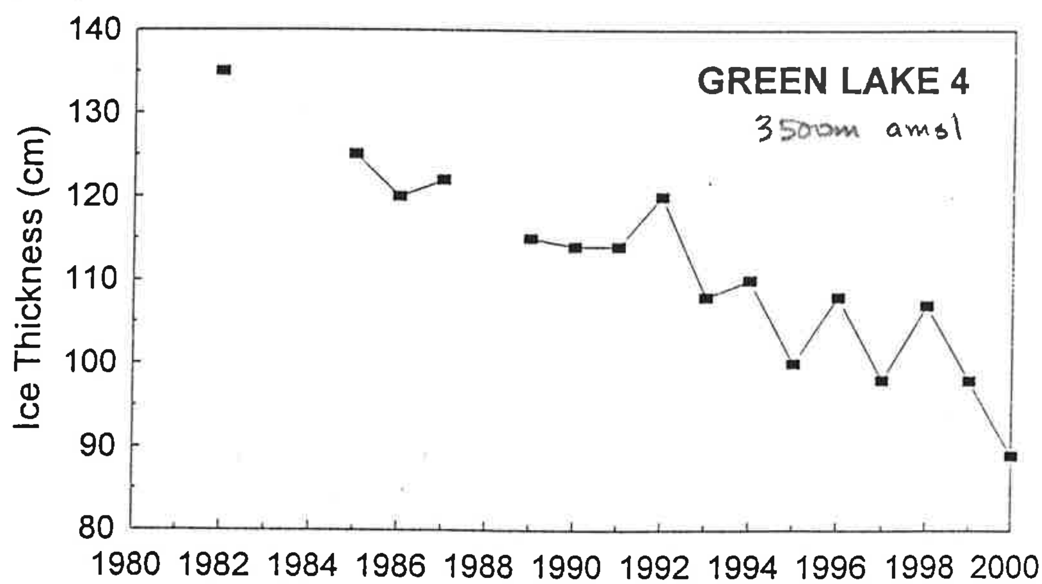
A 20 year record of ice thickness in late-March on Green Lake 4 (3550 m asl) shows a consistent thinning of the ice cover at 2.0 cm/yr ($r = 0.931$; $N = 16$). No corresponding trend is found in air temperature and solar radiation records in this environment. In contrast, Williams et al (1996) document an upward trend in annual precipitation (at 8 mm/yr) since 1950 which has increased to 12 mm/yr in the last 20 years. The correlation between ice thickness and precipitation over the preceding Oct - Mar period is -0.439 ($N = 16$). This seems to reflect the insulating effect of an increased thickness and/or duration of snow cover on the lake. A second empirical correlation occurs between ice thickness and ground water storage (estimated from recessions) in the Green Lakes basin at the end of the previous water year ($r = -0.656$; $N = 16$). An increase in winter ground water flows to the lake is also suggested by an upward trend in Ca^{++} and Si concentrations in the lake water at late-March. Combined, Oct - Mar precipitation and groundwater storage at the end of the previous flow season account for over 50 % of the variability in ice thickness ($R = 0.714$). Thus, the March lake ice signal is produced by two separate influences, both derived from a long-term increase in winter precipitation: one associated with the current winter's precipitation and one with that of the previous winter.

storage ? thickness

Reference

Williams, M.W., M. Losleben, N. Caine & D. Greenland. 1996. Changes in climate and hydrochemical responses in a high-elevation catchment in the Rocky Mountains, U.S.A. Limnol. & Oceanog. v. 51; p. 939-946.



WHEN A YEAR IS NOT A YEAR: SELECTING AN ANNUAL PERIOD FOR HYDROLOGIC ANALYSIS

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ABSTRACT

The U.S. Geological Survey has used a water year of October thru September for the compilation of water data and for the development of annual time series such as annual discharges, annual peak discharge but usually not for minimum flows. Annual minimum flows are typically determined for a climatological year from 1 April thru 31 March of the following year. The objective of this paper is to suggest the analyst should select the period for a 'water year' (in effect using a modified water year). A calculation procedures that may assist the analysis in selecting a modified water year is presented. The calculation procedure uses the lag 1 correlation coefficient. The data used is the annual streamflows (QA) for the years in the streamflow record (NY). The lag 1 correlation is the correlation between variable X where X(i) is QA(i) and the series is from i=1 to i=NY-1; and the variable Y where Y(i) = QA(i+1) and the series from i=2 to i=NY. The Calculation Steps are:

Step 1. Calculate the annual flows using the first day of each month as the starting month.

Step 2. Determine the lag 1 correlation coefficient for each starting month (total of 12).

The objective is to select the beginning month of a water year that minimizes the lag 1 correlation coefficient from the 12 possible starting months for the annual streamflows. The calculation procedure was applied to the Virgin River in Utah and Arizona. The Lag 1 correlation coefficients for three streams in the Virgin River Basin was quite variable and the selection of a modified water year was not obvious. For the Virgin River at Virgin, Utah the minimum absolute lag one correlation coefficient gives a modified water year starting on 1 August, for North Creek near Virgin it is 1 April, and for the Virgin River at Littlefield, Arizona it is 1 January. The overall best day for the beginning of a modified water year is 1 November.

Clear Creek Streamflow Reconstructions from Tree Rings
and
Applications to Water Resource Management

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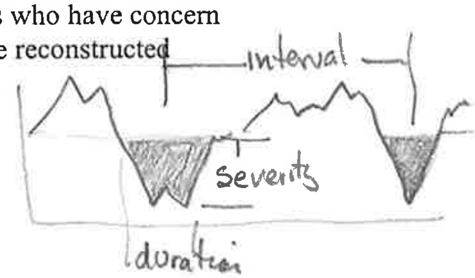
ABSTRACT

Water resource planning is based primarily on 20th century instrumental records of climate and streamflow. Unfortunately, even the longest gage records capture only a limited portion of the range of natural hydrologic variability that is possible. Tree-ring reconstructions of streamflow (i.e. dendrohydrological reconstructions) have proven useful for augmenting existing instrumental streamflow records. These proxy records of streamflow have provided an expanded temporal context from which to evaluate the representativeness of the 20th century instrumental record. However, a lengthened record of streamflow, although valuable, is of limited use to water resource managers. In this study, we are working with the City of Westminster water planners to tailor reconstructions and reconstruction analyses to better meet water resource planning and management needs.

Using dendrochronological techniques, we have produced a high-quality reconstruction of total annual flow for Clear Creek, the sole source of water for Westminster. The reconstruction explains 61% of the variance in the instrumental flow record, and extends from 1685 to 1987. We use the reconstruction to evaluate low flow (below average) duration, severity, and frequency for the past 300 years. In the 20th century, the most extreme low flow periods coincide with the droughts of the 1930s and 1950s. The1930s low flow event was the longest, with below average flow for eight consecutive years, but the 1950s event, although lasting only four years, was more much more severe.
When flow values are standardized, the cumulative sum of negative departures for the 1930s event is -4.541 over eight years. In comparison, the sum for the 1950s event is -4.485, but over the course of only four years. When the full reconstructed record is examined, the magnitude of the 1930s and 1950s low flow events can be evaluated in a broader temporal context. For example, one other eight-year event appears in the full record, but the severity of this event exceeds the severity of the 1950s event. This event occurred from 1845-1852 with a cumulative sum of negative departures equaling -9.263. One six-year (1816-1821) and two five-year (1778-1782, 1809-1813) low flow events occurred in the past 300 years, with severity comparable to the 1930s event. Three four-year events (1706-1709, 1739-1742, 1885-1888) occurred in addition to the 1950s event, with variable severity.

We are now developing methods to generate more accurate reconstructions of low flow using quantile regression. More accurate low flow estimates are needed by Westminster engineers who have concern about water management during periods of drought. Ultimately, we hope to provide reconstructed flow estimates that are suitable as input for hydrologic forecasting models.

Severity Index = Cum. Neg Departure / no. years duration



Median / quantile regression overestimates extremes
mean regression (least squares) underestimates extremes

Magnitude = Severity x duration

IS IT POSSIBLE TO PREDICT STREAMFLOW?

Martyn P. Clark[1] and Lauren E. Hay[2]

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Recent results of coupling atmospheric and hydrologic models for the prediction of runoff will be presented. In this study over 2500 individual 8-day atmospheric forecasts from a global-scale numerical weather prediction model were used as input to a basin-scale hydrologic model configured over the Animas River basin (1820 km2) in southwestern Colorado. It will be demonstrated that, in spite of the large scale mismatch between atmospheric and hydrologic models, raw atmospheric forecasts do provide short-term predictions of runoff with lower forecast errors than those obtained via the current practice where hydrologic predictions are based solely on historical station data. Ongoing research in assessing the skill of various strategies used in "downscaling" atmospheric forecasts will also be presented.

Upper Green
El Nino → dry / La nina → wet
wet ↓ dry / dry ↓ wet
(may have reversed them)
Lower Colorad

The Surface Energy Balance of a High Altitude Wetland

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Abstract

Preliminary results describing the surface energy balance of a high altitude (ca. 2700 m) wetland (fen) are presented. The site, located near Fairplay, Colorado (39°, 7' N, 105°, 58' W), supports several global and state-rare flora and fauna. Currently, there is pressure to access the surface and groundwater resources of the fen, hence an understanding of the hydrology is required before this occurs. Measurements were made starting June 13, 2000 using the Bowen ratio-energy balance approach. Humidity and air temperature gradients were measured at two heights every 20 minutes, with the former alternatively sampled between heights by a solenoid switch before passing through a chilled-mirror hygrometer. Incident solar radiation (S_d), net radiation (R_n), wind speed and direction, precipitation, soil temperature, soil moisture and the soil heat flux (G) were also continuously measured. Measurements are planned to continue through at least two years.

At the start of the measurement period, before leaf growth, R_n/S_d decreased as the surface albedo increased and the surface warmed. The sensible heat flux (H) dominated over the latent heat flux (_E), with daytime mean of ca. 250 and 50 Wm^{-2}, respectively. Ratios of H, _E and G to R_n were 0.68, 0.18, and 0.14, respectively. This pattern reversed with leaf growth. Near mid July, the daytime mean _E approached 300 Wm^{-2}, while H decreased to 50 Wm^{-2}. The ratio _E/R_n increased to 0.80, and sometimes exceeded unity due to advection (downwards-directed H). The daily total evaporation increased from 1 mm d^{-1} at the start of measurements to a maximum of 6 mm d^{-1} near mid-July. Between June 13-Aug. 1, a total of 172 mm of water was evaporated, compared to 71.1 mm total precipitation. Diurnally, _E largely tracked R_n, especially during cloudy periods.

Fen = water flows through + high nutrients
Bog - water "stagnt"

most heat goes off as evaporation

Evap ~ 5x Precip
+ Transpiration

⇩

Source of thunderstorm

Nolan Doeskin

Field mapping and survey observations of debris flows, Ruby Creek basin, Mount Parnassus, Clear Creek County, Colorado

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On July 28, 1999 approximately 100 debris flows were triggered by an intense thunderstorm in an area roughly centered on Loveland Pass and extending north from Grays Peak to Mount Parnassus in the Colorado Front Range. Interstate 70 near the Bakerville exit and U.S. Highway 6 near the Arapaho Basin ski area were temporarily closed as a result of this event. Fortunately, no lives were lost and damage to structures was minimal. Although summer thunderstorms are common in the Colorado Front Range, rarely do they generate numerous debris flows over such a wide area. The goals of this study were to collect a set of survey measurements to estimate the volume of hillslope material transported and to collect field observations the debris-flow erosion and deposition morphology.

The thunderstorm that triggered the debris flows occurred during a prolonged period of moist flow from the southwest which is commonly referred to as the Mexican or Southwest Monsoon. Gauge records at a SNOTEL site on Grizzly Peak (about 9 km from the study site) at 3383 m show that 43 mm of rain fell in a 4-hour period with over 80 percent of the total falling in just 3 hours. These observations concur with NEXRAD radar estimates of between 38 and 50 mm for the same storm.

Field observations following the July, 1999 event indicate that most of the debris flows initiated in ephemeral, zero-order drainages generally above 3400 meters in loose talus or colluvium often near ridgelines with little or no vegetative cover. Many of the flows lacked discreet landslide sources. Large rills and gullies up to 5 m deep and 8 m wide were eroded into hillslopes and debris fans at the base of the slopes. The debris-flow deposits on the valley formed distinctive lobes and levees of which one of the largest identified in the field was about 500 meters in length, over 50 m in width, and up to 2 m in depth.

Detailed field mapping and cross sectional surveys were performed on one debris flow in late August of 2000 in the Ruby Creek basin southwest of Berthoud Pass. This area was selected for study due to the intensity of debris-flow activity and relative ease of access to the entire length of a feature typical of the event. This debris flow feature was over 560 m in length and occurred on a hillslope with a mean gradient of about 25 degrees. Results from the field mapping indicated that erosional and depositional processes vary temporally and spatially. Spatially the feature can be roughly divided into three zones. The upper zone, defined by the dominance of erosive processes extended over 320 m with a gradient of 30 degrees. The middle zone is characterized by evidence of both erosive and depositional processes and is nearly 50 m in length with a lower gradient of about 18 degrees. The lower zone, characterized by depositional features such as levees and lobate structures is almost 200 m in length with a mean gradient of 16 degrees. Temporal variability is inferred from observations of the crosscutting relation of depositional features and the reworking of the deposit by subsequent erosion.

Infiltration Rates for Volcanic and Granitic Soils in Burned Mountainous Watersheds

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Wildfires change the hydrologic response of burned watersheds by reducing the canopy protection of the soil, by removing the vegetative-ground cover, duff, and debris that intercept runoff, and by altering the chemical and physical properties of the soil and consequently the infiltration rates. Measured infiltration curves are needed for soils altered by wildfire in order to improve precipitation-runoff models that predict peak discharge of floods. We made multiple infiltration measurements in severely burned areas and in nearby unburned control areas. One set of infiltration measurements was made in soils derived from volcanic tuffs within the Cerro Grande Fire (May 2000) in the Jemez Mountains near Los Alamos, New Mexico; another set was in granitic soils within the Hi Meadow Fire (June 2000) in the Front Range Mountains near Denver, Colorado; and a third set was in soils derived from metamorphic bedrock within the Bobcat Fire (June 2000) in the Front Range Mountains near Fort Collins, Colorado. We used a portable rain simulator (plot size = 0.017 m^2) to measure the steady-state infiltration rates.

Infiltration rates in the unburned areas were slowest in the very compact soils derived from metamorphic bedrock (10 cm h^{-1}), a little faster in the fine-grained volcanic soils (15 cm h^{-1}), and fastest in the coarse-grain granitic soils (17 cm h^{-1}). Fires apparently reduced infiltration rates. Infiltration rates in the burned granitic soils were about one-half (7.4 cm h^{-1}) of the rate in the unburned soils, and rates in the volcanic soils were about 7 times less (2.2 cm h^{-1}) than in the unburned soils.

Decreases in infiltration rates after a wildfire are probably the result of both chemical and physical processes. Fire may drive off all soil moisture thus requiring a period of initial rewetting (in general we measure less soil moisture in burned areas than in unburned areas). Heat from wildfires may release fine-grained material by disaggregating soil pedons and create additional fine-grained material by fracturing soil particles. These fined-grained materials may seal the soil surface, thereby decreasing infiltration rates. Conceptually, infiltration after a wildfire may be thought of as a two layer process. Infiltration in the thin surface layer is controlled by an effective low saturated hydraulic conductivity caused by the sealing process and below the sealed layer, infiltration is controlled by the saturated hydraulic conductivity.

Displacement of greenback cutthroat trout by brook trout in Rocky Mountain streams

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The greenback cutthroat trout, endemic to the South Platte and Arkansas River drainages, is listed as a threatened subspecies under the Endangered Species Act. The primary threat to restoration of the greenback cutthroat trout is displacement by non-native trouts. In particular, non-native brook trout tend to co-occur with greenback cutthroat trout in high elevation streams and lakes. Recently, we completed the first phase of a 3-year study in which we are investigating mechanisms for displacement of greenback cutthroat trout by brook trout in montane streams. Potential mechanisms that we are examining include competition for food, competition for space, and predation upon native trout by invasive trout. To describe food use by trout we analyze stomach contents and C and N stable isotopic composition of trout tissues. These analyses are currently underway and results are not yet available. A qualitative examination of stomach contents suggests that both greenback cutthroat and brook trout are opportunistic feeders that consume a wide variety of aquatic and terrestrial invertebrates. A small percentage of brook trout and cutthroat trout preyed upon young-of-year trout; this phenomenon was limited to a few sites and occurred soon after emergence of fry. Competition for space will be examined in 2001 using field experiments in which we remove and then reintroduce brook trout to habitats occupied by cutthroat trout. In this talk we present the results of population surveys at 8 streams in the Rocky Mountains. Population data indicate that greenback cutthroat trout decline after invasion of brook trout due to decreased recruitment and/or survival of young age classes. In contrast, recruitment and survival of young-of-year brook trout was strong. Body condition of older individuals did not differ significantly between the two species. These data suggest that displacement of greenback cutthroat trout by brook trout occurs through effects on fecundity or survival of young-of-year cutthroat trout, and not through interspecific competition of adult trout. Subsequent research efforts will be targeted towards mechanisms affecting recruitment and survival of young-of-year greenback cutthroat trout.

Temporal and Spatial Variation in Chemical Transformations of Snowmelt Runoff at Niwot Ridge, Colorado.

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ABSTRACT

Early runoff chemistry from the Saddle and Martinelli streams draining Niwot Ridge (elev. 11,500 ft) in the Colorado Front Range show marked changes in solute concentration between the 1999 and 2000 runoff seasons. The basins also demonstrate spatial variation in response to snowmelt inputs during both years. The two years had varying magnitudes of an "ionic pulse" in early snow meltwaters and it is suggested that these changes in input, combined with basin landcover and predominant flowpaths, may help explain the relative buffering capacity of the two basins and the runoff solute concentrations in the two streams.

Snowmelt chemistry data indicate a more pronounced ionic pulse at the start of snowmelt in 1999 than in 2000. The average Saddle stream pH does not change significantly from year to year during early runoff, however, and concentrations of $SO_4^=$, NH_4^+ and NO_3^- are similar. In contrast, the Martinelli stream shows a significant increase in mean pH in early runoff in 2000 and demonstrates a significant decrease in both average concentration and variance of $SO_4^=$, NH_4^+ and NO_3^-. While both basins are on the south-facing slope of Niwot Ridge, the 23 ha Saddle basin is almost completely vegetated, while the 8 ha Martinelli basin is approximately 50% unvegetated. In general the Martinelli stream appears to respond more directly to changes in snowmelt solute input. Flowpath separations using Na^+ and Si suggest that the Saddle basin has a greater amount of meltwater routed through the soil and subsurface. Higher concentrations of cations in the Saddle stream which may be flushed from soil also suggest that the vegetation and soils of the Saddle basin interact with snow meltwater and result in greater transformations between snowmelt and surface waters than in the Martinelli Basin.

Effect of Environmental Variables on Export of Nitrogen from Undisturbed Watersheds in the Colorado Rockies

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Organic nitrogen has been shown to be an important component of the total nitrogen load of streams draining temperate and tropical watersheds. However, relatively little is known about factors regulating concentration and export of organic nitrogen in undisturbed watersheds. Elucidation of the environmental factors regulating N exports and concentrations in streams draining undisturbed watersheds is essential in assessing the degree to which N dynamics in disturbed watersheds have been affected by deposition. The nitrogen and carbon composition of stream water from two second-order streams draining undisturbed, subalpine watersheds in Colorado was investigated. Samples of stream water were collected at weekly and biweekly intervals and were analyzed for total dissolved nitrogen (TDN), nitrate, ammonium, dissolved organic nitrogen (DON), dissolved organic carbon (DOC), particulate organic nitrogen (PON), and particulate organic carbon (POC). We found seasonal trends in the concentration of DON at both study sites. Concentrations of DON and DOC peaked during early spring snow melt. DON was the most abundant form of total dissolved nitrogen exported from the watershed during summer months when biological activity in the watersheds was highest and nitrate was most dominant form of dissolved nitrogen exported from the watershed during winter months. The proportion of total dissolved nitrogen that was exported from the watershed as DON was significantly related to water temperature. DON was a substantial component of the total dissolved nitrogen load exported from both watersheds (40% and 50%). Total daily export of nitrate and DON were related to runoff by a power function suggesting a disproportionately high release of these dissolved substances during the period of snow melt. Seasonal changes in temperature and hydrology may influence concentrations and export of DON in undisturbed watersheds located in temperate latitudes.

Implications of Climate Variability for Low Flows and Dilution of Discharges from Point Sources in the South Platte River basin

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The National Pollution Discharge Elimination System (NPDES) was created through the Clean Water Act as a mechanism for regulating the release of toxic substances to streams in the U.S. The concentration of each toxic substance in a wastewater discharge is governed by an NPDES permit, which is intended for the protection of designated uses such as maintenance of aquatic life. The allowable concentration limit in the effluent is usually determined with a steady-state model using mass balance calculations, one element of which is the dilution flow available in the receiving water. Dilution flow is defined by analysis of historical data using a specific set of critical, low-flow conditions. The use of historical data implies that the past is a good indicator of future conditions, at least for the duration of a discharge permit. In most cases, the hydrologic record that can be used for the analysis extends no more than a decade or two, depending on the availability of gage records and recent alterations to the flow regime (e.g., dams, diversions, etc.). Short records introduce great uncertainty in the estimation of low flows because they are unlikely to capture events with periodicities of multiple years. For example, ENSO events, which have a frequency of 4-6 years, would be poorly represented by hydrological records shorter than several decades. Major droughts are even less frequent: only 4 in the last 80 years.

We conducted an analysis of daily flows at several gages with long records in the South Platte basin. Low flows were calculated for successive 10-y blocks of data, and these were compared with low flows calculated for the entire period of record (>70 years). Historical variability of stream flows is great enough that it raises concerns about the extent to which low flows derived from a 10-y record will be protective of water quality. In unregulated streams, there was no trend over time, but the low flows for a single 10-y block could differ from the long term value by as much as a factor of 2. The hydrographs of most streams in Colorado have been influenced by dams, diversions, or water transfers. These alterations to the natural flow regime shorten the record that can be used for analysis and generally result in a trend of increasing low flows that is visible when successive 10-y blocks of data are analyzed. Use of a shorter record decreases the chance that significant climate variation will be reflected in the low flows. The presence of a trend based on present patterns of water use may carry an unanticipated risk by failing to incorporate societal response to severe drought conditions, for example. There is a clear need for a mechanism that will incorporate the effects of climate variation in the determination of low flows for NPDES permits.

Historic Geomorphic Analysis on the Middle Rio Grande, New Mexico

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Abstract

Historic analysis of geomorphic changes in a river downstream from a dam can reveal the impacts of sediment detention and flood control on the response of the river. Very few large alluvial rivers in the US have been studied and documented as well or exhibit such large lateral movements and changes in degree of stability as the Middle Rio Grande (MRG), New Mexico. Located downstream from Cochiti Dam in north-central New Mexico, the Cochiti Reach of the MRG spans 45 km from the dam to the Highway 44 bridge in Bernalillo, NM. During the early and mid-1900's the US Army Corps of Engineers and the US Bureau of Reclamation constructed dams and performed channelization in an attempt to reverse the historic aggradational trend and to minimize flood hazards on the MRG. Cochiti Dam, completed in 1973, was designed for sediment detention and flood control and traps virtually all of the sediment entering the Cochiti Reach.

Hydraulic, topographic, photogrammetric and sediment data collection efforts conducted by numerous federal and state agencies have tracked changes in the Rio Grande since 1895. Utilizing this extensive database, the Cochiti reach of the Middle Rio Grande was thoroughly characterized through analysis of flow regime, sediment transport, cross-sectional form, bed material, longitudinal profile, planform, and lateral movement rates. The response of the river to altered hydrologic regimes was studied through application of hydraulic geometry equations, sediment budget analysis, and examination of lateral migration rates. The level of lateral stability of the river was quantified using digitized coverages of the active channel over 74 years (1918-1992). Preliminary results show that since construction of the dam, the bed coarsened from sand to gravel size sediment and degraded and the sinuosity increased. During the entire time period studied (pre and post dam), the channel narrowed and appears to be moving toward an equilibrium width as predicted by hydraulic geometry equations. Lateral movement rates declined since 1918 and the channel shifted from a multi-thread to a more single-thread pattern. The geomorphic changes that began prior to construction of Cochiti Dam appear to be the result of changes in the hydrologic regime rather than the sediment regime.

Julien and W ______ regime eq for equilibrium

LONGITUDINAL TRENDS IN CHANNEL CHARACTERISTICS OF THE COLORADO RIVER AND IMPLICATIONS FOR FOOD-WEB DYNAMICS

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ABSTRACT

The present paper describes how lengthwise variations in the physical characteristics of the upper Colorado River (width, depth, substrate sediment size, water quality, etc.) influence the production and availability of foods used by benthic invertebrates and native fishes. Field measurements characterizing the geomorphology of the Colorado River were obtained at closely spaced intervals along a 300-km reach from approximately Rulison, CO, to Potash, UT. These data were augmented with streamflow and sediment data from four US Geological Survey gauging stations to evaluate temporal and spatial trends in suspended sediment loads.

Our field measurements indicate that the characteristics of the Colorado River change systematically downstream, but not in the typical manner. Specifically, we observe that the grain size of the substrate sediment decreases rather slowly downstream in comparison to the average gradient. In addition, we observe that the average bankfull depth increases downstream more rapidly than the average bankfull width. Over the 300-km length of the study area, the bankfull depth increases by roughly 100% while the bankfull width increases by only about 30%. This result contrasts with results from many other studies showing that the bankfull width of alluvial rivers typically increases faster downstream than the bankfull depth. Our analysis of sediment loads indicates that the annual suspended sediment load of the Colorado River increases markedly through the study area, from 0.4 x 10^6 tons/yr at Glenwood Springs, to 1.5 x 10^6 tons/yr at Cameo, to 3.4 x 10^6 tons/yr at the Colorado-Utah state line, and to 5.4 x 10^6 tons/yr at Cisco, UT.

The trends in channel characteristics and sediment load appear to have a strong influence on the distribution of aquatic organisms and fish. Environmental factors that enhance primary and secondary productivity are optimized in the upper reaches where flows are generally shallower and less turbid; densities of benthic invertebrates and adult native fishes are generally highest in these upper reaches. In the lower reaches, the transition to a deeper, more box-like channel presents a situation where proportionally less and less of the bed receives sufficient sunlight to allow primary production; these reaches are characterized by lower invertebrate biomass and fewer adult fish.

Colo R. gets disproportionally deeper faster than width

$W = 190e^{0.0016x}$ $r^2=0.14$

$D = 6.8e^{0.0030x}$ $r^2=0.50$

Leopold & Maddock rivers get width faster than deep