Potential Correlations of Historical Otowi Gage Sediment and Water Flows to Upstream Groundwater Management Practices

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Some minor annotations and corrections applied on March. 5, 2014.
The Upper Rio Grande Watershed

Background map from DEM Explorer
The Upper Rio Grande above Otowi Gage is a significant US Southwestern Watershed. It covers a domain of roughly 14,300 square miles.

Principal Targets of investigation and the broad outline of the Upper Rio Grande Watershed are sketched to facilitate discussion.
Hydrographic map
Of Upper Rio Grande Watershed with tributaries

image adapted from DEM Explorer
The Otowi Gage Time Series begins over 100 years ago. Flow measurements commence at Otowi by 1895.

Otowi Gage Time Series as Represented by Various Moving Averages

Data source: USGS online search for USGS 08313000 Rio Grande At Otowi Bridge, NM
San Luis Basin Ag uses about 640,000 af/y
An anomaly related to the measured sediment discharge at Otowi has been observed.

1955 Sediment measurements begin.
Anomaly begins ~1979  ~1990 anomaly ends
Possible Causes of Sediment Loading Depression

1. Addition of low sediment water
2. Reduction of high sediment water or varying degrees of each

Otowi Sediment Calculated Concentration (mg/l)

Data source: USGS online search for USGS 08313000 Rio Grande At Otowi Bridge, NM
Premise: the CBP permanently adds low-sediment water to the system
Projected Annual Supply = 100K af/y
A network of 170 wells with 40 miles of canal
ON LINE in 1986. Continues to date
Production targets have never been met

2. San Juan Chama Diversion Project (SJC).
Premise: the SJC temporarily reduces sediment to the system
Projected Annual Supply = 96,000 af/y
A network of 4 reservoirs.
~ 30 miles of tunnel
ON LINE in 1979. Reservoir filling begins several years earlier
Production targets have always been met

3. Instrumental Error, Natural Variability
CANDIDATE 1. CLOSED BASIN PROJECT
San Luis Basin Irrigated Agriculture uses ~640,000 af/y

CBP uses < 20,000 af/y

The Closed Basin Project

170 wells tap into the NE quadrant of the San Luis Valley basin aquifer.

The ‘closure’ of the CBP is through an evaporative sump only.

There are no physical obstacles to prevent groundwater from moving along any southern gradients that exist.

CBP Aquifer Profile, Colorado

The ‘closure’ of the CBP is through an evaporative sump only. There are no physical obstacles to prevent groundwater from moving along any southern gradients that exist.

By Laura M. Bexfield and Scott K. Anderholm

in *Conceptual Understanding and Groundwater Quality of Selected Basin-Fill Aquifers in the Southwestern United States*

Edited by Susan A. Thiros, Laura M. Bexfield, David W. Anning, and Jena M. Huntington

Precambrian bedrock is as deep as 11,000 feet below land surface.

Lobatos gage, Colorado

Measures Rio Grande streamflow near the state line.

Data source: USGS online search for USGS 8251500 Rio Grande At Lobatos, Colorado
CANDIDATE 2. SAN JUAN CHAMA DIVERSION PROJECT
San Juan Chama Project

Imports water from adjacent basin

Data source: USGS online search for USGS 08287000 RIO CHAMA BELOW ABIQUIU DAM, NM

Chama gage below Abiquiu
Wet period over 80s not as distinct as other gages.

San Juan Chama Project
Imports water from adjacent basin
Spectral analyses aid in the estimation of primary hydrologic cycles and their relative powers.
Otowi Spectral Analysis A. Fast Fourier Transform (FFT)
The FFT shows clear annual and semi-annual periods but no other significant resonances.

Water Flow

![Graph showing water flow analysis](image_url)
Otowi Spectral Analysis B. Wavelets part 1 CWT

The continuous wavelet analysis also shows clear annual and semi-annual periods.

Non stationary feature suggested over the ‘wet’ period by the CWT profile

Lowermost two red bands define 6 month and 12 month periods
Otowi Spectral Analysis B. Wavelets part 2 CCWT

The complex-continuous wavelet analysis also shows clear annual and semi-annual periods.
All Flows Summed and a Solution Proposed

1. Closed Basin Ruled Out. Too little, Too late (red zones)
2. San Juan Chama Ruled In. Timing right.
Lake Cochiti is downstream from Otowi gage.
RUSLE calculation compares favorably to Otowi sediment flow measurements on a decadal basis.

<table>
<thead>
<tr>
<th>sq miles</th>
<th>acres</th>
<th>tons/acre/yr from RUSLE</th>
<th>tons/yr</th>
<th>RUSLE calculated Rio sediment tons/decade</th>
<th>Tons of Sediment Monitored by Otowi over 80's</th>
</tr>
</thead>
<tbody>
<tr>
<td>14,300</td>
<td>9,152,000</td>
<td>0.16</td>
<td>1,464,320</td>
<td>14,643,200</td>
<td>15,112,041</td>
</tr>
</tbody>
</table>

RUSLE calculation compares favorably to Otowi sediment flow measurements on a decadal basis.
Otowi sediment flows reach Cochiti Lake first.

Figure 1. Contributing area of Cochiti Lake and location of sediment coring sites.
CANDIDATE 3.  NATURAL VARIABILITY
Lewis and Hathaway summarized ocean PDO and related tree ring trends, along with other climatic forcing candidates. They suggested that first order predictions of SW climate, based in part on the correlation of Otowi gage records to the PDO, would be possible.

Chylek et al. summarized ocean PDO and related trends, along with other climatic forcing candidates, and they related this to SW climate:

Petr Chylek, Manvendra K. Dubey, Glen Lesins, Jiangnan Li, Nicolas Hengartner

Climate Evaluation of Otowi Flows yielded unanticipated high fidelity to Pacific Decadal Oscillation

Pacific Decadal Oscillation (PDO) Compared to Otowi Gage Time Series

Otowi source: USGS 08313000 Rio Grande At Otowi Bridge, NM
PDO Sources:
Correlation of PDO to Otowi Flows are highest, .72 at a lag of ~1 yrs. Suggests further work may benefit.

**PDO Sources:**
Can the PDO – OTOWI CORRELATION be used to predict near future annual New Mexico weather patterns?

The profiles of the correlogram and the time series, along with other proxy data, along with external publications, support that the PDO is likely a **cyclo-stationary (CS)** phenomenon. We start with that CS assumption.

We might then assume a Markov model to estimate future PDO and Otowi behavior. This is supported the auto-correlograms of both time series as shown below.

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Can the PDO – OTOWI CORRELATION be used to predict near future annual New Mexico weather patterns?

If the ~ 1 yr lag between PDO and OTOWI phasing is confirmed, and if the assumptions are borne out, and with an enhanced focus on the PDO throughout the US southwest, including the upper Rio Grande watershed, it is conceivable that a powerful and simple capability can be developed to support ~ 1 year rough projections of stream flow in targeted regions of NM and its neighbors.

Until then, and as an educated guess, given the time series and correlogram profiles of the latest ~ 50 to 60 year period of the PDO and the OTOWI gage streamflows, it would not be surprising if:

The current drought conditions in the Upper Rio Grande persisted for a few decades (~10 to 40 years), ± 10 years followed by a return to significantly wetter conditions.

Past NM droughts have been both longer and shorter, and more and less severe. Also, longer term cycles and/or trends, if any, are not captured by the ~ 100 year record used in this exercise. The above thoughts are no more than that, based on subjective expert judgement. If the approach is found to show promise, then future work is required in many lines of investigations.

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Conclusions:

The Otowi gage 1980’s sediment anomaly appears to be a consequence of the initial releases of San Juan Chama reservoir waters, coincidentally timed with a PDO peak. The sediment – poor waters flowed past the gage over the same time frame as the high PDO natural stream flows.

By the end of the 1980’s a new equilibrium appears to have been established and sediment flows returned to the typical pattern.

A strong, high resolution correlation exists between Otowi flows and the PDO.

As already noted by others, the PDO correlates positively with lagged US Southwest moisture patterns and with the Otowi gage record.

The new high fidelity lag correlation record of Otowi streamflow, compared to the PDO, suggests intriguing possibilities for improved multi scale drought forecasting in New Mexico and its neighbors.

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