Development of RiverWare model for flood control planning for the Lower Rio Grande

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US Army Corps of Engineers®

Outline

- Objectives
- Lower Rio Grande Reaches
- Surface Water/Groundwater Interactions
- ARIMA Transfer Functions
- RiverWare Model Development
- RiverWare Model Results
- Conclusions

Objectives

- Develop conceptual model for surface/ground water interaction
- Develop RiverWare model for Lower Rio Grande (LRG)
- Use RiverWare DMI to link data to the model

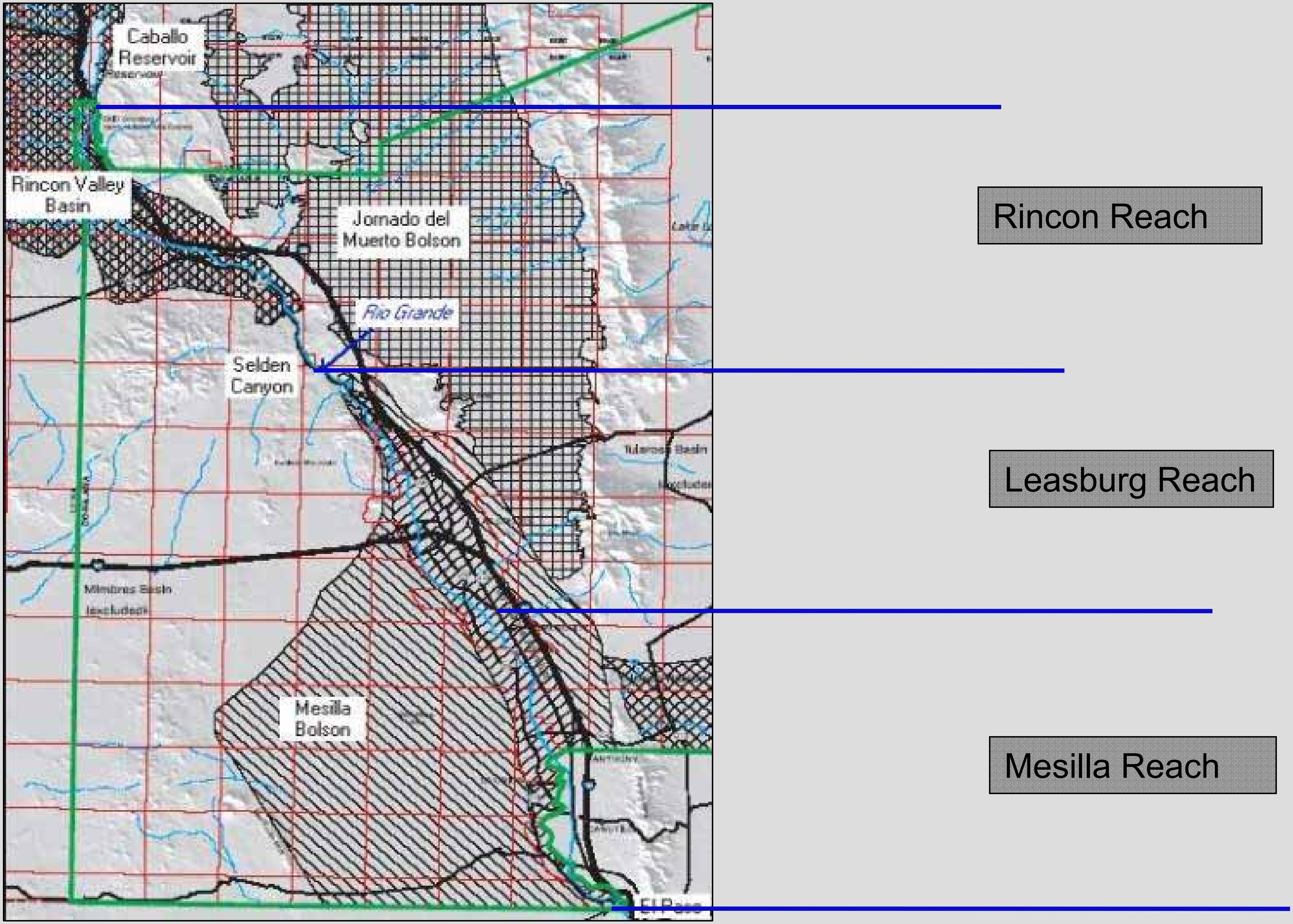

Figure 1. Lower Rio Grande Basins (Terracon et al., 2004)

Leasburg Reach:

- Between Leasburg Div. Dam and Mesilla Div. Dam
- Leasburg Canal carries diverted water for irrigation
- City of Las Cruces WWTP return flow is in this reach

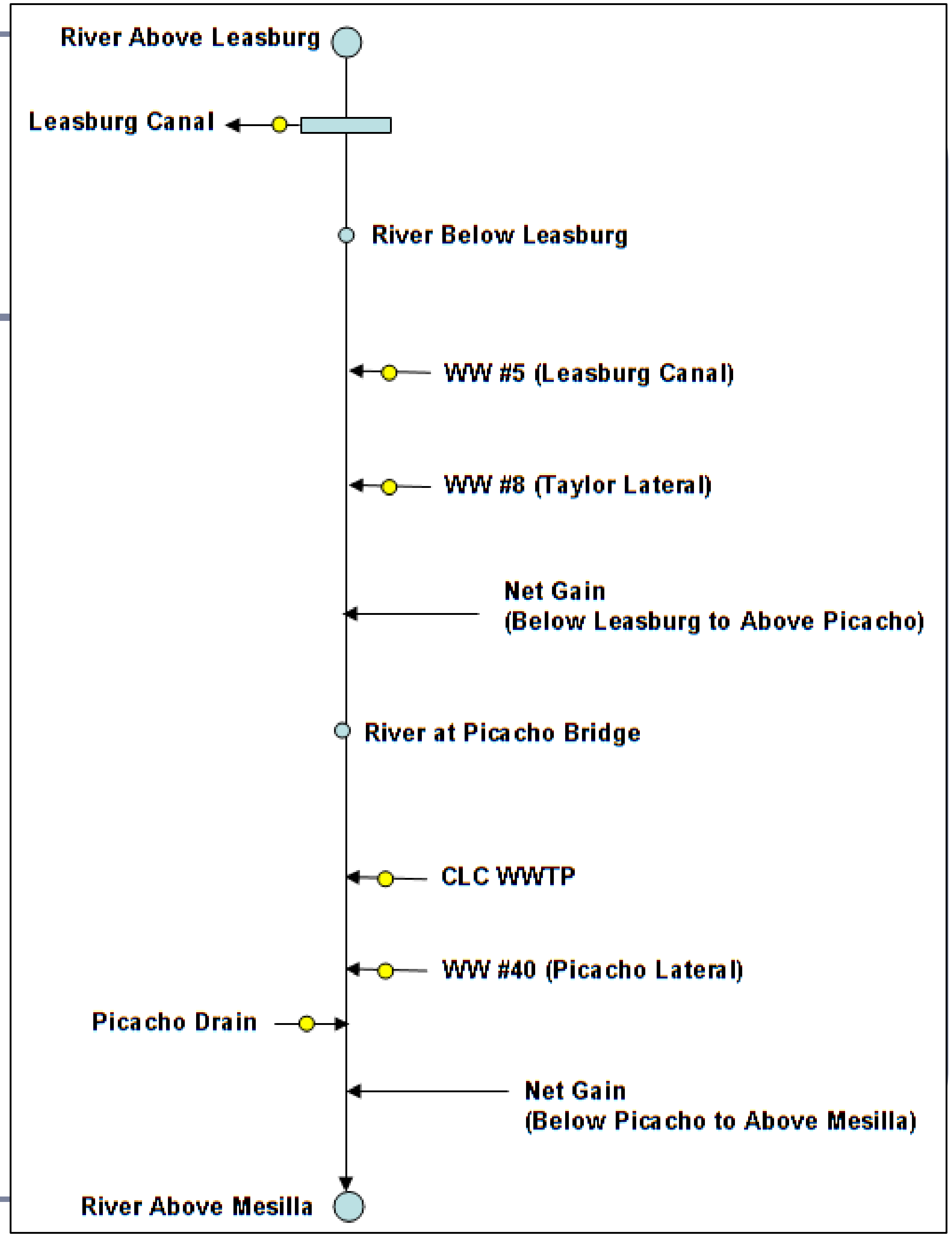

Figure 4. Schematic of the Leasburg Reach

Surface/Groundwater Interactions

- Conceptual Model
  - The main variables of interest for forecasting flows
    - Diversions
    - Conveyance infiltration
    - Deep percolation from irrigation
    - Groundwater withdrawal
    - Precipitation
  - The variable with largest effect on interactions = DIVERSION

ARIMA *Transfer Function* Analysis

AutoRegressive Integrated Moving Average

Commonly called Box-Jenkins Approach

- Use ARIMA *Transfer Function* model to
  - Simulate relationships between diversions and drain return flows
- Return flow predictions are made from a linear combination of
  - Past values of the return flow
  - Current and past values of the diversion
  - Past errors (or residuals)
- Residuals are represented by ARMA model

Transfer Function Model Form

$$\left(1-B^{12}\right)Z_t = \omega_o\left(1-B^{12}\right)X_t + \frac{\left(1-\theta_1 B^{12}\right)}{\left(1-\phi_1 B\right)\left(1-\phi_2 B^{11}\right)}a_t$$

Z_t = Drain flow (LN) at time period t (AF)
X_t = Diversion at time period t (AF)
a_t = Residuals = Y_t (actual) – Y_t (predicted)
B = Back-shift operator, used to take differences over time of a value
t = Time period
ω_o= Regression coefficient for diversion
$\phi_{1,}$ ϕ_2 = Autoregressive parameters for the residuals ARMA model
θ_1= Moving-average parameter for the residuals ARMA model

SAS System for Windows, V9.1 used for Time Series Analysis

Forecast Equation Form

$$\begin{aligned}\hat{Z}_n = Z_{n-12} + \phi_1\left(Z_{n-1} - Z_{n-13}\right) - \phi_1\phi_2\left(Z_{n-12} - Z_{n-24}\right) + \\ \phi_2\left(Z_{n-11} - Z_{n-23}\right) + \omega_o\left[X_n - X_{n-12} - \right. \\ \phi_1(X_{n-1} - X_{n-13}) + \phi_1\phi_2\left(X_{n-12} - X_{n-24}\right) - \\ \left.\phi_2\left(X_{n-11} - X_{n-23}\right)\right] - \theta_1\left(Z_{n-12} - \hat{Z}_{n-12}\right)\end{aligned}$$

Z_{n-i} = Drain flow for first month after observed data (AF)
X_{n-i} = Diversion (AF) at month n-i
n = number of observations
i = number of months of lag
ϕ_1 = 0.54189
ϕ_2 = 0.22134
θ_1 = 0.72055
ω_o = 0.00005324

Transfer Functions Implemented

- Rincon Reach
  - Garfield Drain from Arrey Canal Diversion
  - Hatch Drain from Arrey Canal Diversion
  - Rincon Drain from Arrey Canal Diversion

- Mesilla Reach
  - Del Rio Drain from Eastside Canal Diversion
  - La Mesa Drain from Westside Canal Diversion
  - East Drain from Eastside Canal Diversion
  - Montoya Drain from Westside Canal Diversion

RiverWare Model Development

- Time period simulated in model
  - Jan 1985 through Dec 1999
- Using observed data
  - Jan 1985 through Dec 1998
- Flow data units
  - Acre-feet/month
- Monthly time steps

Model Development (con't)

- Rules were used to calculate transfer function expressions
  - To make sure equations were executed in proper order
  - To make sure there are valid values for all time steps

- Dimensionless data were used in transfer function calculations
  - To circumvent RiverWare's automatic conversions on monthly data based on number of days in the month
  - Exponential function does not work with units of AF/mo on value to be exponeniated

Policy Group Editor - "LRGFCM.rls : Mesilla Reach Group"

File Edit Group View

Name: Mesilla Reach Group

RPL Set Not Loaded

Name	Priority	On	Type
Eastside Canal Forecast	30	✓	Rule
Eastside Canal Forecast No Units	31	✓	Rule
Westside Canal Forecast	32	✓	Rule
Westside Canal Forecast No Units	33	✓	Rule
Net Gain Mesilla to Anthony Forecast	34	✓	Rule
Net Gain Anthony to Vinton Forecast	35	✓	Rule
Net Gain Vinton to El Paso	36	✓	Rule
Del Rio Z No Units	37	✓	Rule
Del Rio LN Transfer Function No Units	38	✓	Rule
Del Rio Transfer Function No Units	39	✓	Rule
Del Rio Forecast No Units	40	✓	Rule
Del Rio Drain Forecast	41	✓	Rule
La Mesa Transfer Function No Units	42	✓	Rule
La Mesa Forecast No Units	43	✓	Rule
La Mesa Drain Forecast	44	✓	Rule
East Drain Transfer Function No Units	45	✓	Rule
East Drain Forecast No Units	46	✓	Rule
East Drain Forecast	47	✓	Rule
Montoya Drain Transfer Function No Units	48	✓	Rule
Montoya Drain Forecast No Units	49	✓	Rule
Montoya Drain Forecast	50	✓	Rule

Rule Editor - "LRGFCM.rls : Mesilla Reach Group : Del Rio LN Transfer Function No Units"

File Edit Rule View

Name: Del Rio LN Transfer Function No Units

```
Del Rio Drain.LNTranferFunctionNoUnits []
  = IF( @"Current Timestep - 23 Timesteps" < @"Start Timestep" )THEN
      # Use historic data for first two years
      Del Rio Drain.ZNoUnits []
    ELSE
      # After 2 years of historic data, for 1 year use previous forecast (for 1986) that was input for lagged forecast
      IF( @"Current Timestep - 35 Timesteps" < @"Start Timestep" )THEN
        Del Rio Drain.ZNoUnits [@"Current Timestep - 12 Timesteps"]
        + Del Rio Drain.phi1 []
          * Del Rio Drain.ZNoUnits [@"Current Timestep - 1 Timesteps"]
        - Del Rio Drain.phi1 []
          * Del Rio Drain.ZNoUnits [@"Current Timestep - 13 Timesteps"]
        + Del Rio Drain.phi2 []
          * Del Rio Drain.ZNoUnits [@"Current Timestep - 8 Timesteps"]
        - Del Rio Drain.phi2 []
          * Del Rio Drain.ZNoUnits [@"Current Timestep - 20 Timesteps"]
        + Del Rio Drain.omega0 []
          * ( Eastside Canal.ForecastNoUnits []
            - Eastside Canal.ForecastNoUnits [@"Current Timestep - 12 Timesteps"]
            - Del Rio Drain.phi1 []
              * Eastside Canal.ForecastNoUnits [@"Current Timestep - 1 Timesteps"]
            + Del Rio Drain.phi1 []
              * Eastside Canal.ForecastNoUnits [@"Current Timestep - 13 Timesteps"]
            - Del Rio Drain.phi2 []
              * Eastside Canal.ForecastNoUnits [@"Current Timestep - 8 Timesteps"]
            + Del Rio Drain.phi2 []
              * Eastside Canal.ForecastNoUnits [@"Current Timestep - 20 Timesteps"]
        - Del Rio Drain.theta1 []
          * ( Del Rio Drain.ZNoUnits [@"Current Timestep - 12 Timesteps"]
            - Del Rio Drain.PrevForecastNoUnits [@"Current Timestep - 12 Timesteps"]
```

```
ELSE
  IF( @"Finish Timestep - 4 Timesteps" < @"Current Timestep" )THEN
    ( Del Rio Drain.ZNoUnits [@"Current Timestep - 12 Timesteps"]
    + Del Rio Drain.phi1 []
      * Del Rio Drain.LNTranferFunctionNoUnits [@"Current Timestep - 1 Timesteps"]
    - Del Rio Drain.phi1 []
      * Del Rio Drain.ZNoUnits [@"Current Timestep - 13 Timesteps"]
    + Del Rio Drain.phi2 []
      * Del Rio Drain.LNTranferFunctionNoUnits [@"Current Timestep - 8 Timesteps"]
    - Del Rio Drain.phi2 []
      * Del Rio Drain.ZNoUnits [@"Current Timestep - 20 Timesteps"]
    + Del Rio Drain.omega0 []
      * ( Eastside Canal.ForecastNoUnits []
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        - Del Rio Drain.phi1 []
          * Eastside Canal.ForecastNoUnits [@"Current Timestep - 1 Timesteps"]
        + Del Rio Drain.phi1 []
          * Eastside Canal.ForecastNoUnits [@"Current Timestep - 13 Timesteps"]
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          * Eastside Canal.ForecastNoUnits [@"Current Timestep - 8 Timesteps"]
        + Del Rio Drain.phi2 []
          * Eastside Canal.ForecastNoUnits [@"Current Timestep - 20 Timesteps"] )
    - Del Rio Drain.theta1 []
      * ( Del Rio Drain.ZNoUnits [@"Current Timestep - 12 Timesteps"]
        - Del Rio Drain.LNTranferFunctionNoUnits [@"Current Timestep - 12 Timesteps"] ) )
```
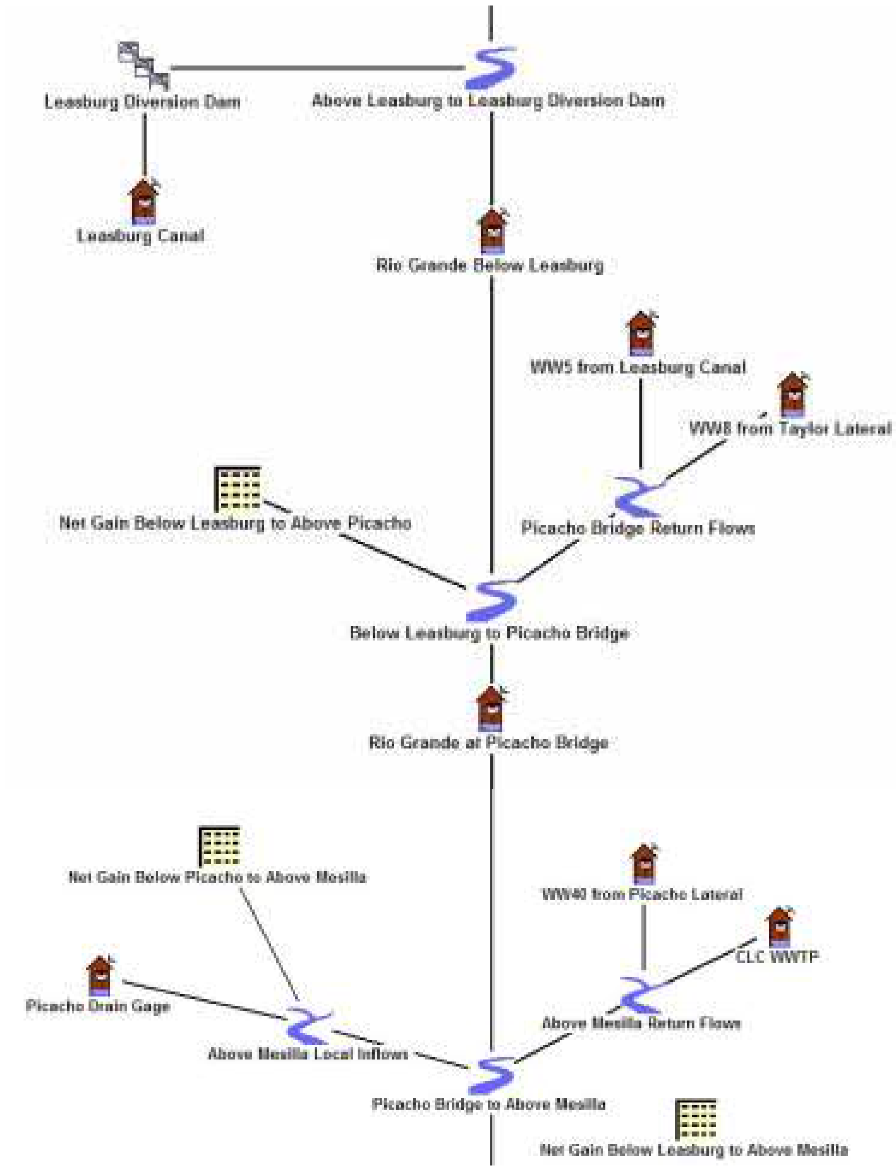
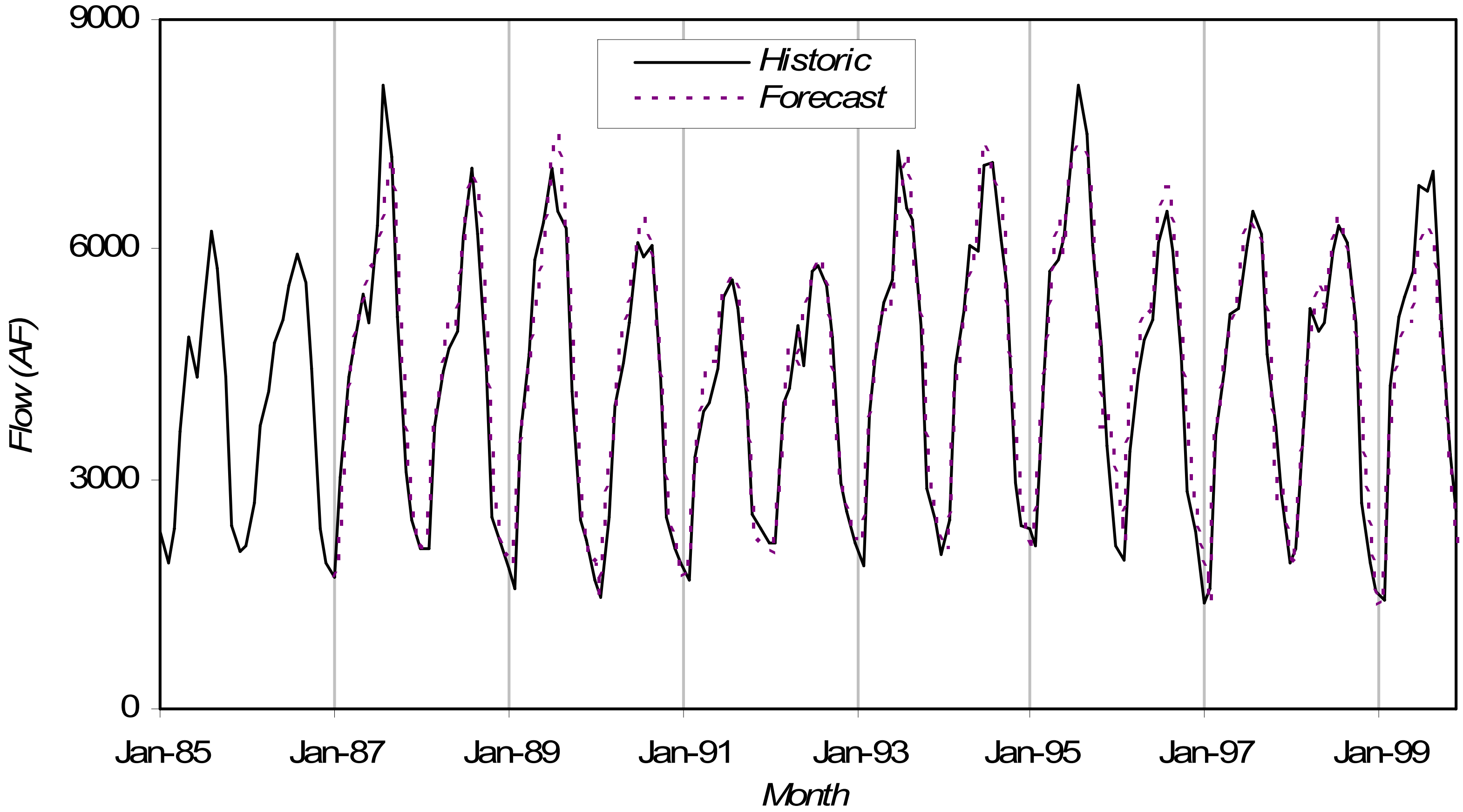
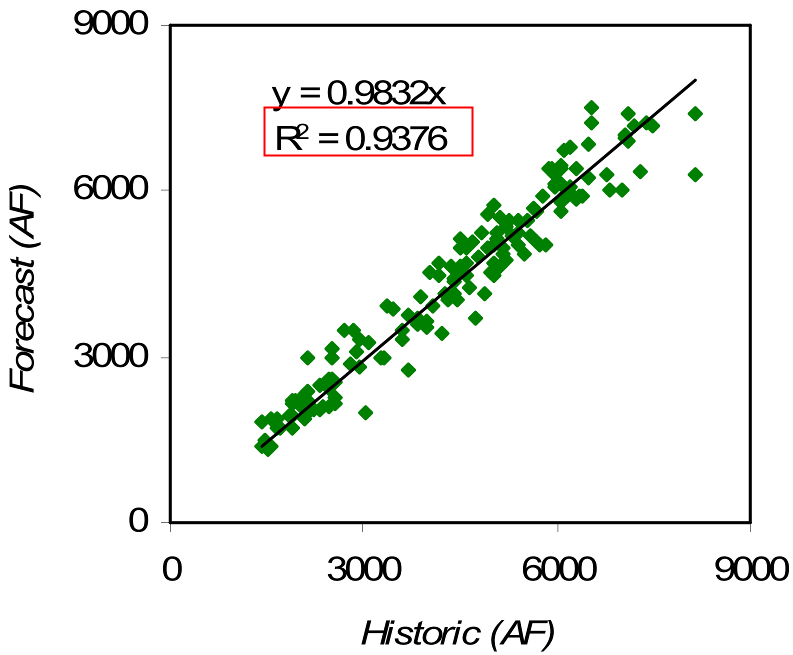

❑RiverWare Model Layout

➢Leasburg Reach



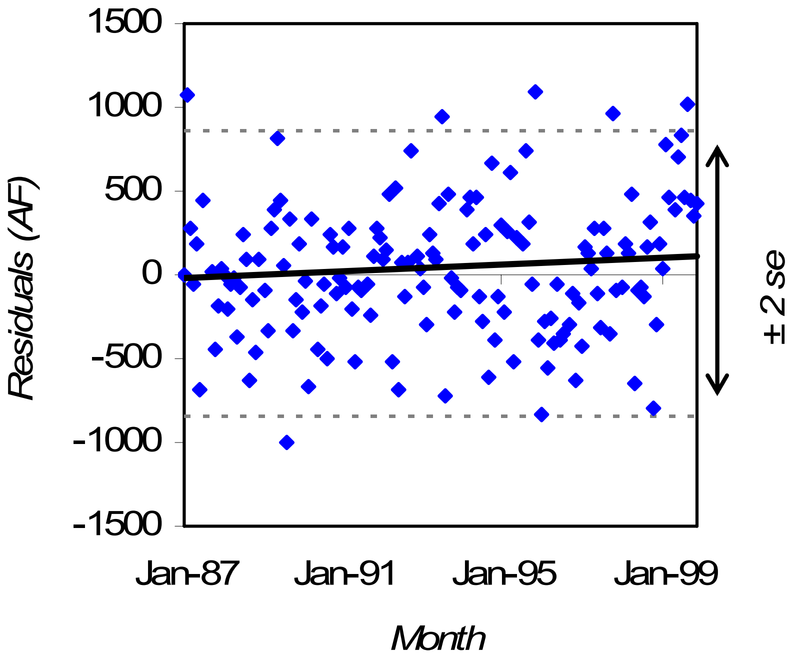
Results for Montoya Drain



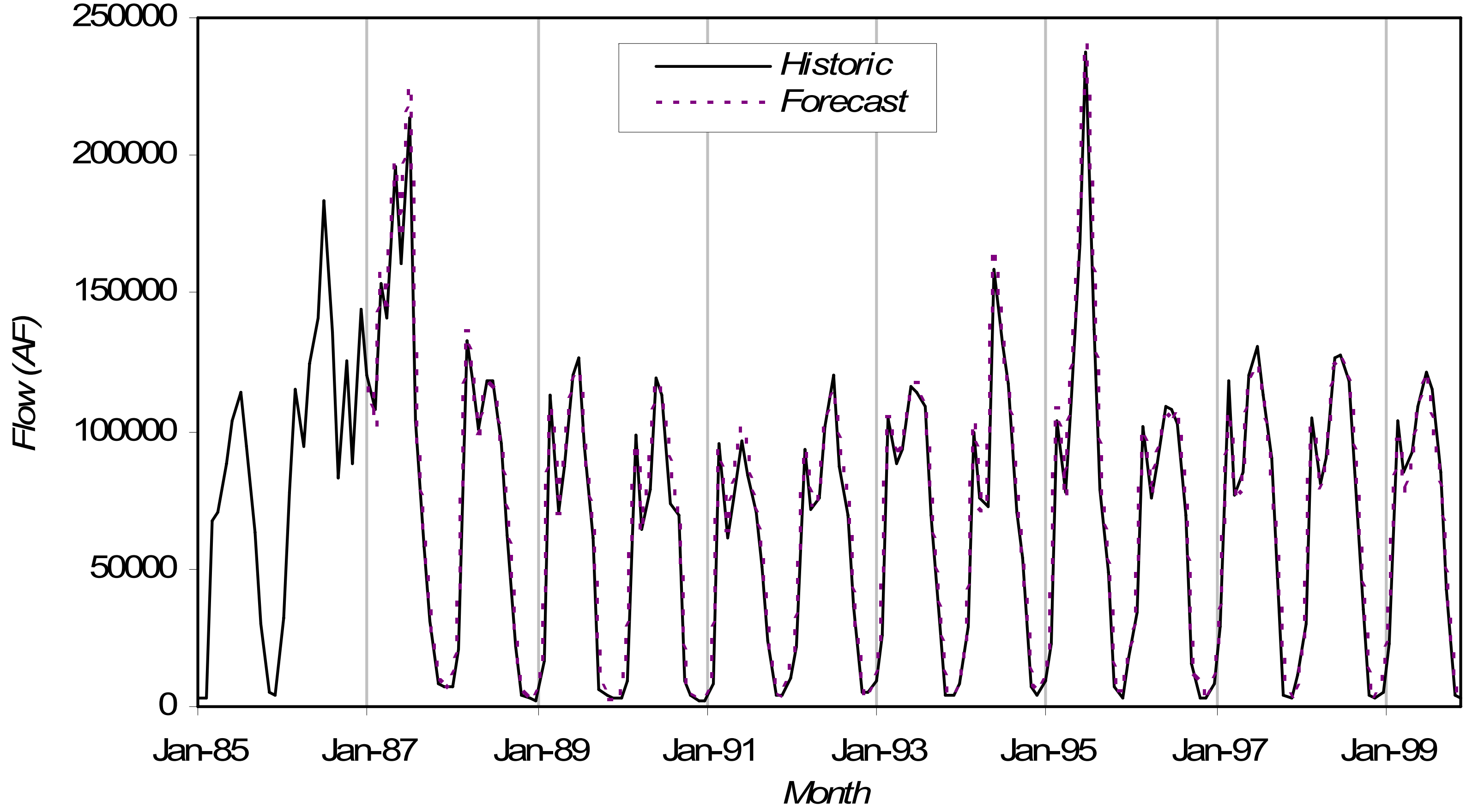


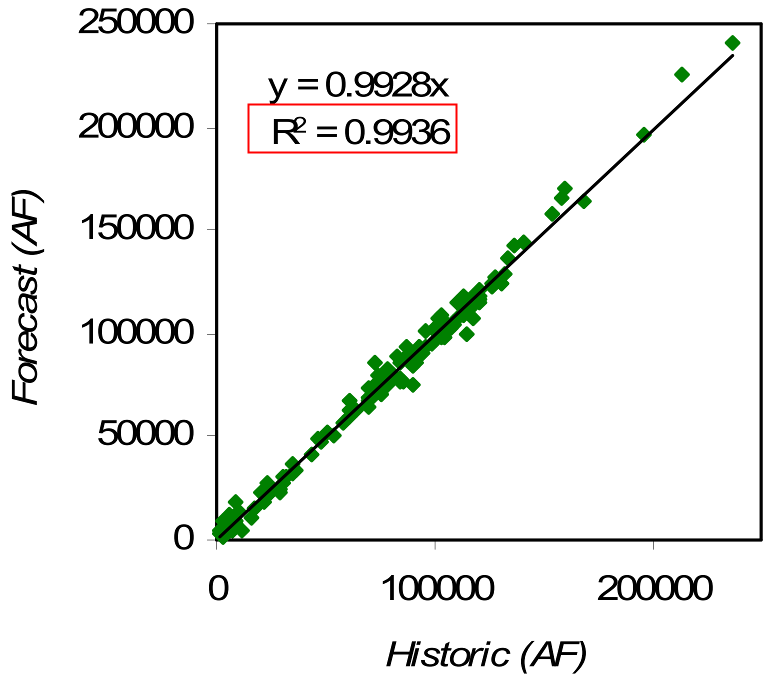
Correlation for Montoya Drain forecast data vs. actual data

Residuals

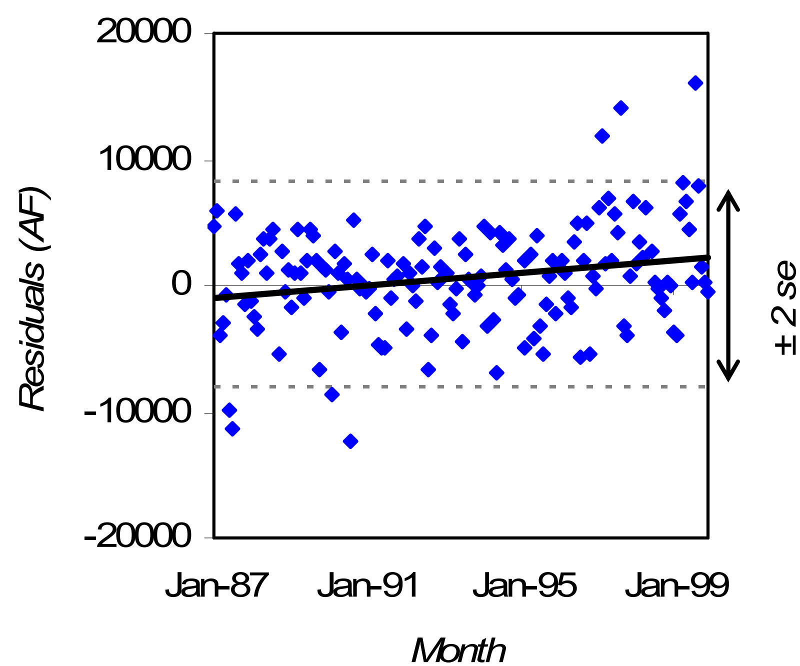


Results for River Above Leasburg



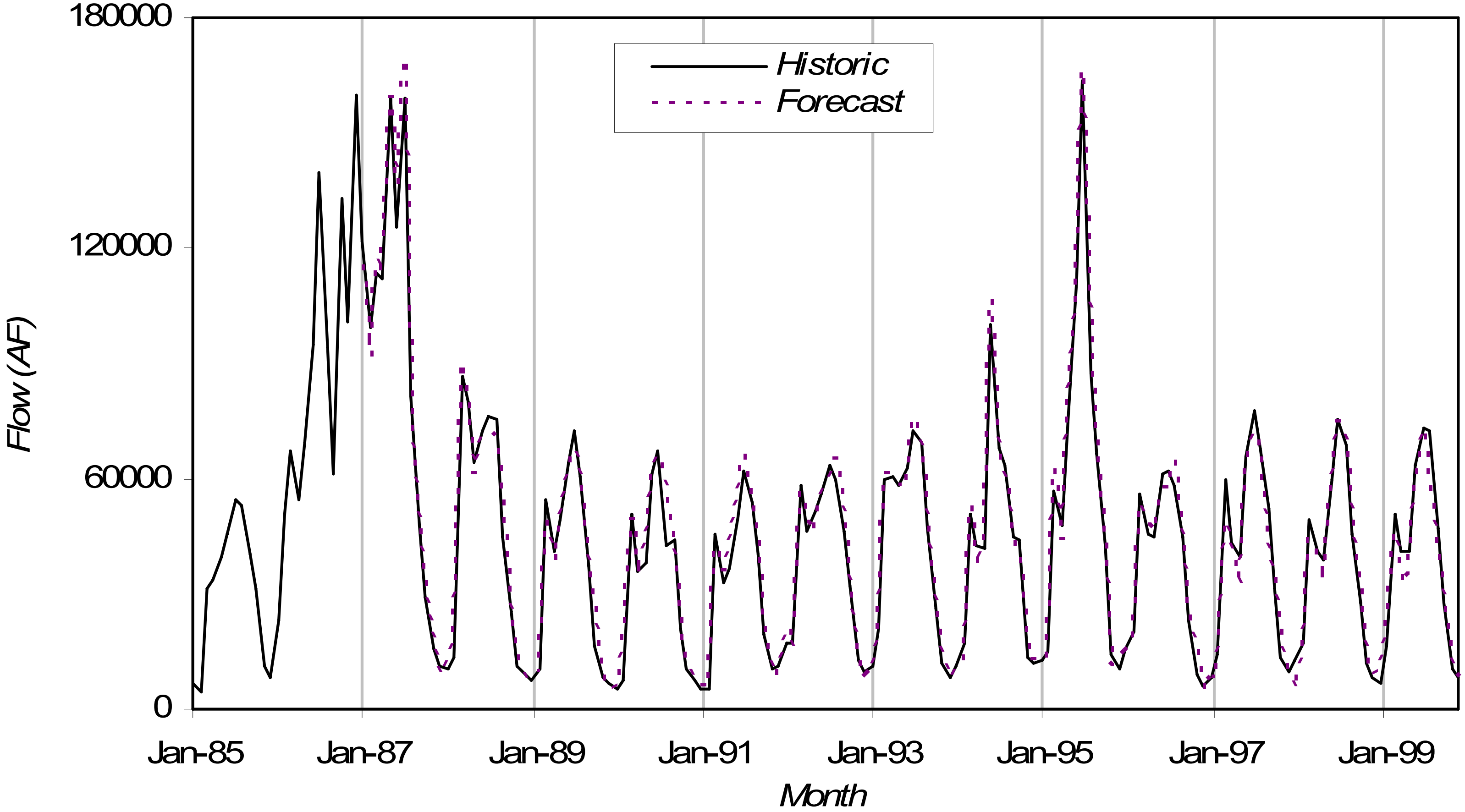


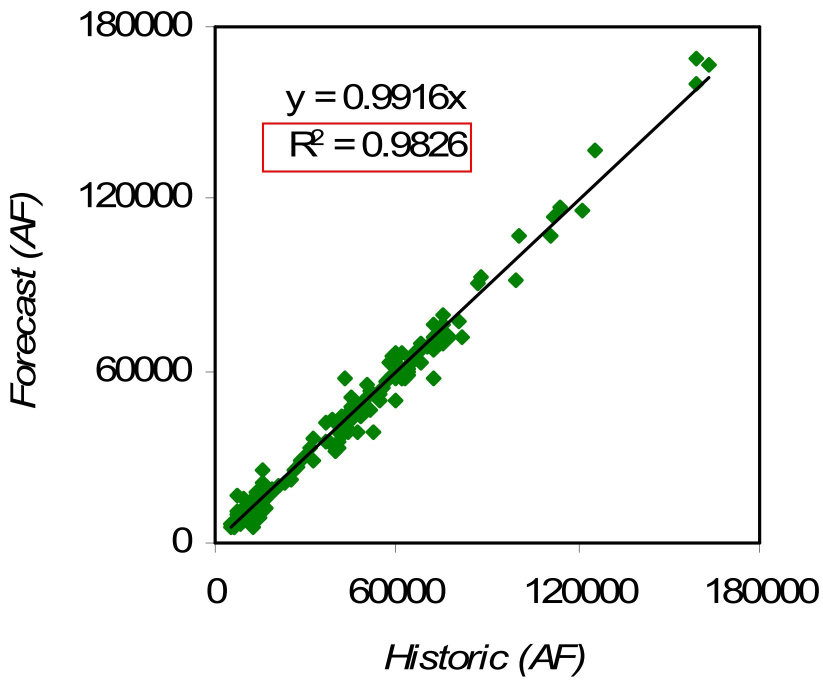
Residuals



Correlation for River Above Leasburg forecast data vs. actual data

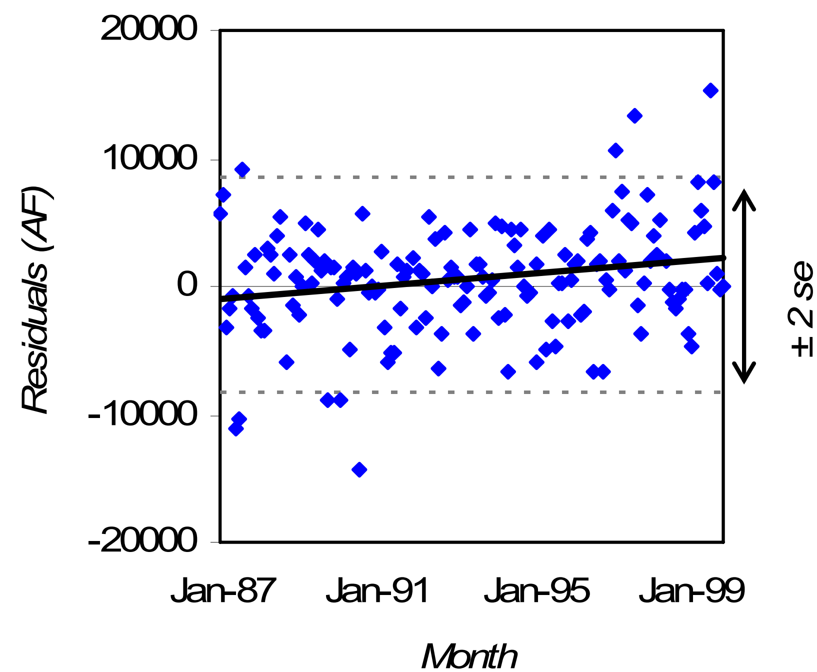
Results for River At El Paso





Correlation for River At El Paso forecast data vs. actual data

Residuals



CONCLUSIONS

- ARIMA *Transfer Functions* are adequate for estimating drain return flows from diversions
- Results are highly correlated with historic values
- Equations provide more accurate results than simple linear relationships
- However, deriving and implementing the *Transfer Function* equations can be difficult and time consuming

Questions?