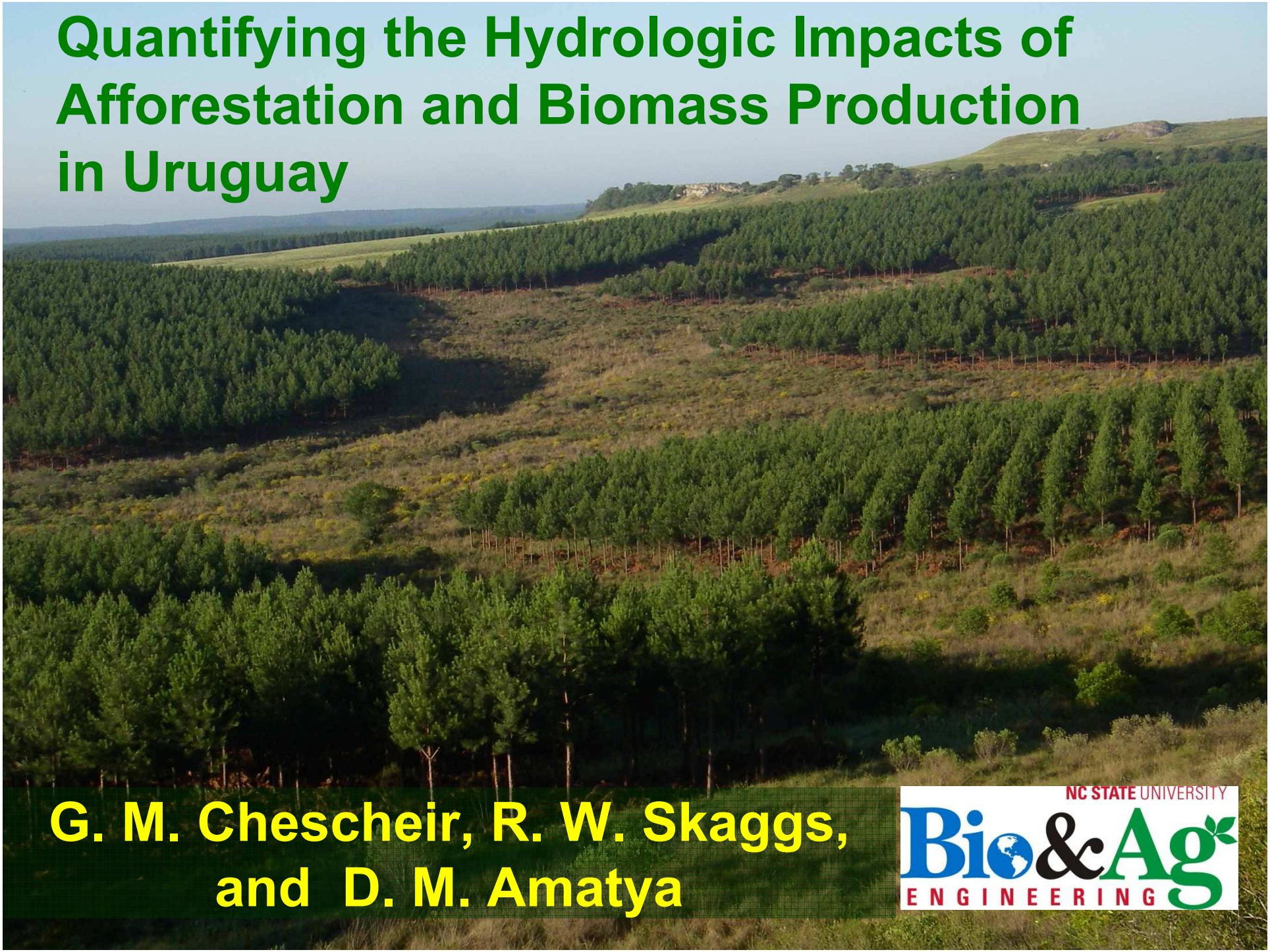
Quantifying the Hydrologic Impacts of Afforestation and Biomass Production in Uruguay



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NC STATE UNIVERSITY
Bio&Ag ENGINEERING

A cooperative project including researchers from:

Universidad de la República Uruguay

Instituto Nacional Investigaciones Agropecuarias (INIA)

Weyerhaeuser Uruguay

U. S. Forest Service

N. C. State, Dept. of Bio. and Ag. Engineering

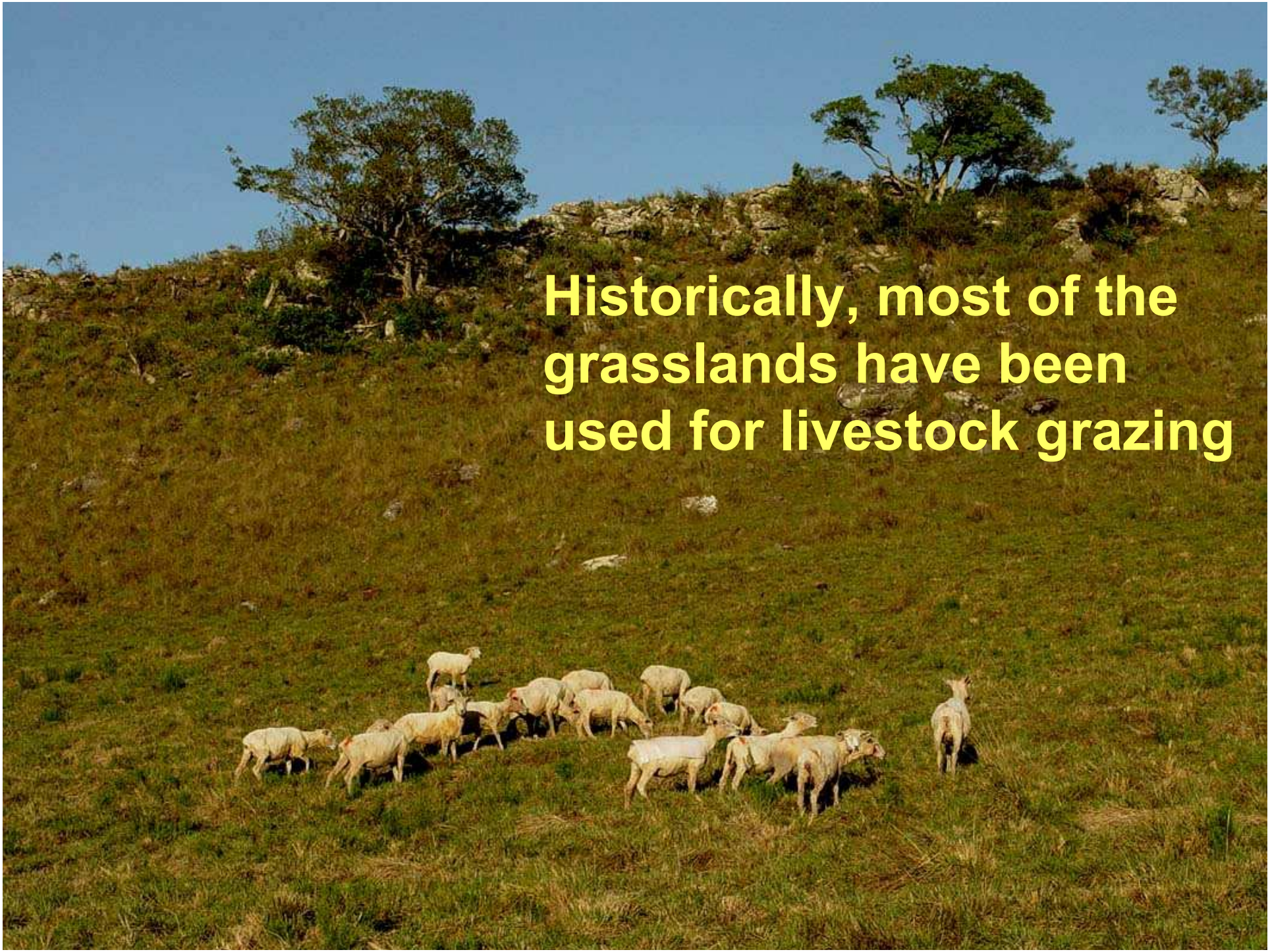
Uruguay

Humid subtropical to temperate climate

Ecologically characterized by native grasslands (Savannah)

Topography ranges from plains to rolling hills with elevations to 500 m

85% of land mass is in agriculture (highest percentage in the world)


Historically, most of the grasslands have been used for livestock grazing

Products of Uruguay

In an effort to diversify the rural economy, the Uruguayan government instituted financial incentives promoting forest production

Approximately 800,000 ha of grasslands were planted to trees between 1990 and 2007. Primarily eucalyptus and loblolly pine

Local stakeholders have expressed concerns about the impact of converting grasslands to tree plantations on water resources

Of particular concern are the impacts on water yield and downstream water supply, as well as base flows in the receiving streams.

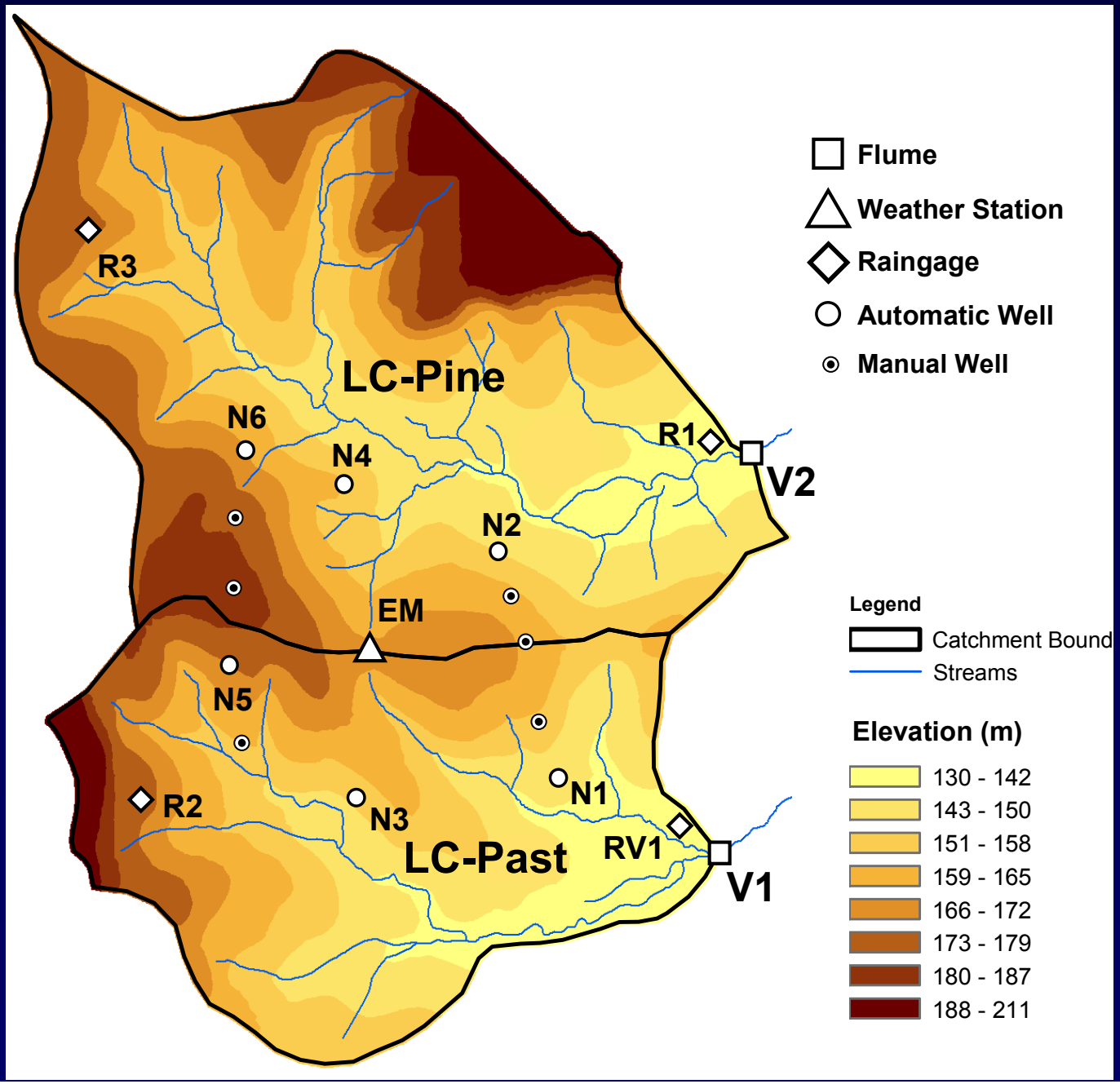
Overall Objective

Determine the hydrologic and environmental effects of converting grass lands to managed forest in Uruguay

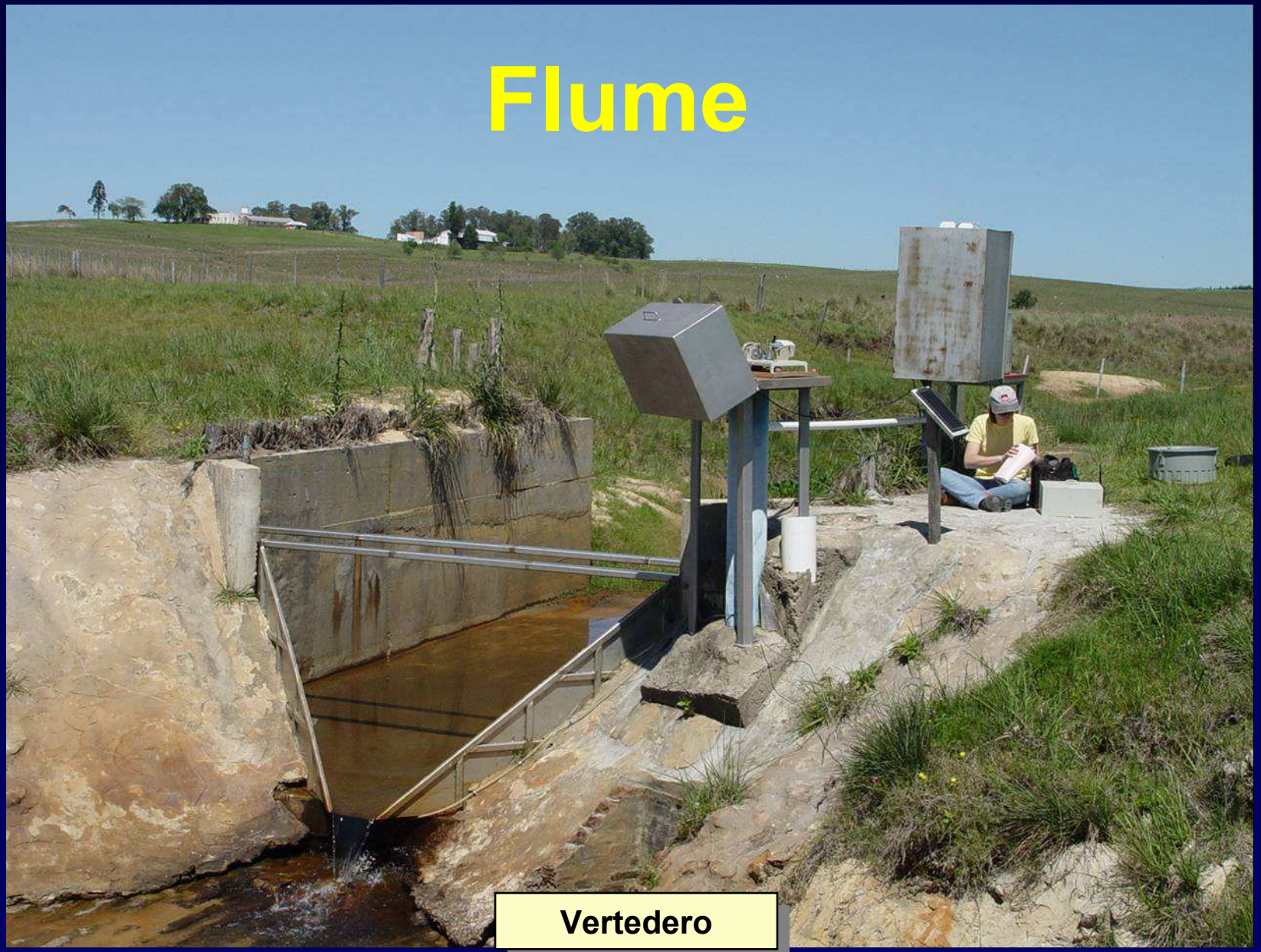
Researchers from NCSU – BAE study the Hydrology of the systems	Researchers from: Universidad de la República Instituto Nacional Investigaciones Agropecuarias (INIA)
Weather	Water Quality
Runoff Volume	Soil Properties
Runoff Timing	Tree Growth and LAI
Water Table	Flora and Fauna
Hydrologic Modeling	Pasture and Cow Health

Paired Watershed Approach

- Two similar adjacent watersheds
- Hydrologic calibration period: 3 years
- Control Watershed – Remains Pasture
- Treatment Watershed – Planted with pine trees
- Treatment period: (Growth Cycle)
- Compare hydrology of control vs. treatment in order to determine effects


Flume
Weather Station
Raingage
Automatic Well
Manual Well
R3
LC-Pine
N6
N4
R1
V2
N2
EM
N5
R2
N3
N1
LC-Past
RV1
V1
Legend
Catchment Bound
Streams
Elevation (m)
130 - 142
143 - 150
151 - 158
159 - 165
166 - 172
173 - 179
180 - 187
188 - 211

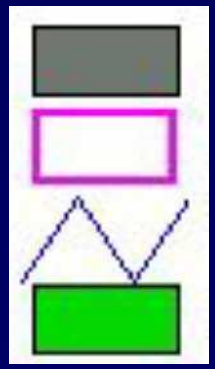
Flume



Vertedero

After trees are planted on LC-Pine

- June 2003

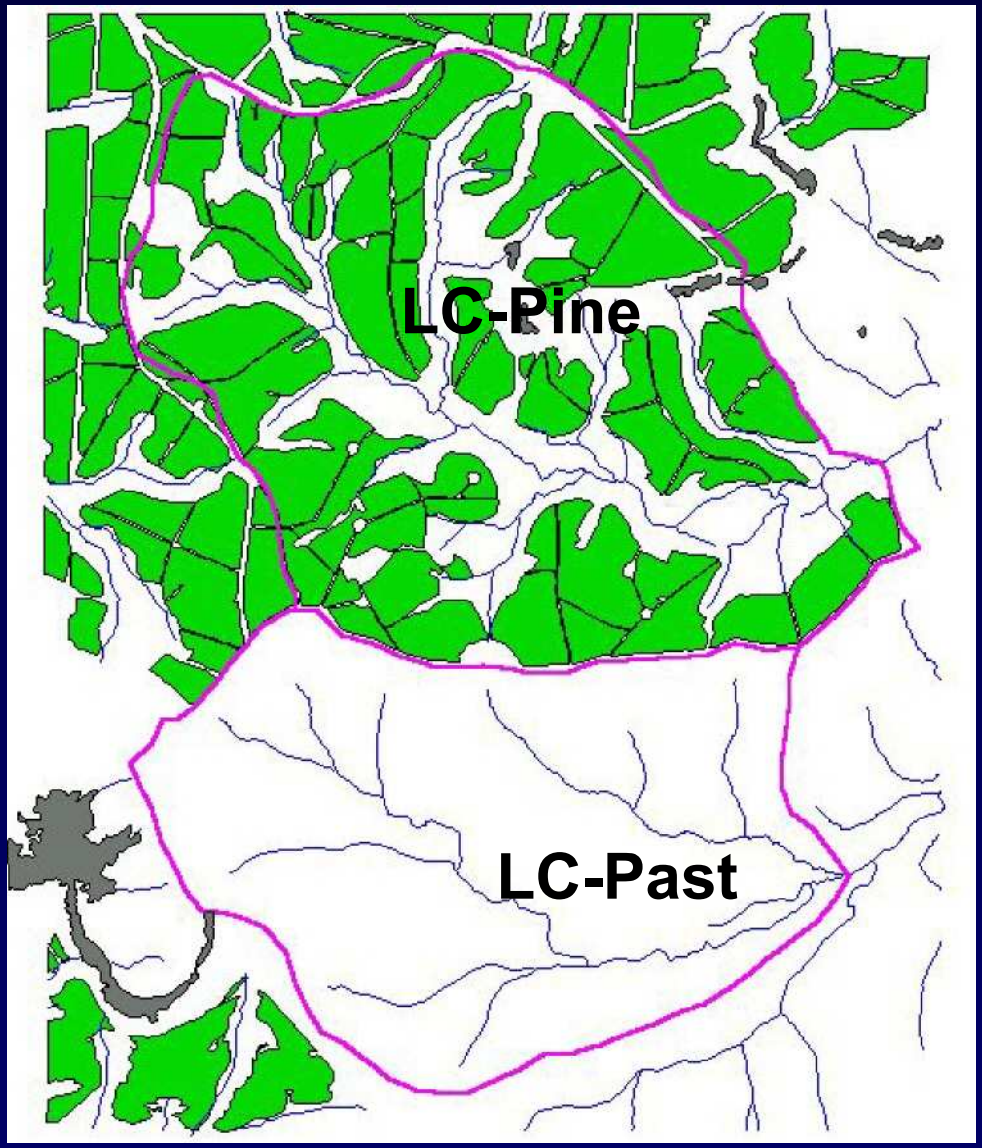


Rock

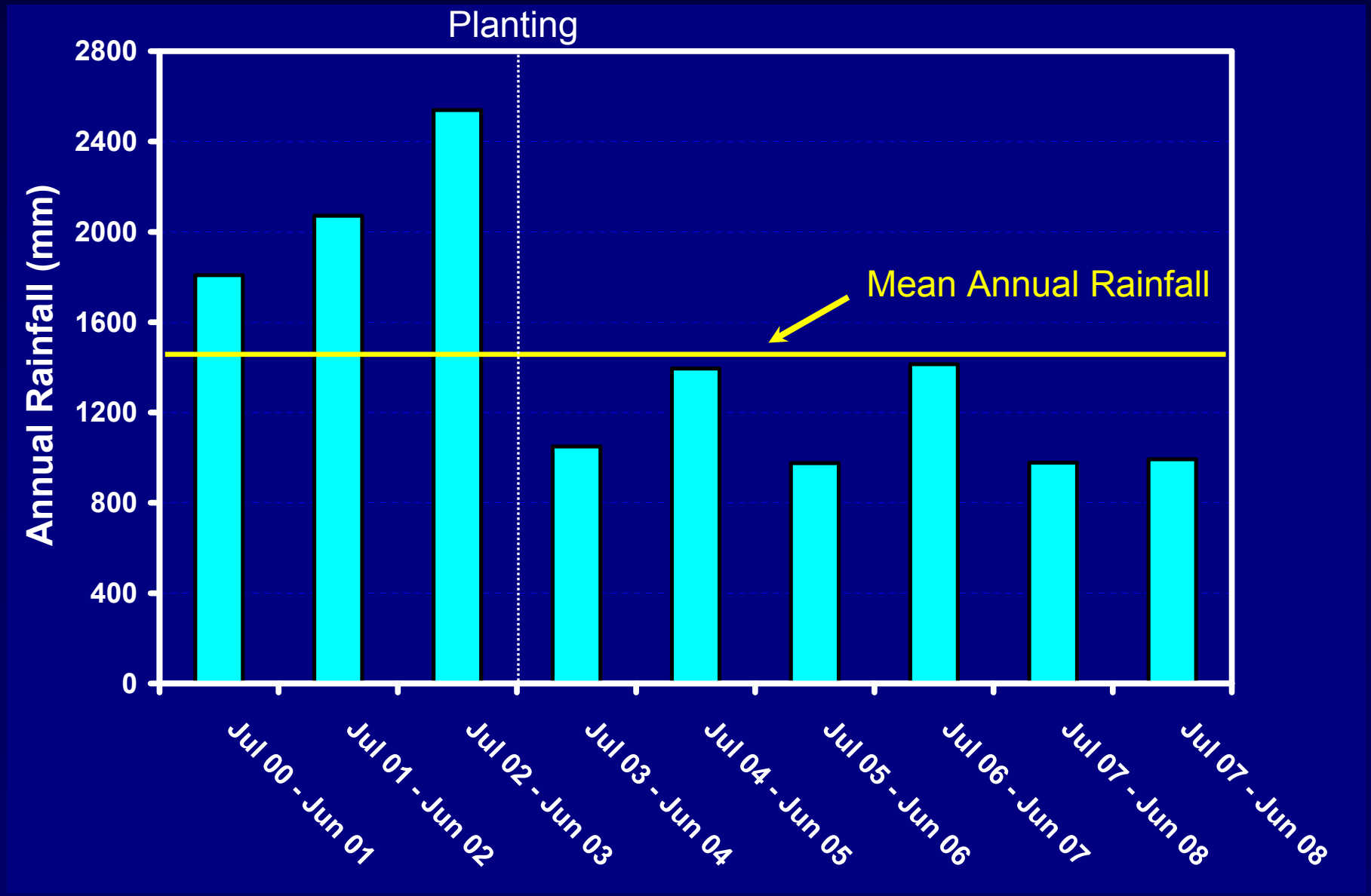
Catchment

Stream

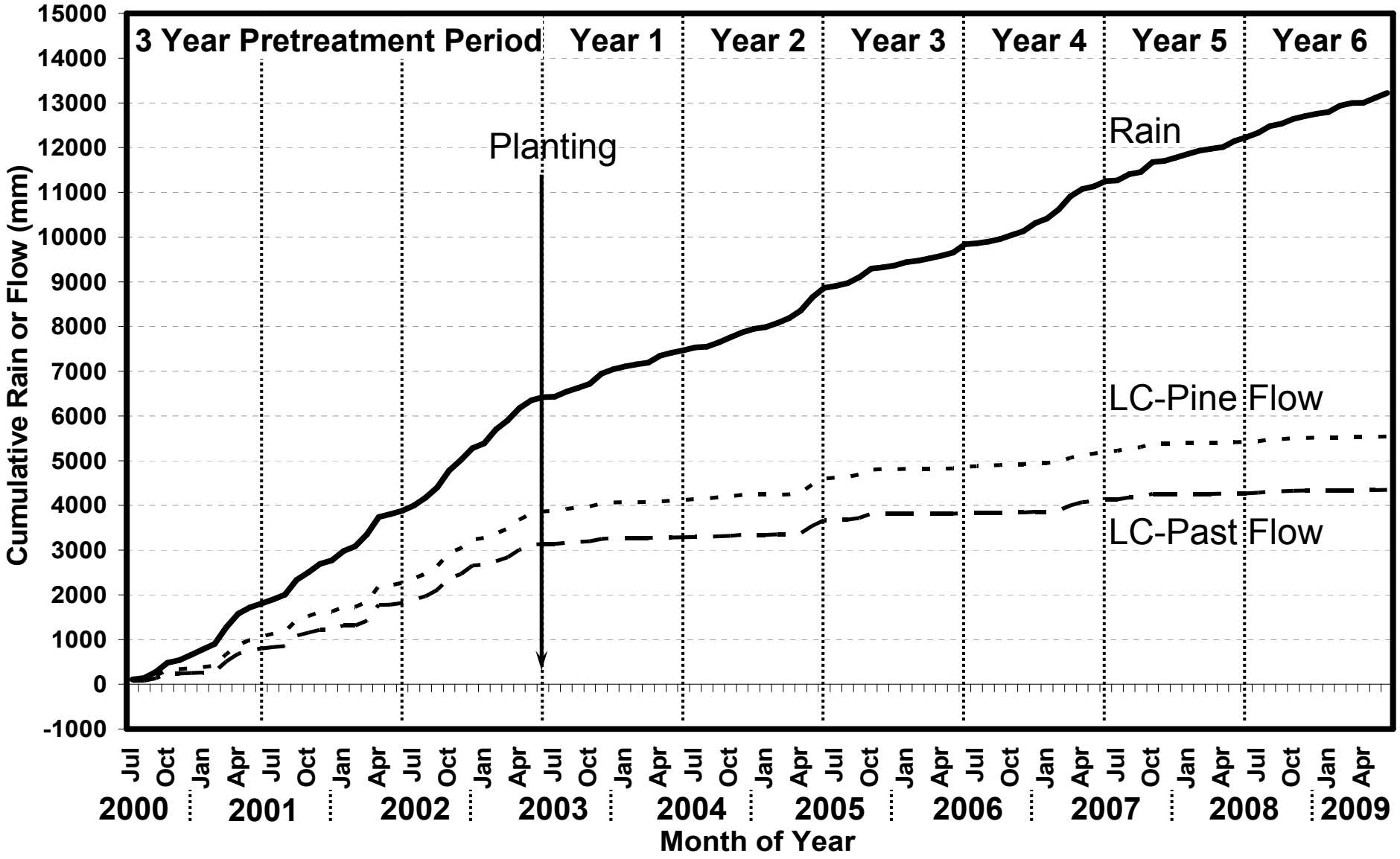
Pine Planting



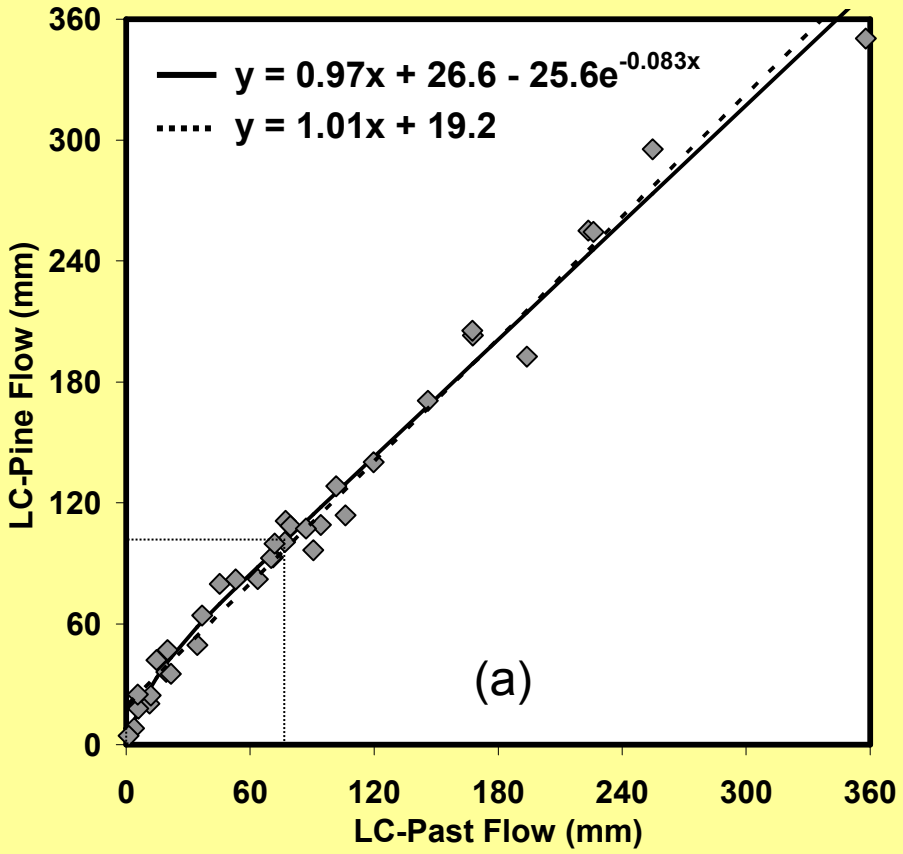
Annual Rainfall During the Study Period

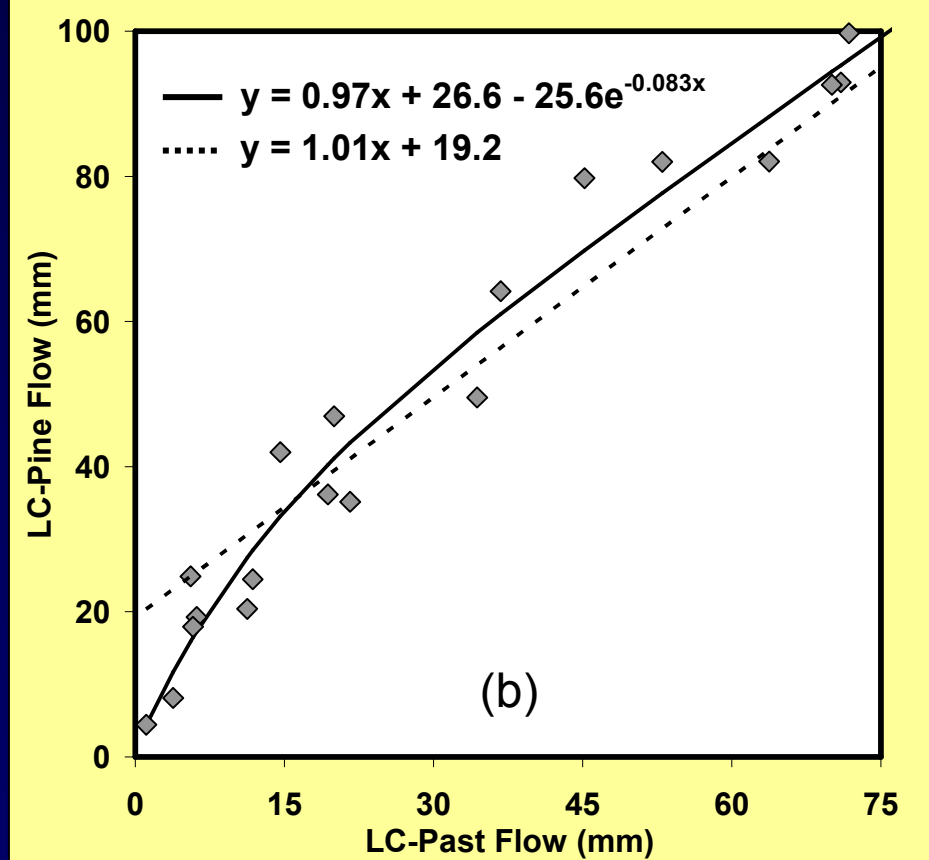


Cumulative Rainfall and Flow During the Study Period

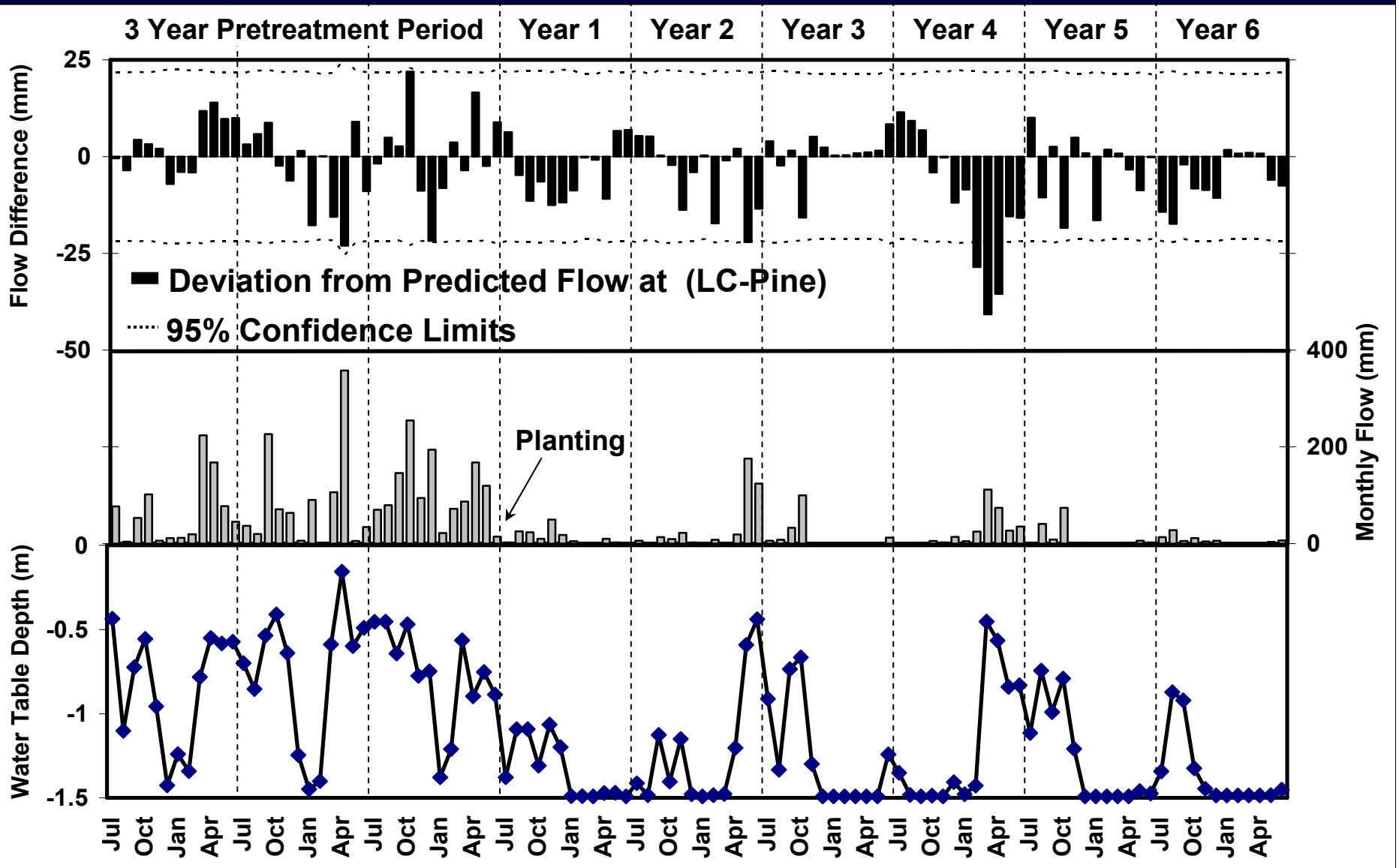


Relationship for LC-Pine vs. LC-Past Monthly Flow during Pretreatment





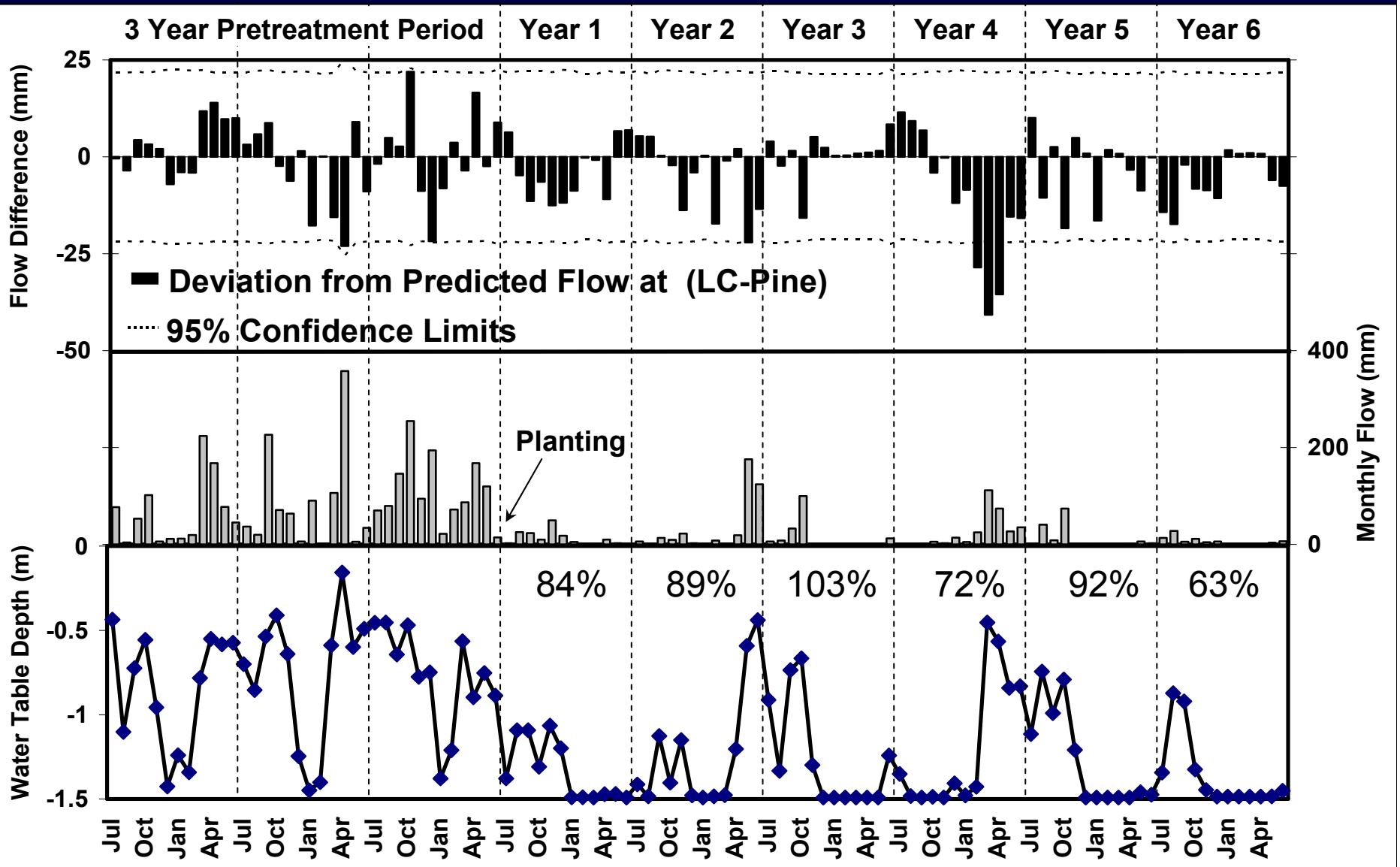
Deviation from Expected Flow for the Treatment Watershed (LC-Pine)



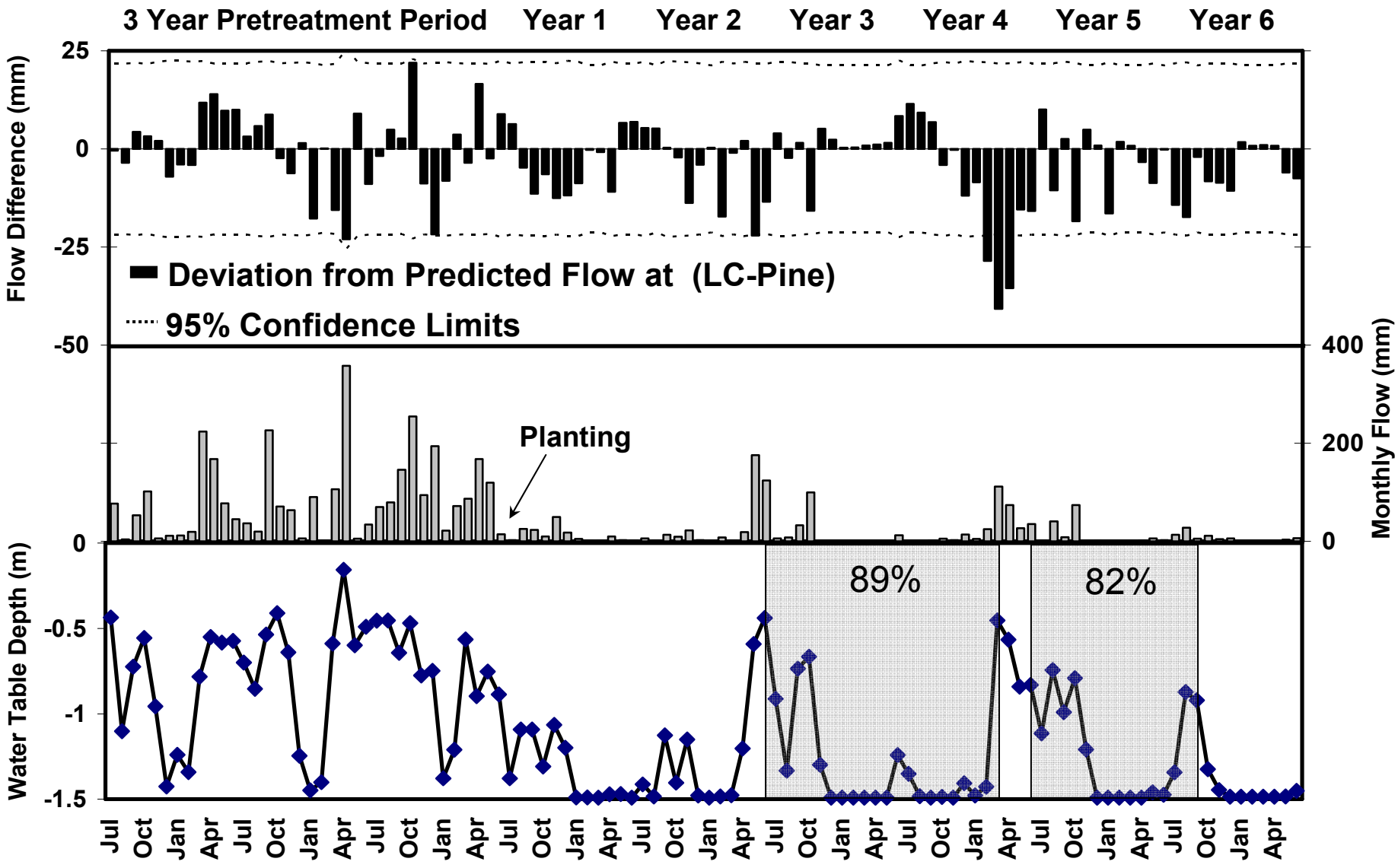
Measured and Expected Flow at LC-Pine for Each Year after Planting

Year after planting	LC-Past Flow mm	LC-Pine Flow mm	LC-Pine Expected Flow mm	Percent of Expected Flow
Year 1	150	253	301	84
Year 2	383	480	540	89
Year 3	160	265	257	103
Year 4	303	340	474	72
Year 5	137	217	235	92
Year 6	78	119	189	63

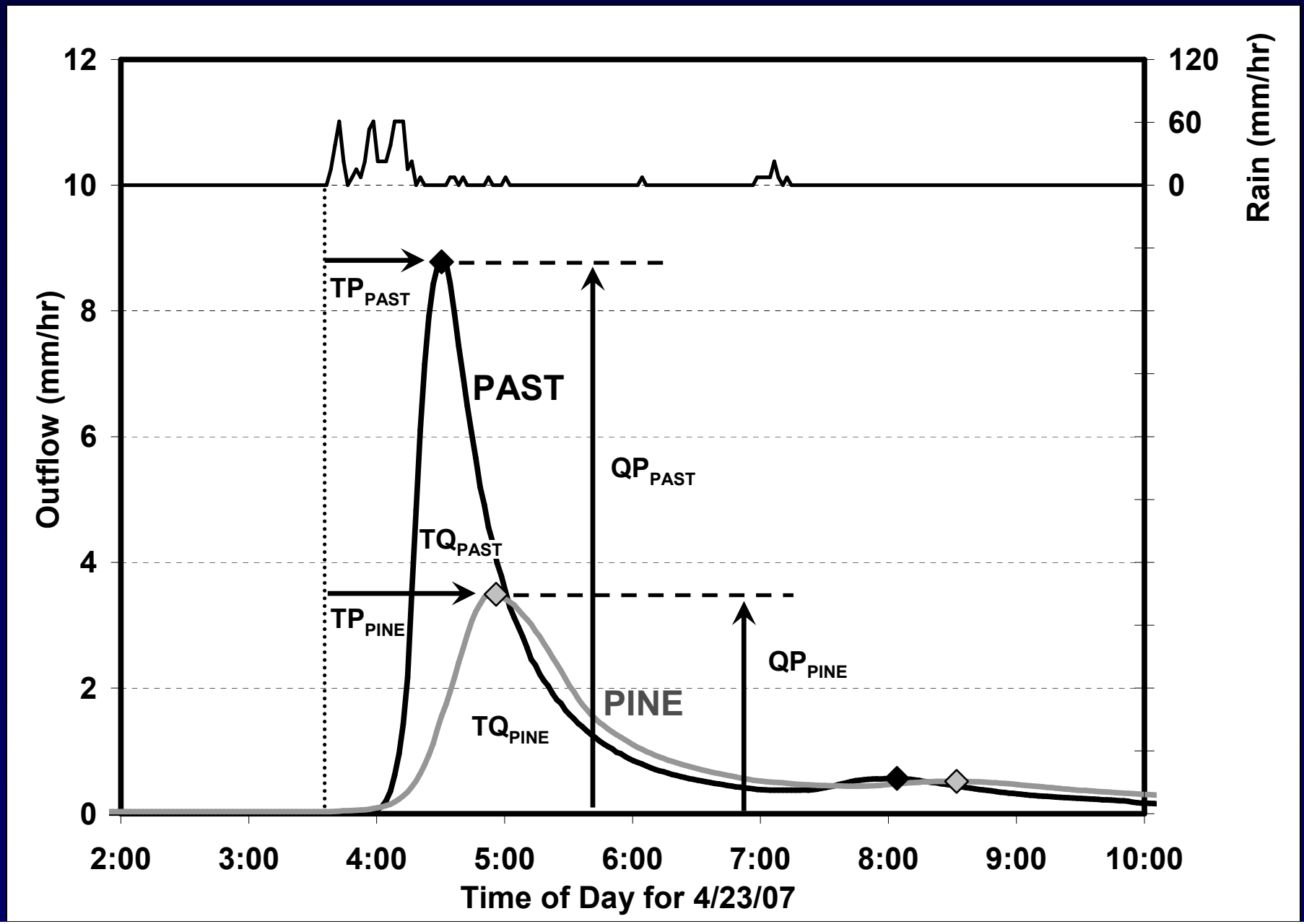
Deviation from Expected Flow for the Treatment Watershed (LC-Pine)



Deviation from Expected Flow for the Treatment Watershed (LC-Pine)



Hydrograph Characteristics

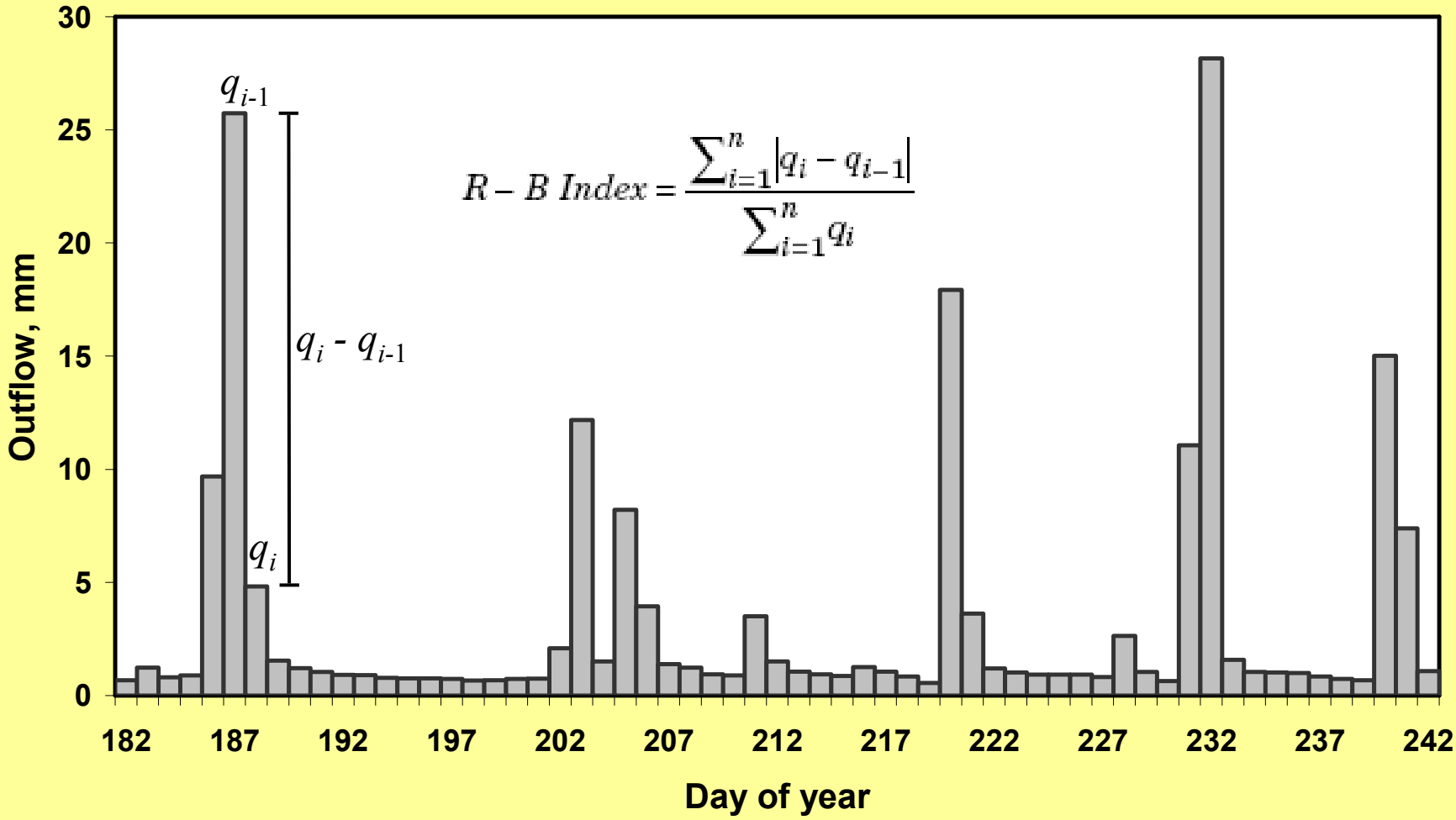


Hydrograph Comparisons

		Time to Peak TP_{Pine}-TP_{Past} mm:ss	Peak Flow QP_{Pine}/QP_{Past}	Storm Flow TQ_{Pine}/TQ_{Past}
2001	Mean	09:09 a	1.52 a	1.56 ab
	Stdev	11:07	1.00	0.62
	N=20			
2005	Mean	26:20 bc	0.75 b	1.21 ab
	Stdev	11:48	0.35	0.43
	N=12			
2007	Mean	35:16 bc	0.39 c	0.69 c
	Stdev	18:07	0.17	0.17
	N=18			

Means followed by different letters are significantly different from each other at P<0.02 – Student's t-Test

Flashiness Index

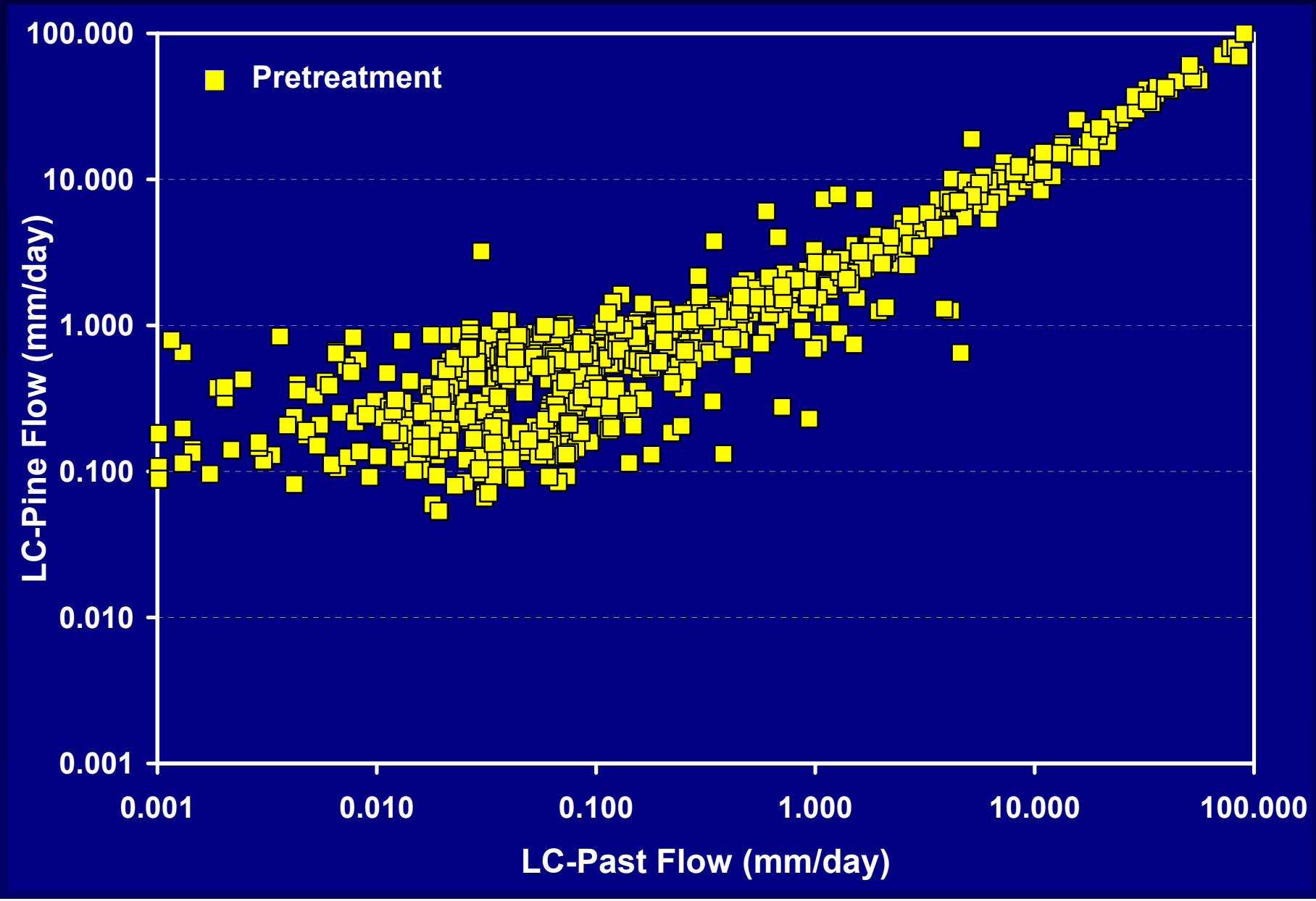


Baker et al., 2004

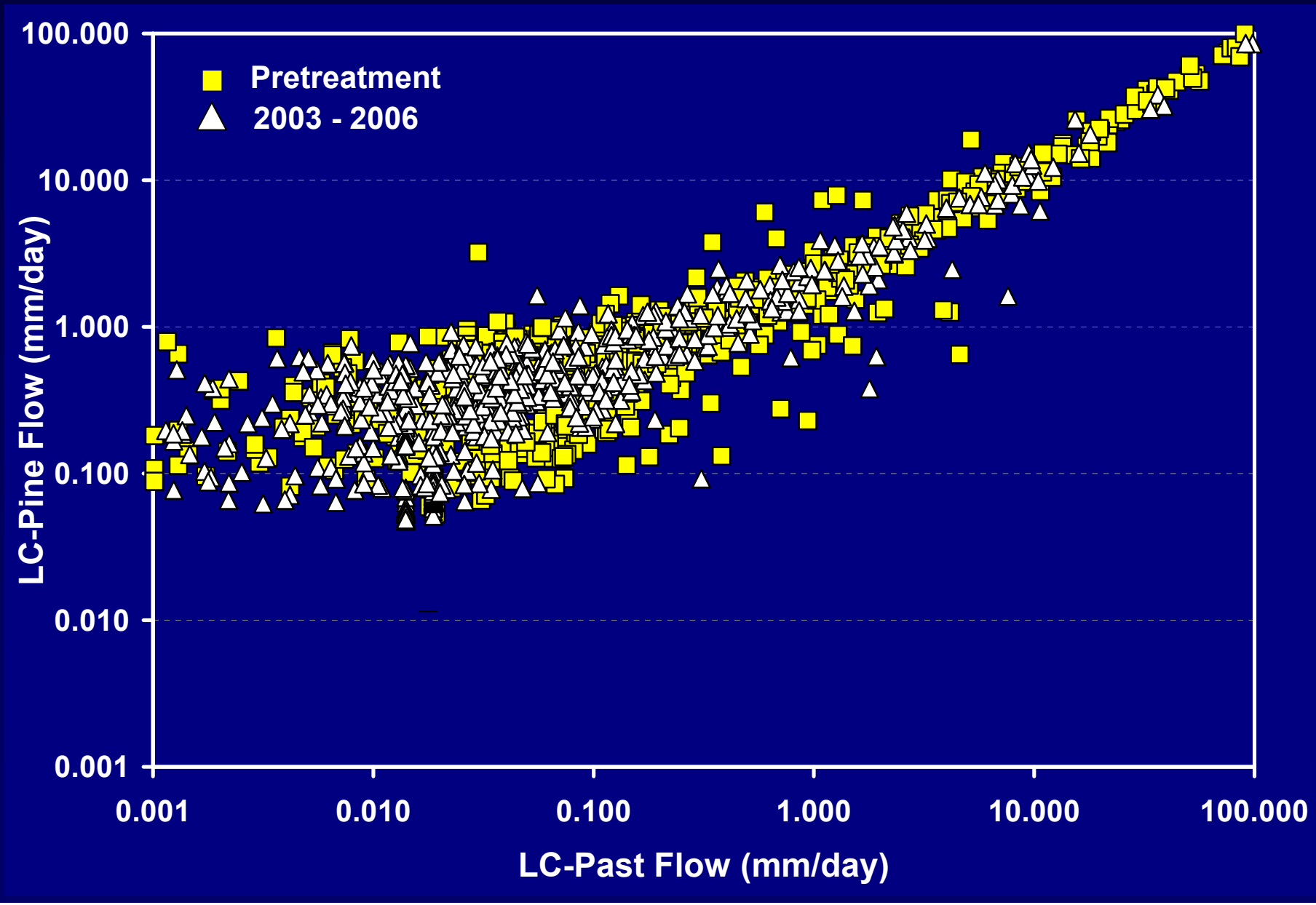
Flashiness Index for LC-Past and LC-Pine for 2001, 2003, 2005, and 2007

	Flashiness Index LC-Past	Flashiness Index LC-Pine	$\frac{\text{LC-Past}}{\text{LC-Pine}}$
Jan-Jun-01	0.105	0.086	1.22
Jan-Jun-03	0.132	0.081	1.63
Jan-Jun-05	0.152	0.064	2.38
Jan-Jun-07	0.173	0.058	3.00

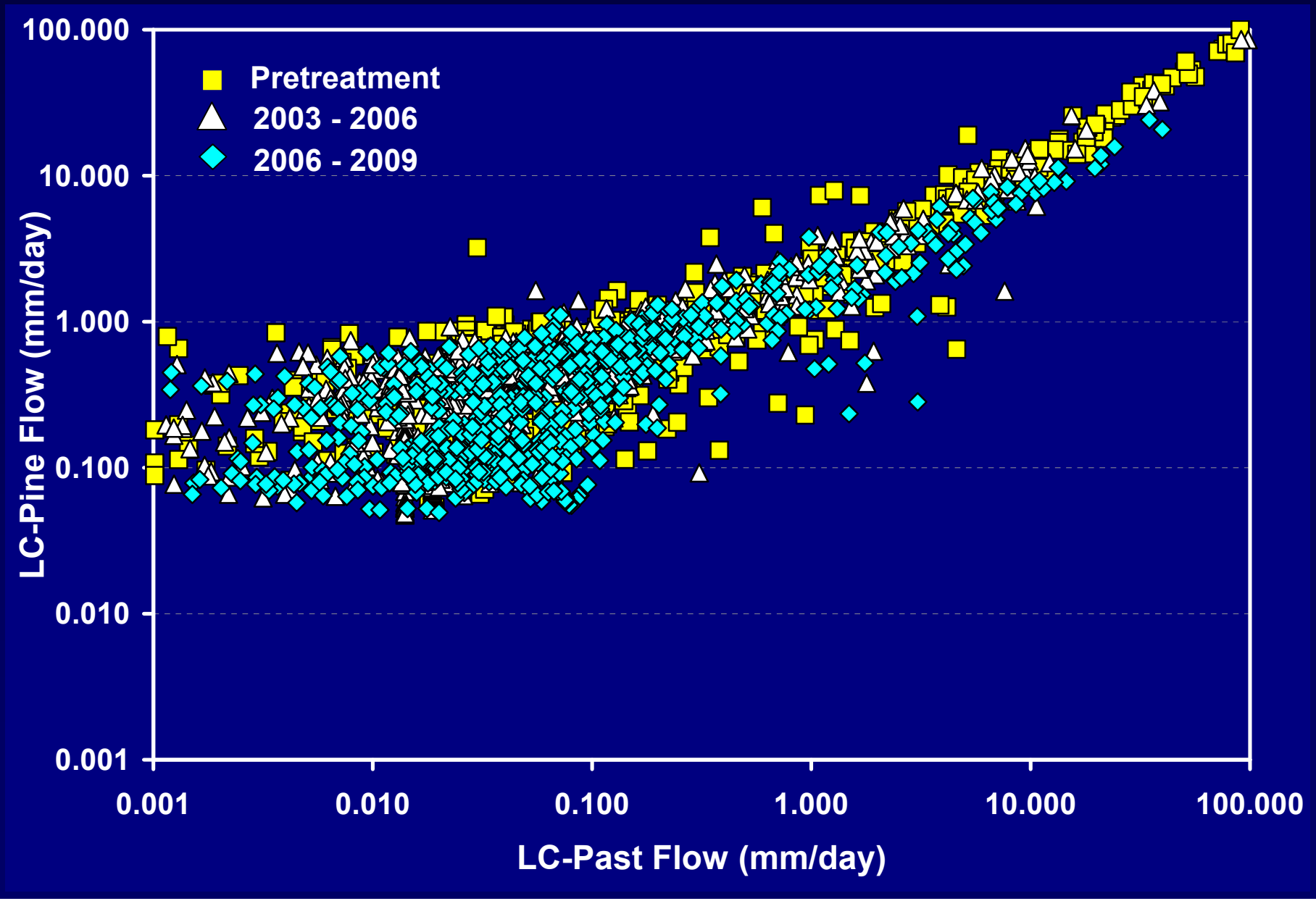
LC-Pine Flow vs. LC-Past Flow
Log-Log Scale (2000-2003)



LC-Pine Flow vs. LC-Past Flow
Log-Log Scale (2000-2003) & (2003-2006)



LC-Pine Flow vs. LC-Past Flow
Log-Log Scale (2000-2003) & (2003-2006) & (2006-2009)



Conclusions From Field Observations

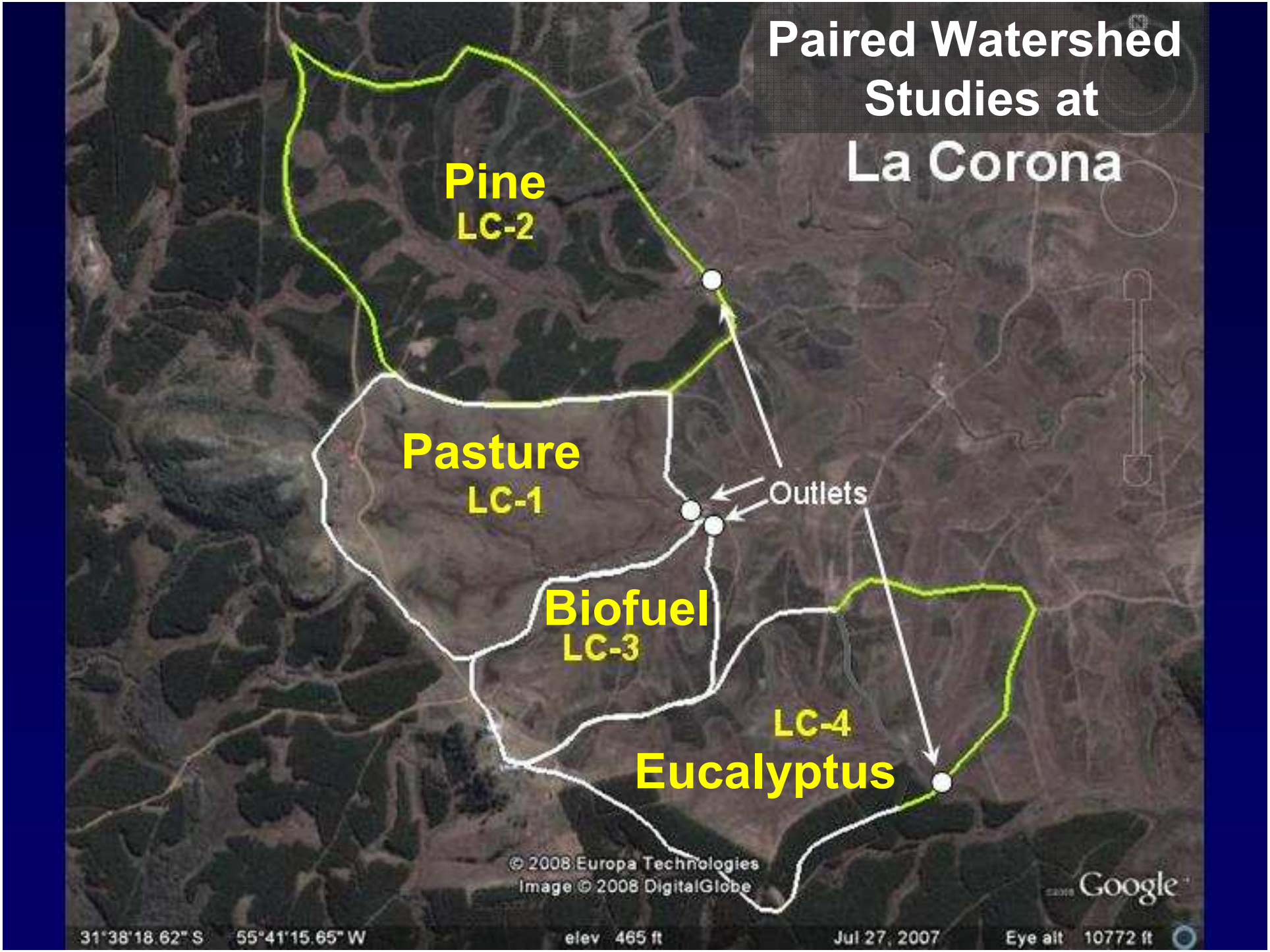
Water yield reductions varied year to year depending on weather patterns. (0% to 37%)

Greatest reductions occurred when a very dry period was followed by a wet period.

Afforestation reduced total storm flow and peak flow rates, and delayed times to peak outflow.

Afforestation reduced the flashiness of the runoff.

Base flow has not been affected in the first six years of tree growth.


Paired Watershed Studies at
La Corona
Pine
LC-2
Pasture
LC-1
Outlets
Biofuel
LC-3
LC-4
Eucalyptus
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Google
31°38'18.62" S 55°41'15.65" W elev 465 ft Jul 27, 2007 Eye alt 10772 ft