

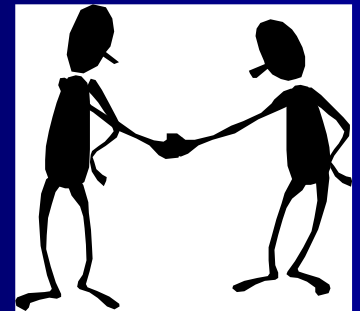
Water Resources Management in the Rio Grande/ Bravo River Basin using Cooperative Game Theory

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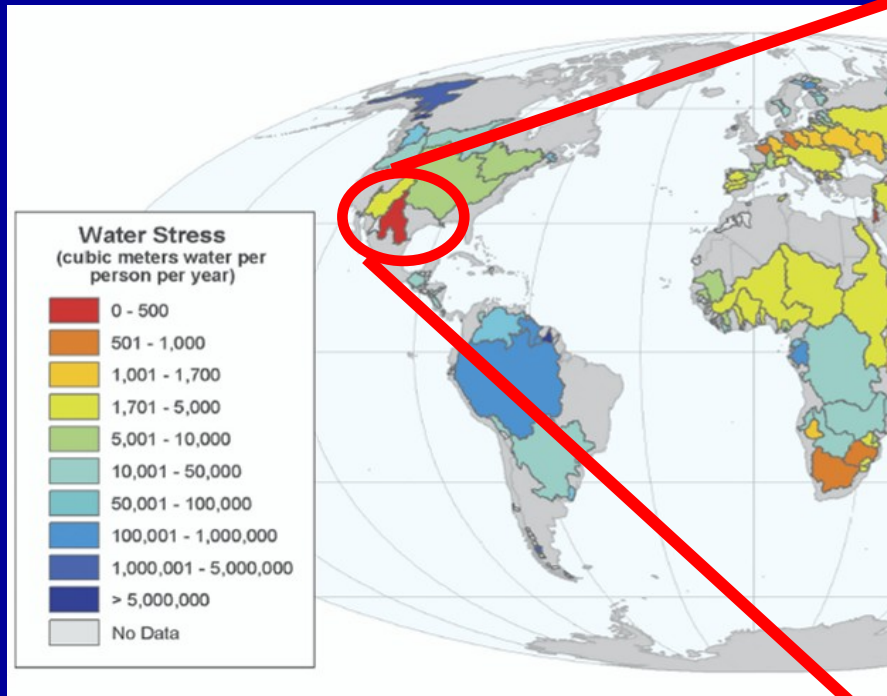
Cooperative Game Theory

- Games involve coalitions
- Coalitions act cooperatively to maximize benefits
- Coalition value allocated to coalition players
- Can reveal increased benefits from cooperation



Rio Grande/Bravo Basin

Water Stress ($\text{m}^3/\text{person}/\text{year}$)



2895 km
500k sq. km

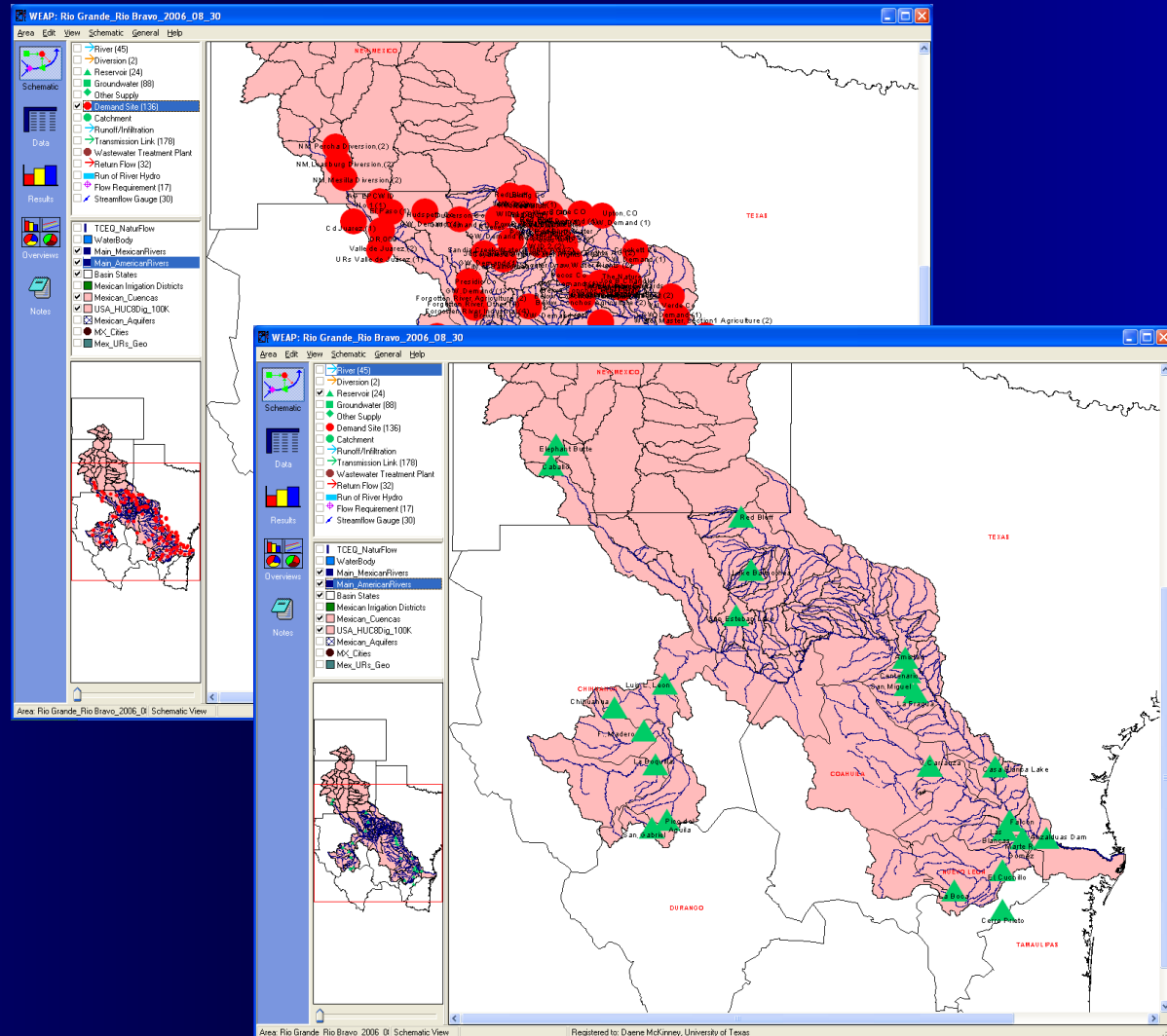


Methodology

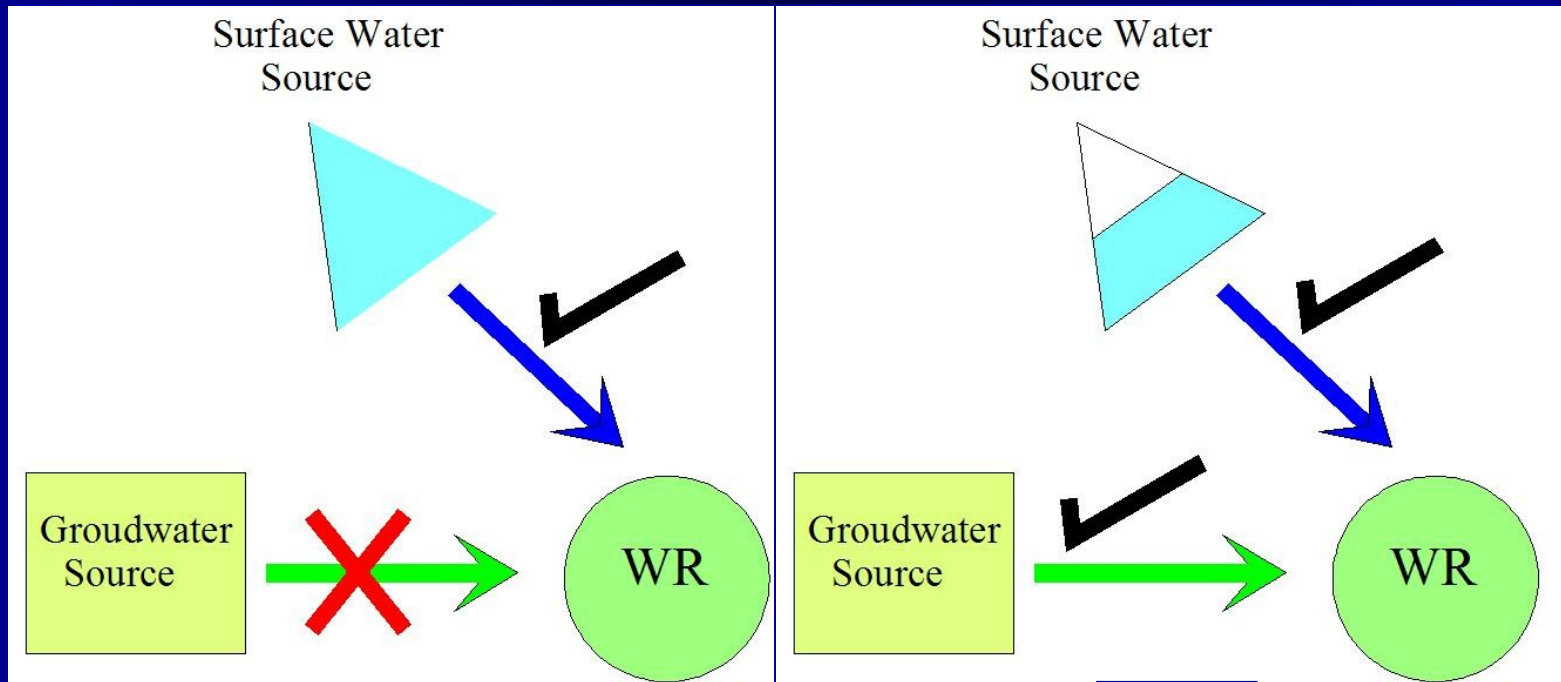
- Determine Coalitions
- Calculate Coalition Values with WEAP
- Determine the Core
- Select an Cooperative Solution

Rio Grande/Bravo WEAP Model

- **Agricultural Sector**
- **Mexico**
 - 22 Irrigation Districts
 - 33 Uderales
 - 3375 MCM/yr
- **US**
 - 56 Irrigation Districts
 - 3869 MCM/yr
- **Municipal Sector**
- **Mexico**
 - 13 cities
 - 608 MCM/yr
- **US**
 - 23 cities
 - 349 MCM/yr
- **Reservoirs**
- **International**
 - 2 (7.18 BCM)
- **Mexico**
 - 15 (11.4 BCM)
- **US**
 - 6 (3.43 BCM)



Groundwater Banking Scenario



(A)

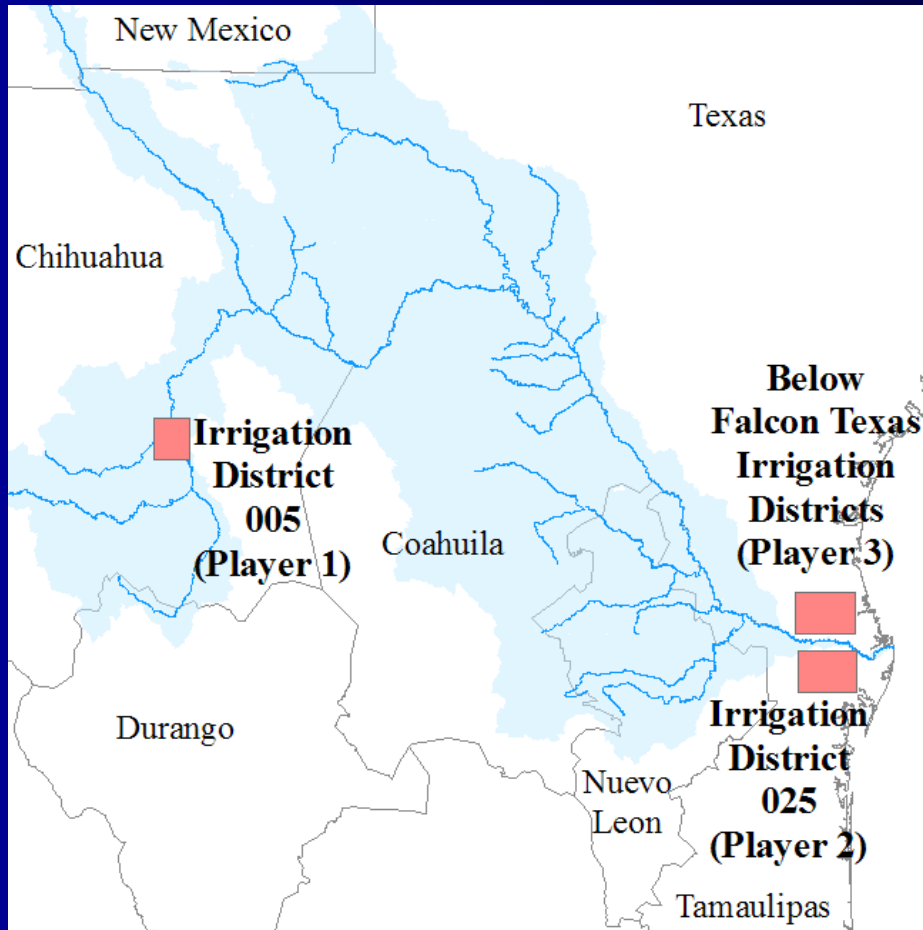
Sufficient Surface Water Supply

(B)

Surface Water Supply Shortage

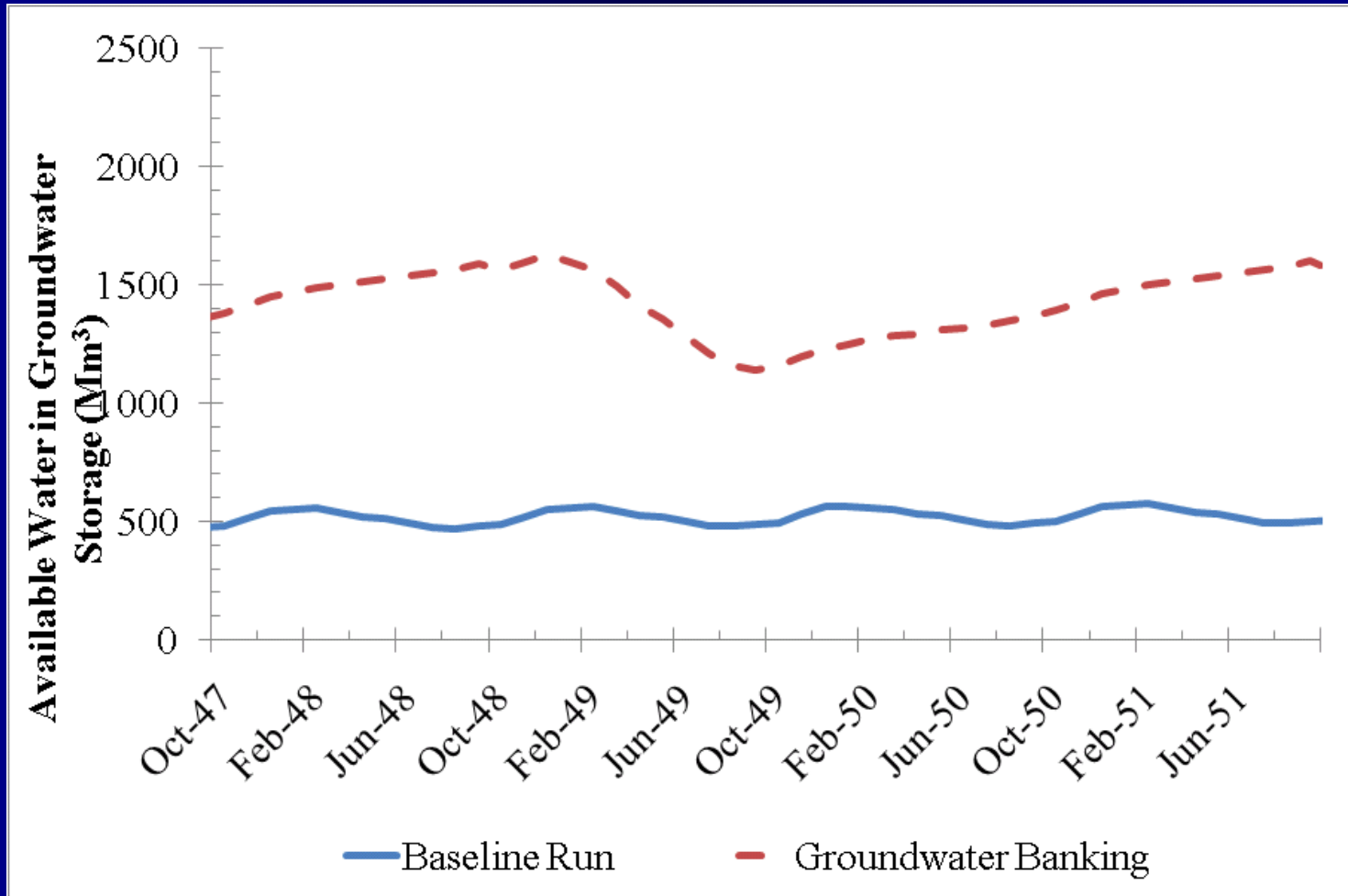
Reduction of evaporative losses > 140 mm/yr

Players in the Game



- Coalitions
 - Non – Cooperative
 - Partial Cooperation
 - Full Cooperation
- Coalition Values Calculated with WEAP model

Modeled Aquifer Storage



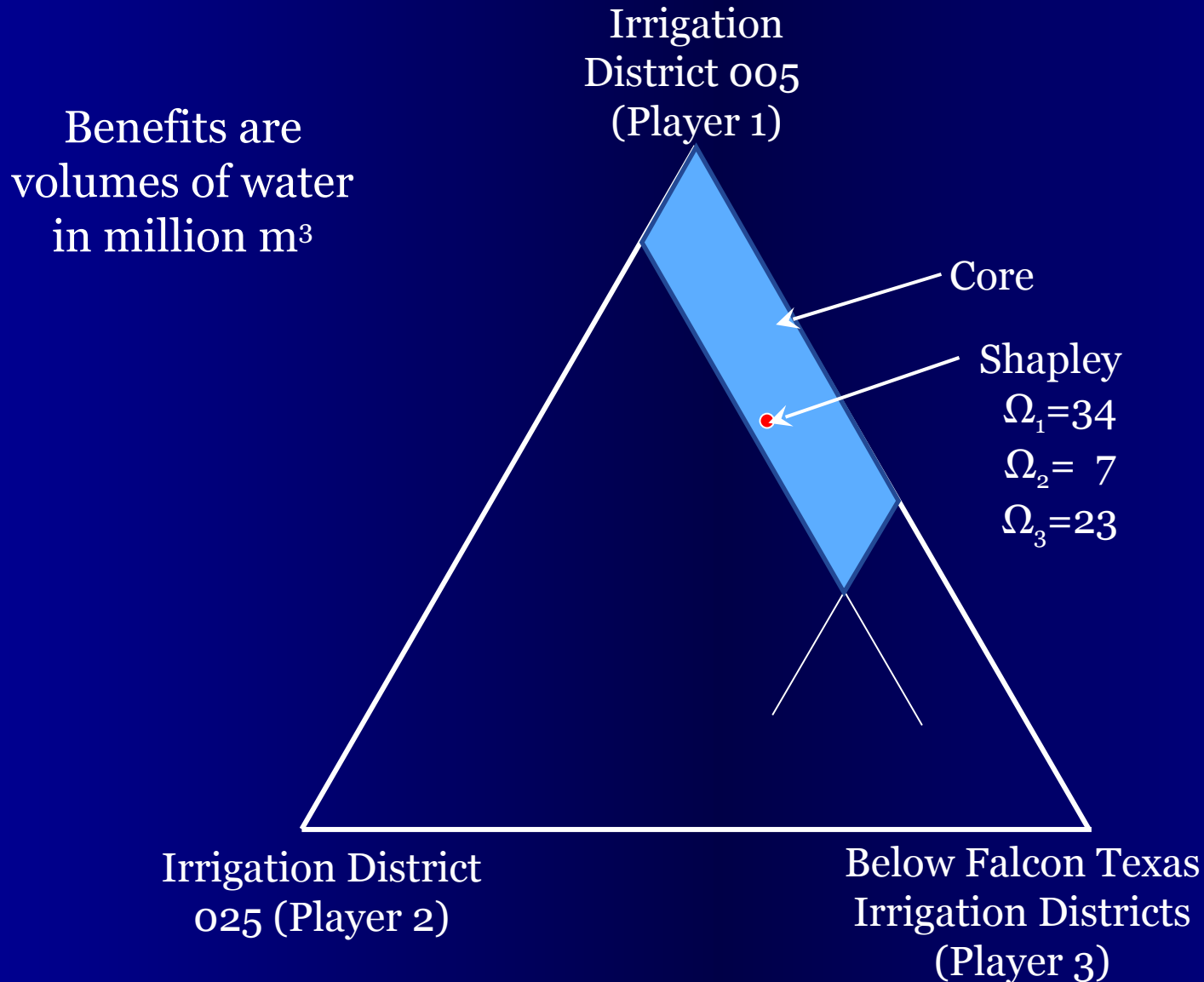
First 5 years of the drought of record

Characteristic Functions

Coalition Type	Players in Coalitions	Characteristic Value (million m ³)
Non-cooperative	1	0
Non-cooperative	2	0
Non-cooperative	3	0
Partial Cooperation	1,2	22
Partial Cooperation	1,3	53
Partial Cooperation	2,3	0
Full Cooperation	1,2,3	63

Characteristic Values are Calculated with the WEAP model

Shapley Allocation



Benefits of Cooperation

- Each player receives an increased allocation of water through cooperation

	Status Quo Allocation (million m ³)	Cooperative Allocation (million m ³)
Player 1	0	34
Player 2	0	7
Player 3	0	23



Thank you



Stakeholder Suggested Areas for Improvement

- **Objectives**

- Increase Whole System Benefits
- Improve Agricultural Supply Reliability
- Increase Municipal Water Supply
- Restore Environmental Flows

- **Methods**

- Water Right Buybacks & Transfers
- Groundwater Banking & Conjunctive Management
- Non-treaty Tributary Flows
- Water Conservation & Reuse
- Facility Reconfiguration & Reoperation
- Brackish Water Desalination



The Core

Irrigation District 005
(Player 1)

Benefits are
volumes of water
in million m³

