Optimal, Sustainable, Water Management and Conflict Resolution: The WAS and MYWAS Models

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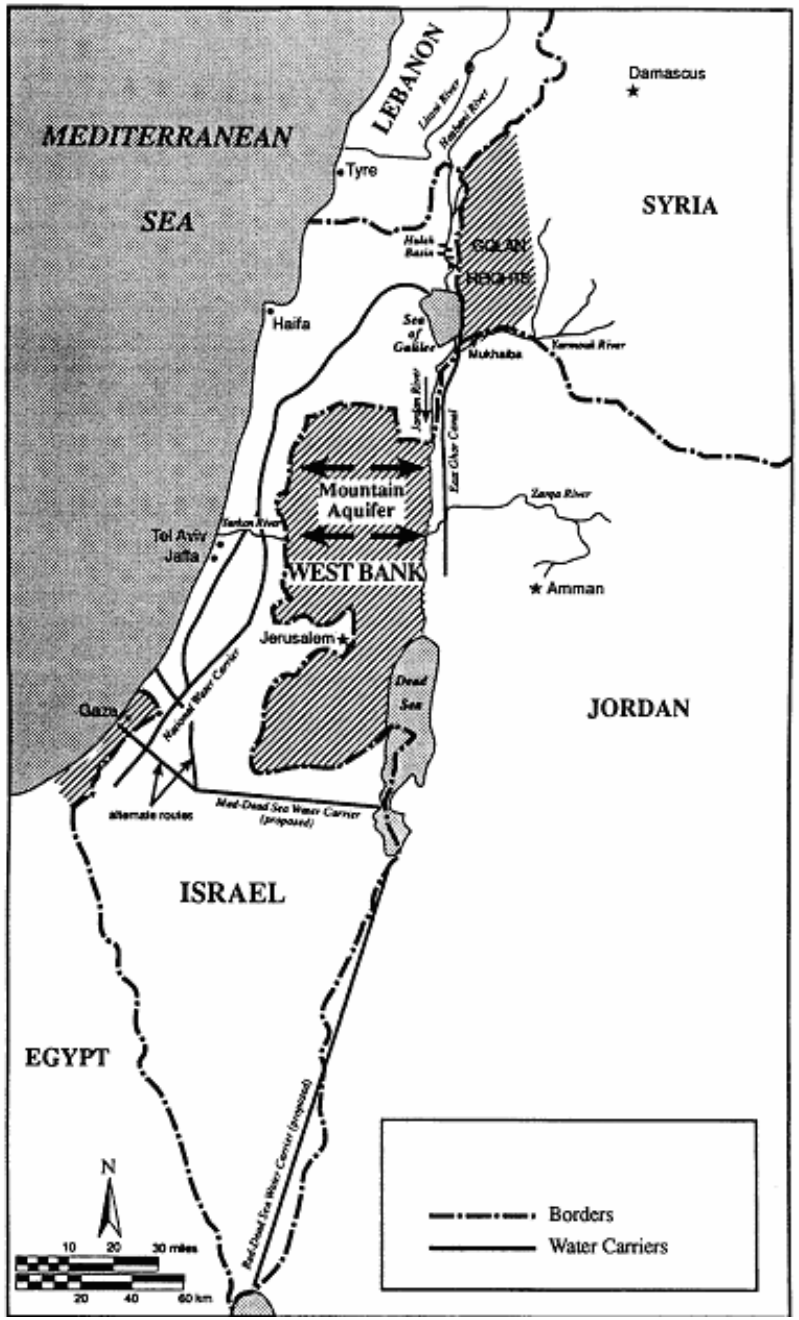
Thinking about Water:
Water Values, not Water Quantities


MEDITERRANEAN
SEA
LEBANON
Litani River
Hasbani River
Damascus
SYRIA
Tyre
Huleh Basin
GOLAN HEIGHTS
Haifa
Sea of Galilee
Mukhaiba
Yarmouk River
Jordan River
East Ghor Canal
Mountain Aquifer
Zarqa River
Tel Aviv Jaffa
Yarkon River
WEST BANK
Amman
Jerusalem
Dead Sea
JORDAN
Gaza
National Water Carrier
alternate routes
Med-Dead Sea Water Carrier (proposed)
ISRAEL
EGYPT
Red-Dead Sea Water Carrier (proposed)
N
10 20 30 miles
20 40 60 km
Borders
Water Carriers

Fishelson's Example

"Water is a scarce resource. Scarce resources have value. And the value of the water in dispute is bounded above by the replacement cost given by desalination, with that upper bound not very high."

Gidon (Jedda) Fishelson

Fishelson's Example Elaborated

- The cost of desalination on the Mediterranean coast of Israel and Palestine is about $0.60/cm
- Water in the coastal cities is not worth more than $0.60/cm
- Water in the Mountain Aquifer (e.g.) isn't on the coast; it is underground and it would cost roughly $0.40 to pump it up and bring it to the coastal cities
- Hence ownership of such water (*in situ)* is not worth more than $0.20/cm ($0.60/cm - $0.40/cm)

General Principles

- **Despite its importance, water can be given a money value. That value is not the narrowly considered economic value of money but takes into account the special role of water and the values and priorities of the user of the model.**
- **Further, it is important to think about water in terms of water value and not just water quantity. That is what WAS and MYWAS embody.**

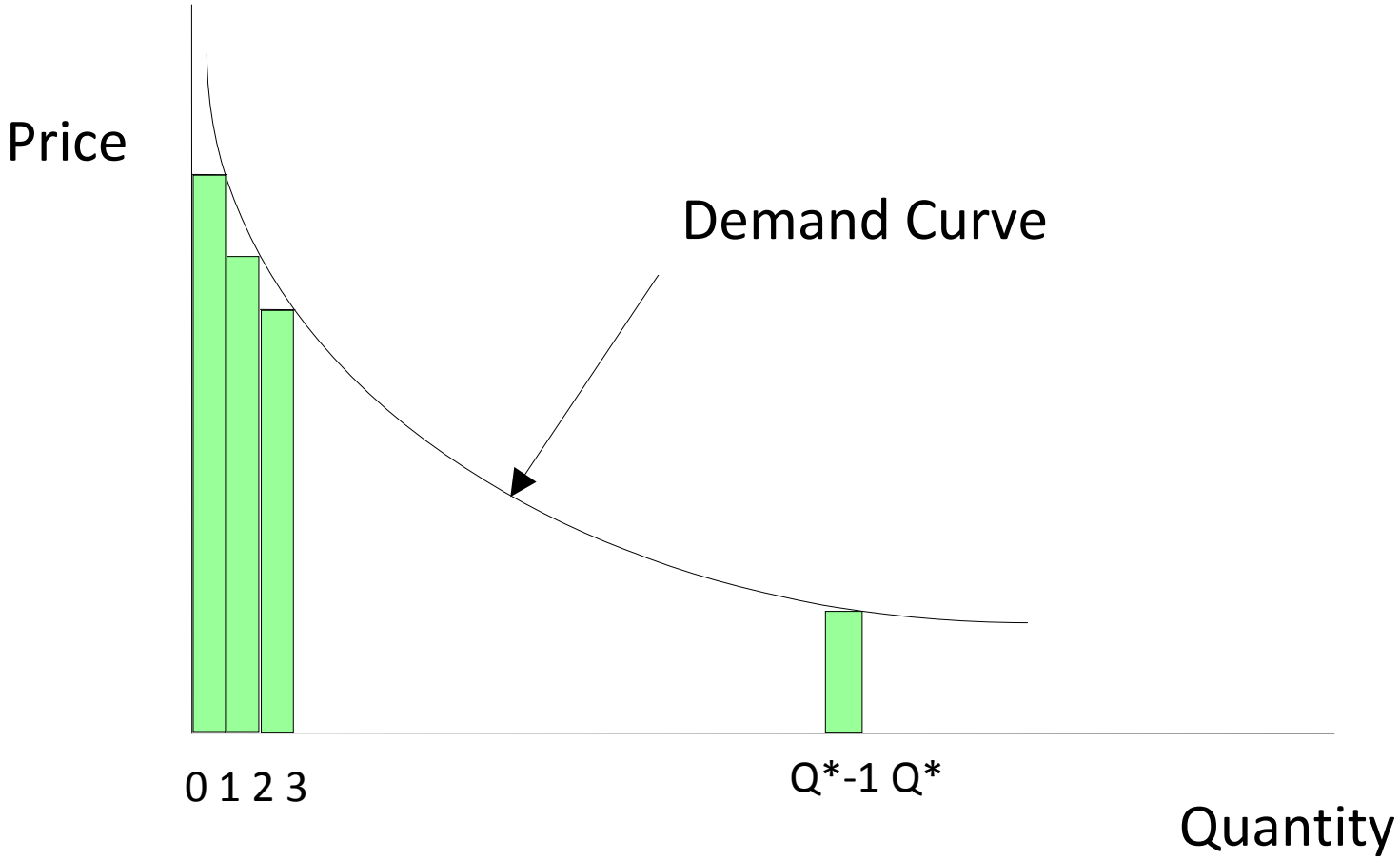
Why Actual Water Markets Won't Work

- It is often true that the efficient way to allocate resources is through a free market.
- But that is not always true. That result requires:
  - Markets to be competitive – many small sellers and buyers
  - All social benefits and costs to be private benefits and costs.
- These requirements are *not* met in the case of water in the Middle East (and probably not in anywhere else in the world).

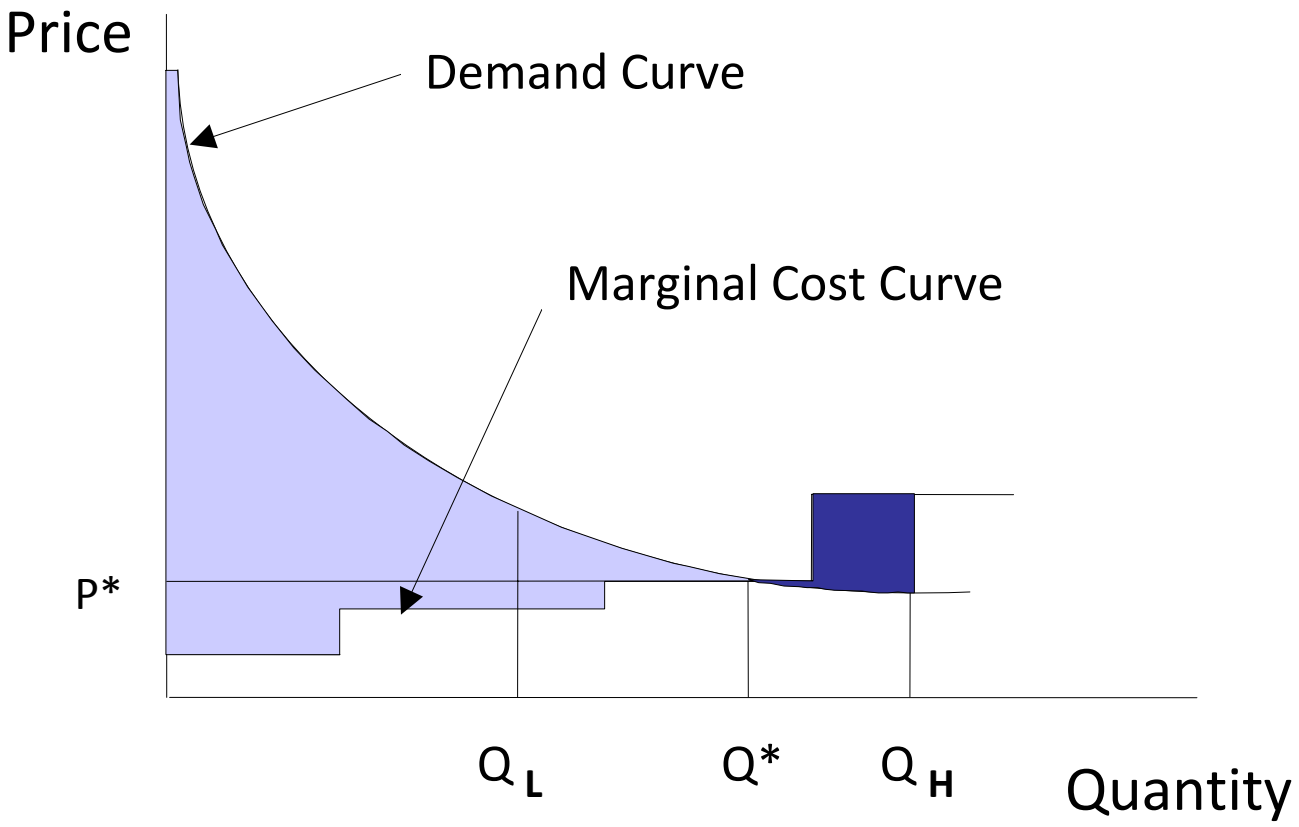
Why WAS and MYWAS work

- **Hence it is useful to build an optimizing water model that deals with these things.**
- **WAS and MYWAS are such models – in effect producing an efficient solution that a real market would reach if it could deal with the problems listed.**
- ***In particular, WAS and MYWAS permit the user to impose conditions on the optimization that reflect the user's own values and policies.***

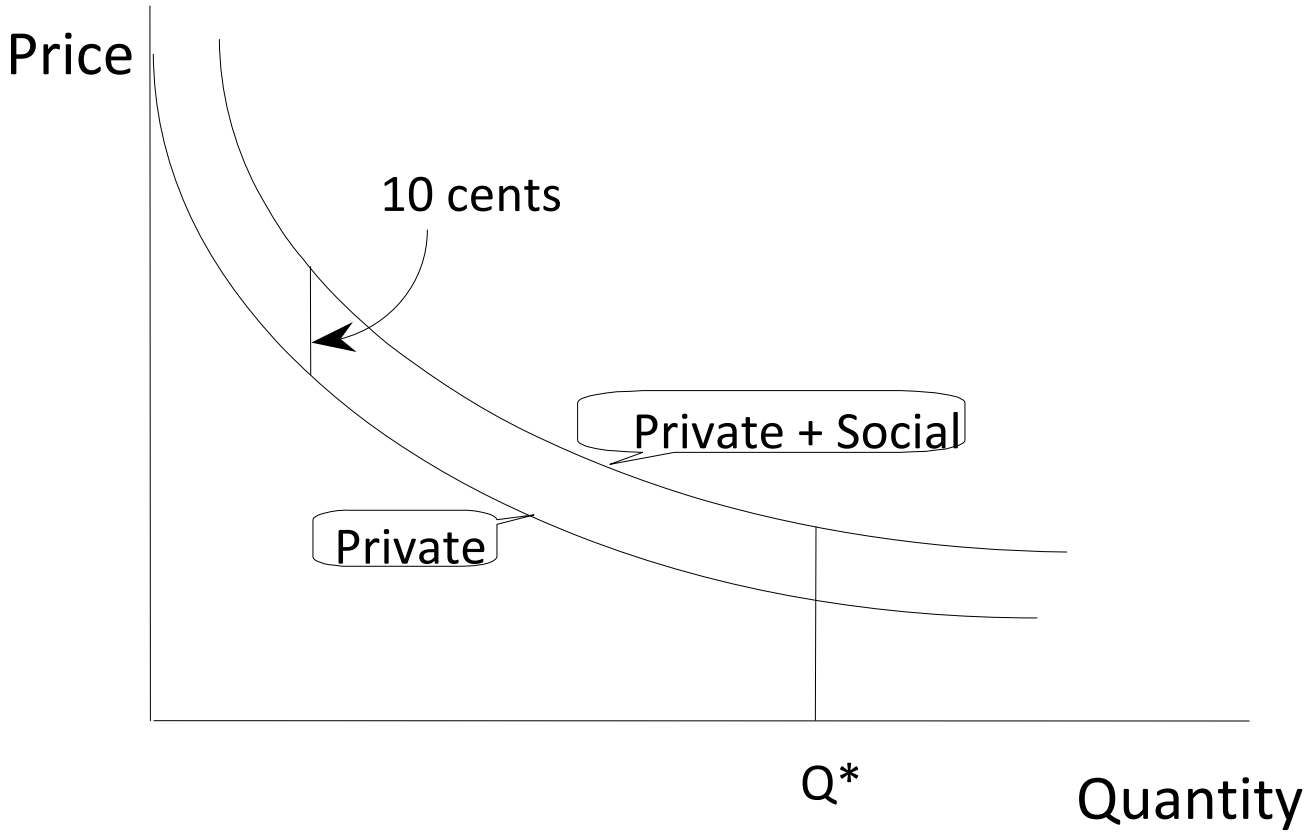
Gross Benefits from Water



Net Benefits from Water



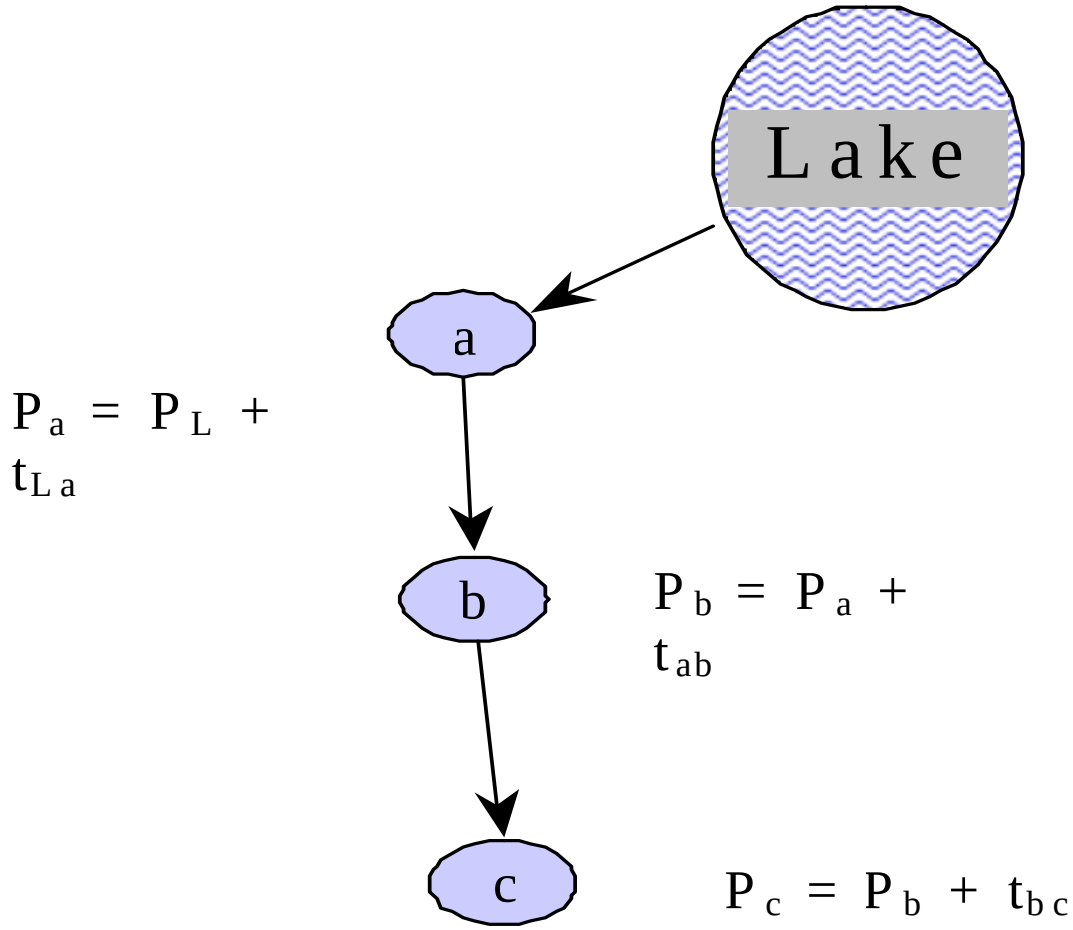
Social Value of Water as Revealed by a Subsidy



Shadow Values and Scarcity Rents

- A “shadow value” associated with a constraint shows the rate at which the objective function would increase if the constraint were relaxed.
- The shadow value of water in a district is the amount by which benefits would increase (system-wide) if there were one more cm of water there for free.
- The “scarcity rent” of a water source is the shadow value at the source – the value (system-wide) of an additional cm there.

Efficient Water Allocation and Shadow values

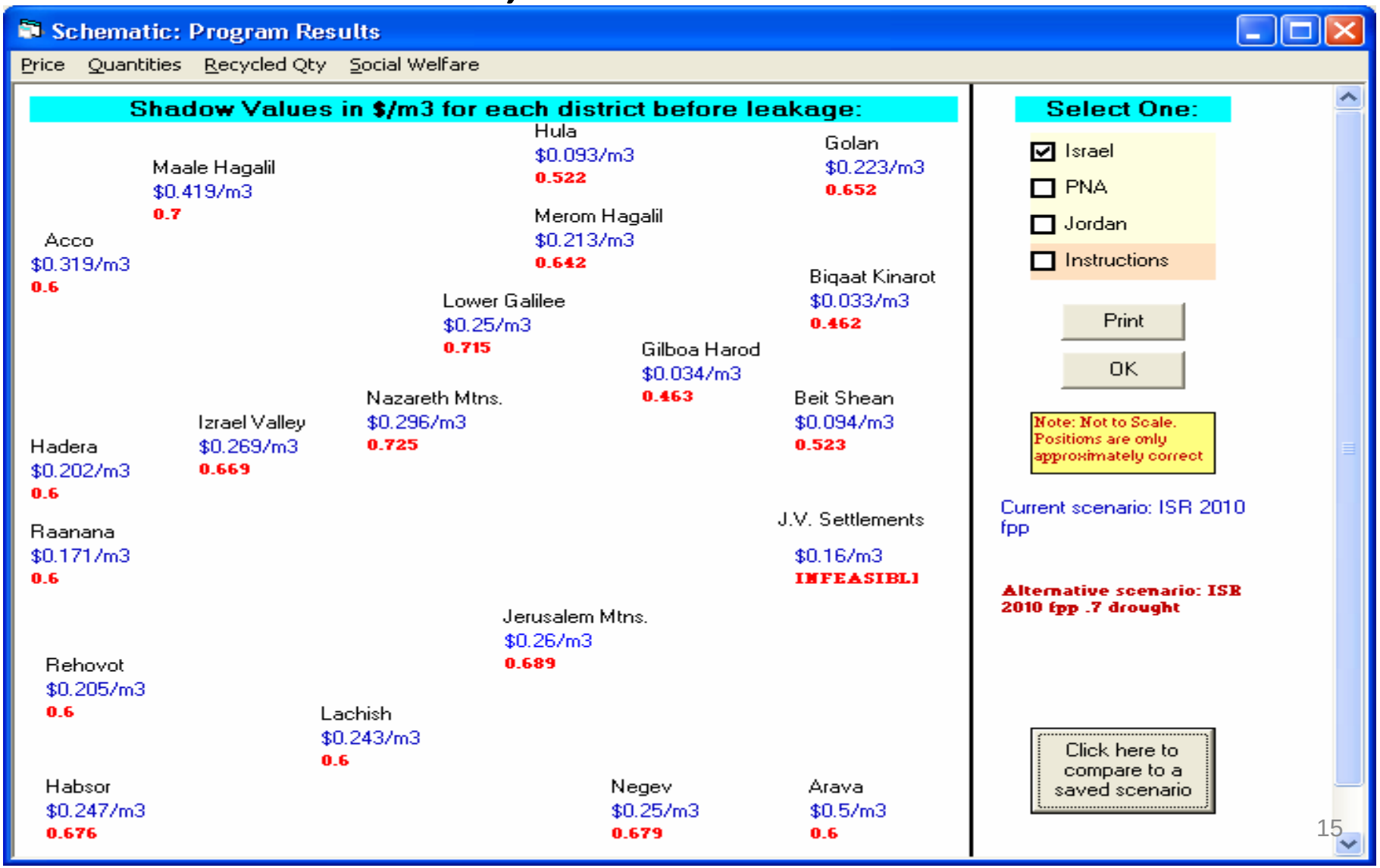


Infrastructure Analysis in WAS

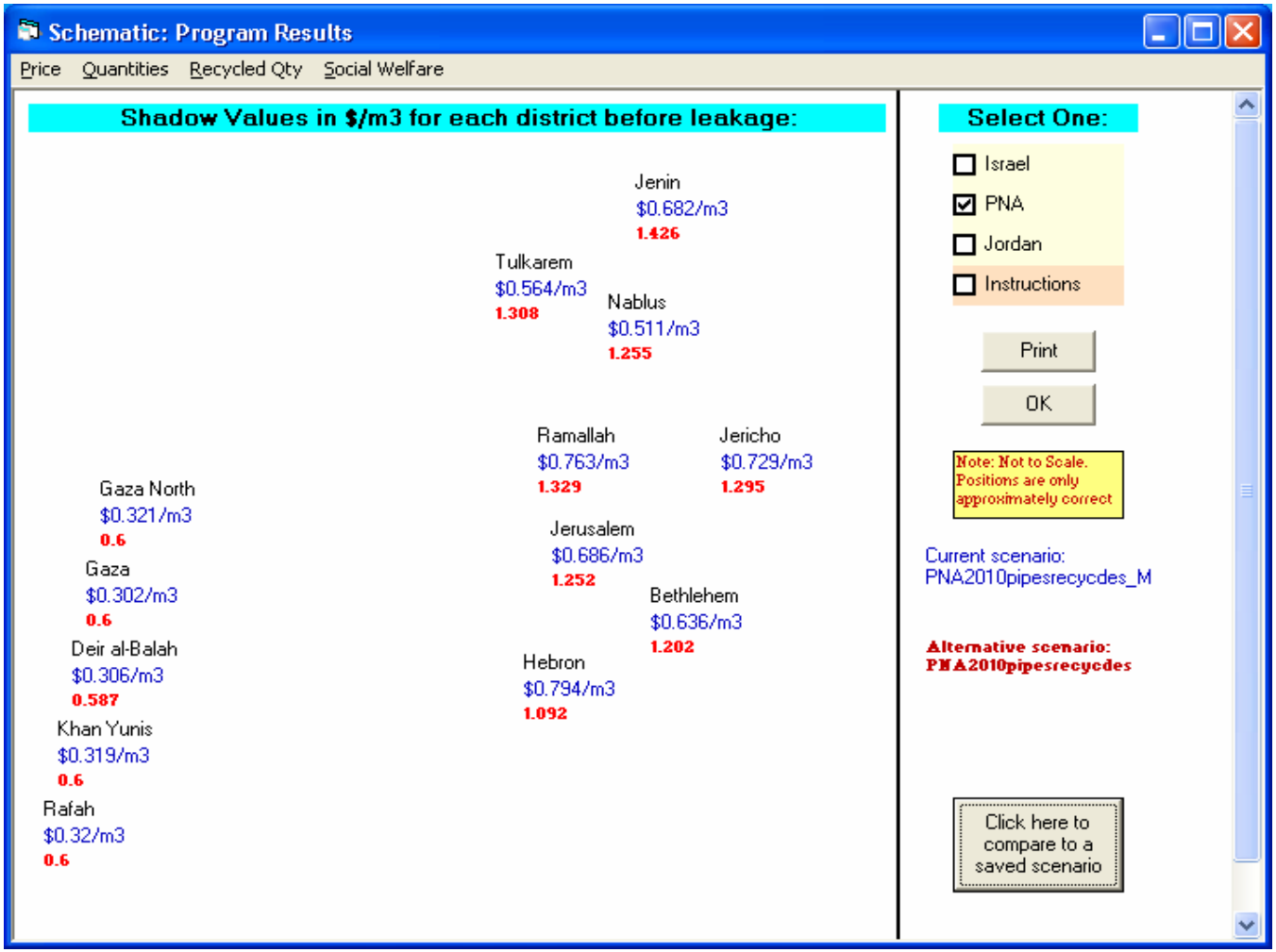
WAS has 2 ways of helping infrastructure analysis:

1. **Asking whether the project would be used**
   a) **As in the previous figure for conveyance lines**
   b) **Running the model without a planned new source of water and seeing whether shadow values would lead to that source being used.**
2. **Running the model with and without the project and evaluating if the present value of added benefits justifies the costs.**

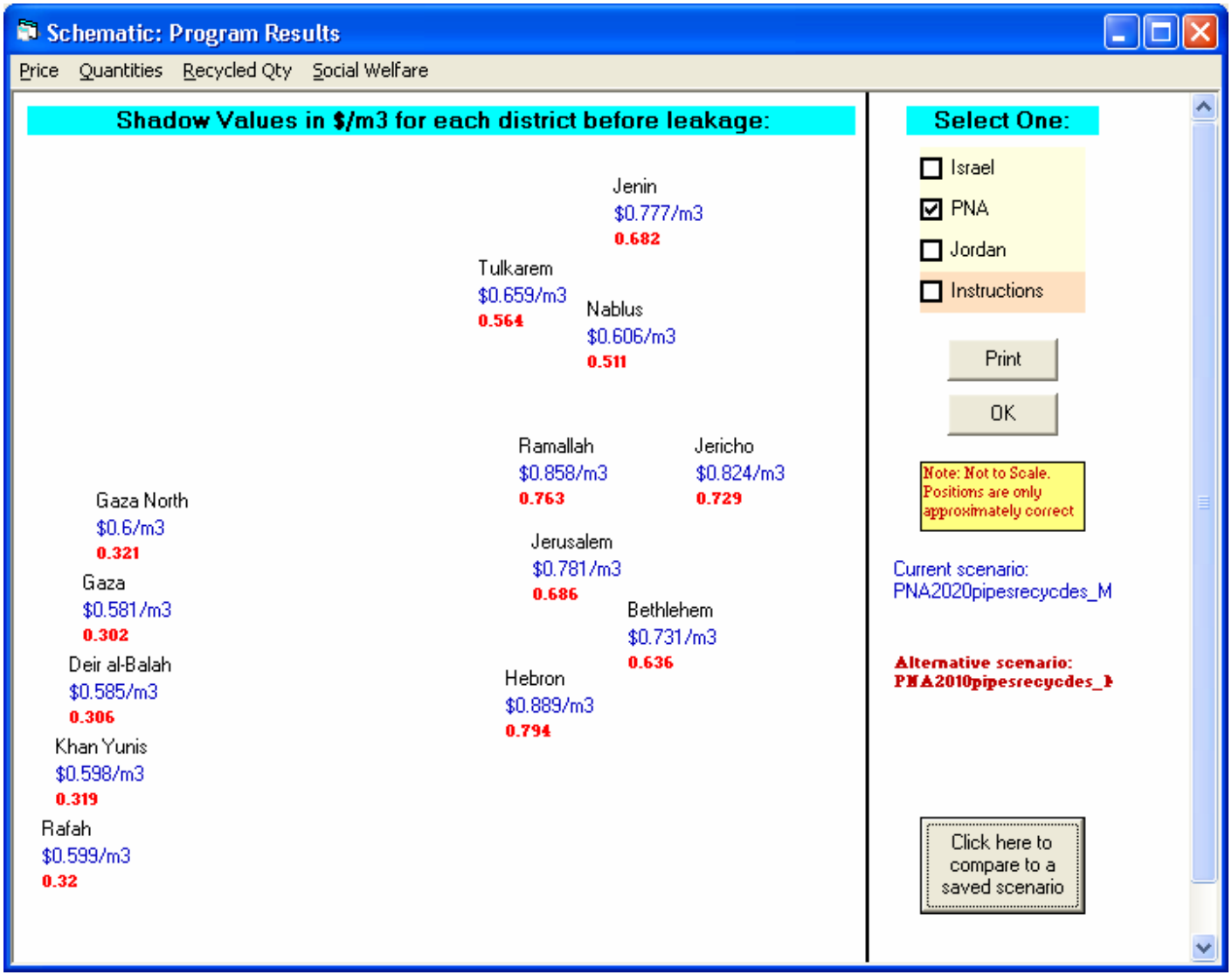
Israel: 2010 Shadow Values with Desalination: Normal Hydrology vs. 30% Reduction in Naturally Occurring Fresh Water, Fixed-Price Policies in Effect



Palestine: Full Infrastructure Scenario in 2010 With and Without Double the Quantity from the Mountain Aquifer



Palestine : Full Infrastructure Scenario with Double the Quantity from the Mountain Aquifer in 2010 and 2020



Regional Management vs. Individual Management

- Was (and MYWAS, discussed later) can also be used to guide regional water management.
- Suppose that, with only individual management, the shadow value of water in a district of country A (as shown by A's own WAS model) is less than the shadow value in a nearby district of country B (as shown by B's own WAS model).

Regional Management vs. Individual Management

- Then both countries could benefit if A sold to B some water in the relevant districts at a price between the two shadow values.
- A would receive money greater than the value to it of the transferred water.
- B would receive water valued by it higher than the money it would pay.

Regional Management vs. Individual Management

- This would be fairly and optimally accomplished if the sale were in the quantity and at the price given by the shadow value resulting from a joint running of the two WAS models together.
- Note that such an arrangement keeps the price from being affected by relative monopoly or bargaining power.

Regional Management vs. Individual Management

- Moreover, such a joint WAS model would then guide regional management of the resources to the benefit of all parties.
- I shall not go into great detail just now, but I shall present an example of the potential gains – especially to Palestine for such an arrangement with Israel and Jordan.

Regional Management vs. Individual Management

- To do this requires some assumptions about water ownership.
- These assumptions are not intended as a political statement. They are one example from very many that have been or could be studied.
- The conclusions drawn are quite general, however.

Regional Management vs. Individual Management

- The example is for 2020.
- It is first assumed that Palestine owns 20% of the Mountain Aquifer (roughly what it is now permitted to pump).
- Then this is doubled to 40%.

Regional Management vs. Individual Management

- **Three cases for the Jordan River are examined:**

A. Israel 92%, Jordan 8%; Palestine 0.
(This is approximately the existing situation.)

B. Israel 66%; Jordan 17%; Palestine 17%.

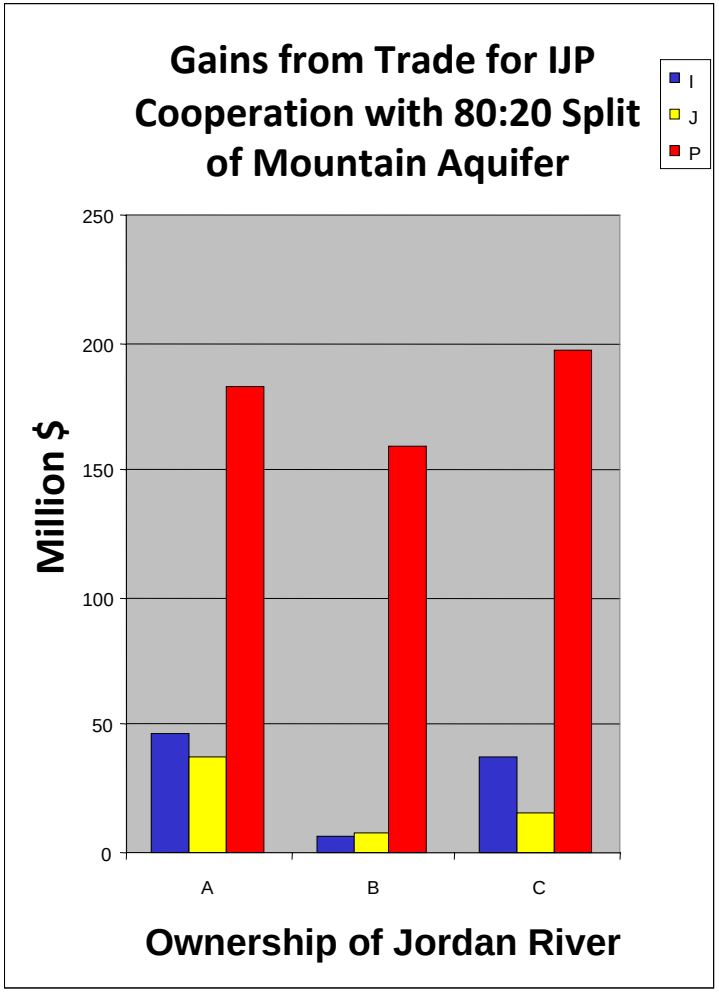
C. Israel 33.3%; Jordan 33.3%; Palestine 33.3%.

Regional Management vs. Individual Management

- In the following Figures, Palestine is represented in red, Israel in blue, and Jordan in yellow.

- The heights of the columns show the gains (measured in millions of dollars) to the respective countries from regional versus individual management,

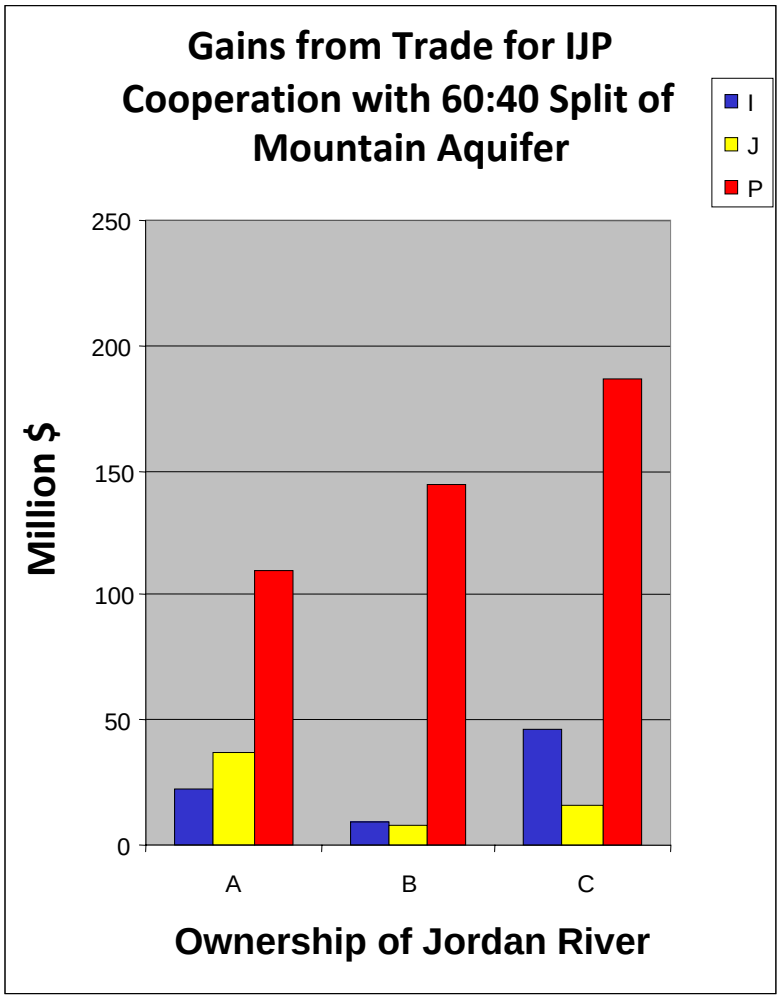
Gains from Trilateral Cooperation in 2020
MA 80-20



Regional Management vs. Individual Management

- In this picture, at the left, Palestine has roughly the water it has now.
- It gains from regional management by acquiring water from Israel.
- Those gains decrease in the middle where Palestine has more Jordan River water.
- But they increase again at the right where Palestine gains as a *seller,* selling Jordan River water *to* Israel.

Gains from Trilateral Cooperation in 2020
MA 60-40



Regional Management vs. Individual Management

- **In this picture, Palestine has so much Mountain Aquifer water that it always gains as a *seller*, selling more and more Jordan River water to Israel .**

Regional Management vs. Individual Management

- These are not special cases. *In all cases, all parties gain, and that is not an accident.*

- In fact, the gains from regional management typically exceed the gains from large amounts of additional ownership.

Note that this sort of WAS-guided cooperation can also be used for the resolution of disputes among states or among groups within a state.

I now return to a discussion of the tools.

MYWAS

- MYWAS is a multi-period version of WAS. The periods can be years, but they can also be seasons or periods several years in length, as the user specifies.

- Given a discount (interest) rate -- chosen appropriately to match the period lengths used -- MYWAS maximizes the present discounted value of future benefits out to a time horizon chosen by the user.

Features of MYWAS

1. **Infrastructure Programs:**

   Given a menu of possible infra-structure projects and projections of future demands and climatic conditions, MYWAS will yield:

   a) **The optimal order and timing for the projects to be built (if at all);**
   b) **The optimal capacity to be built;**
   c) **In doing this, MYWAS treats capital costs as outlays when they occur, removing the need for external comparison of costs and benefits;**
   d) **And costs and benefits are calculated *system-wide, including the opportunity costs involved*.**

Features of MYWAS

2. **Climatic Uncertainty:**
   a) **Since such results (and those listed later) depend on rainfall, etc., MYWAS can readily be run for a variety of climate scenarios to enable study of decision-making under uncertain conditions.**
   b) **Note that this includes studying the effects of global warming on infra-structure planning.**

Features of MYWAS

3. MYWAS handles inter-seasonal or inter-year storage issues:
   a) Construction and management of man-made storage facilities
   b) The optimal extraction program for fossil aquifers
   c) The optimal treatment of natural storage facilities such as lakes or aquifers

Features of MYWAS

- WAS handles the management of aquifers (and other natural water sources) by restricting extraction to annual renewable amounts (which could be varied by the user).

- This is not necessary in MYWAS which can produce guidance on such management including over-pumping in dry years and replenishment in wet ones.

Features of MYWAS

- **The user specifies a floor on the contents of an aquifer, a lake (or other storage facility.**
- **Further, the user specifies the amount that must be retained at the end of the planning period.**
- **This is where sustainability comes in.**