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Waste water treatment in oil refineries

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Legend

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ORTEC is one of the largest providers of advanced planning and optimization solutions and services.

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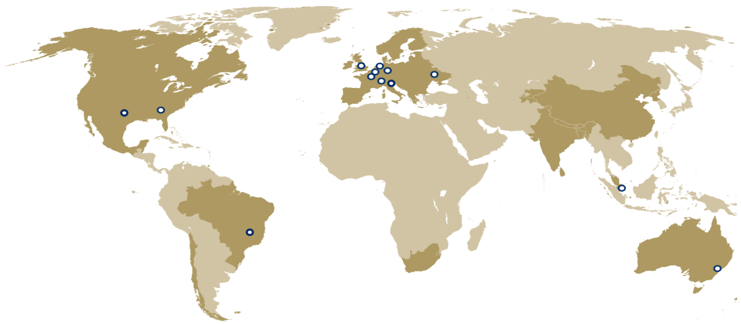

ORTEC has operates in over 80 countries and 750 employees working from 15 country offices.

Expertise areas

Business Analytics & Big Data

Supply Chain Management

Capacity & Resource Planning

Pricing and Revenue Management

Cost Estimation & Project Services

Motivation: water

1. Water as a resource is abundant; however, freshwater is not.
2. Freshwater is not evenly distributed around the world.
3. About 2 million die every year due to lake of freshwater (World Water Assessment Program, 2009).

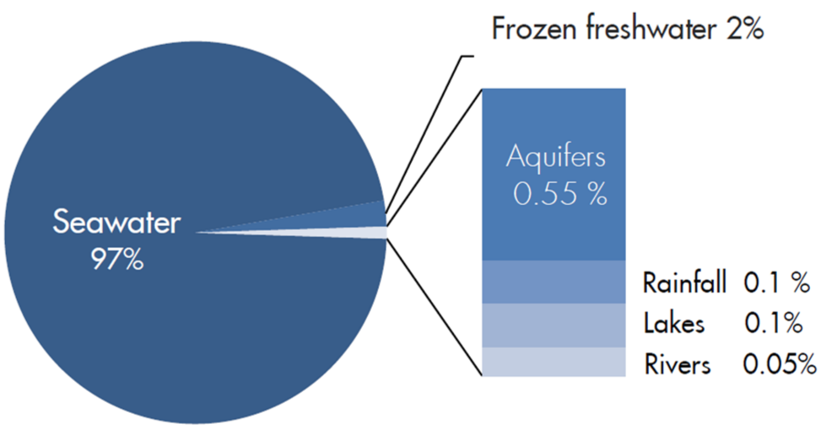

Figure 1: Worldwide water distribution (World Business Council for Sustainable Development, 2009).

Motivation: population

1. Better health care.
2. More food supply.
3. Efficient food production.

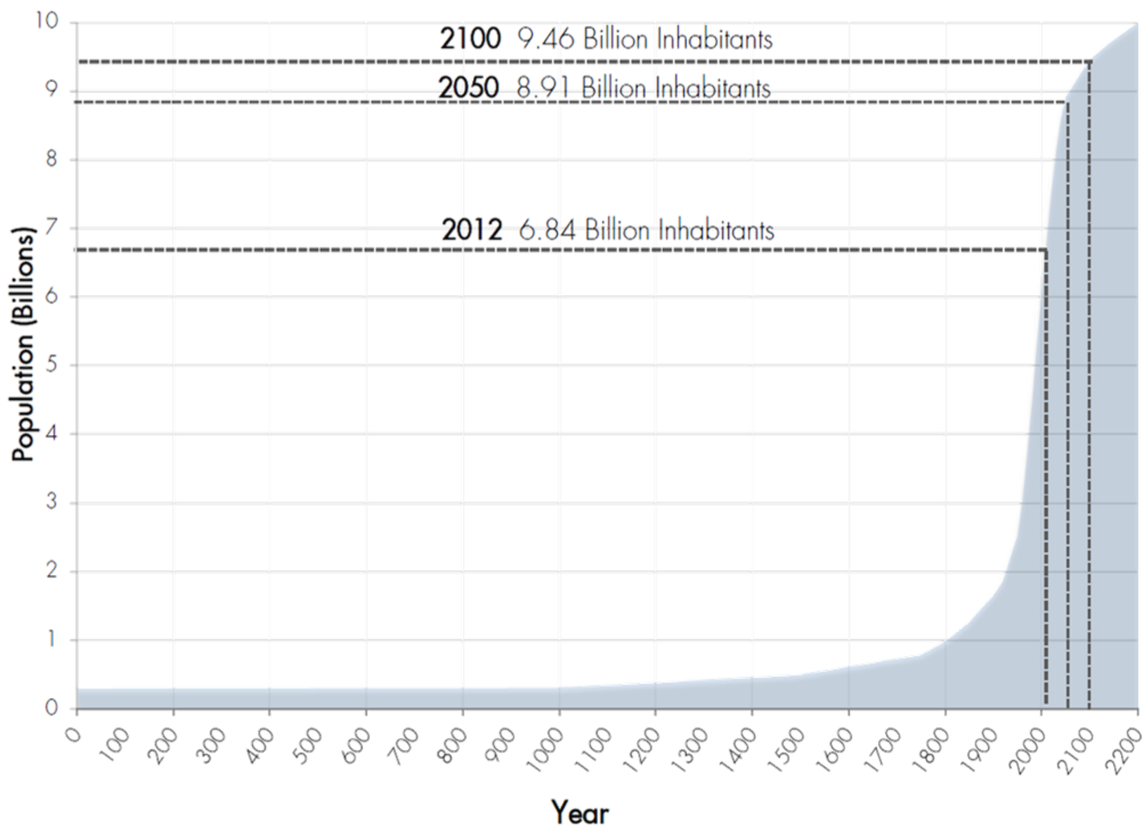

Figure 2: Historic population growth (UN Population Division, 2012).

Motivation: population

1. Fresh water demand will increase by 40% in developing nations, and 18% in developed nations, over the next 20 years (Addams, et al., 2009).
2. Energy demand will increase by 38% over the next 20 years (Shell International BV, 2008).

Motivation: population

3. To feed the world's population in 2050 the current food production needs to be doubled (International Water Management Institute, 2007).

- Example: meat production uses 8-10 times more water, for the same caloric content, compared to cereal production (World Water Assessment Program, 2009).

Motivation: energy

1. Oil is used for energy production, agriculture, petrochemicals, cosmetics, etc.
2. Oil is far from being exhausted. Only 1 trillion (19%) of the estimated 5.2 trillion barrels (discovered and accessible oil) that was originally present on the planet has been produced.

Motivation: energy

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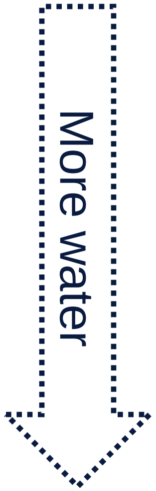
3. Oil extraction may go through three phases (Kokal, et al., 2010):

- Primary: take advantage of the natural reservoir pressure, and don't require water or gas injection to the reservoir. The average recovery factor is 30 to 35%.
- Secondary: involves the injection of water (typically seawater) or gas into the reservoir to increase its pressure to a desired level. The average recovery factor is up to 50%.
- Tertiary: more water injection, plus thermal, microbial or gas injection. The average recovery factor is up to 80%.



For example, the largest oilfield in the world, Al Ghawar, in The Kingdom of Saudi Arabia, needs about 400,000 m^3 of water per day. It has its own seawater treatment plant with more than 400 km of pipelines (Bayona, et al., 1993).

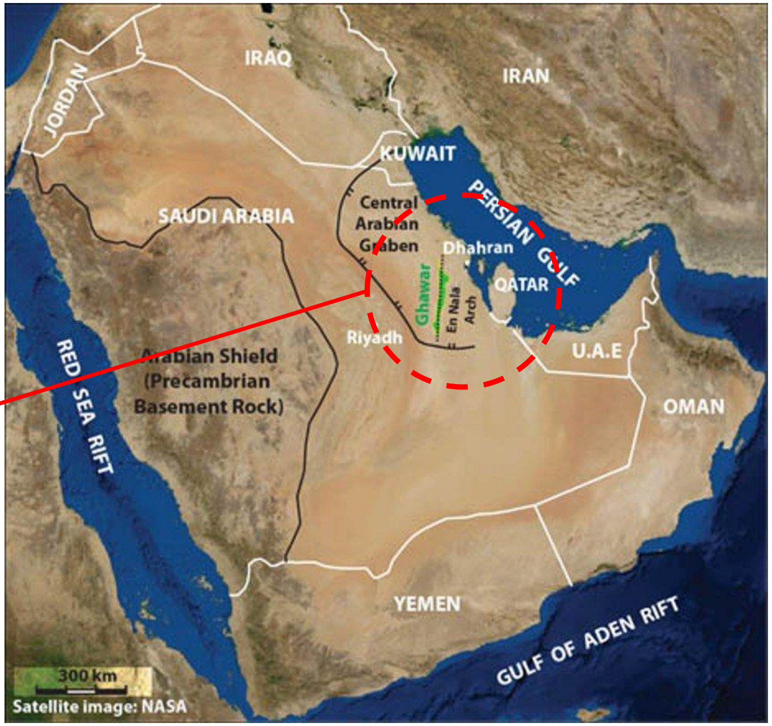


Figure 3: Al Ghawar oildfield.

Motivation: regulations

1. No underground water withdrawal.
   - Example: The Schoonebeek oilfield in Emmen, The Netherlands uses steam injection, with ultrapure water, to decrease the viscosity of the oil, and thereby increasing the productivity of the oilfield. Shell and Exxon joint ventures to treat sewage water in Emmen. The treatment plant produces 10,000 m^3 of ultrapure water daily.

Figure 4: The Shoonebeek water treatment facility.

Motivation: regulations

2. Zero discharge of liquids
   - Example: The Pearl Gas to Liquids complex in Qatar converts natural gas into liquid petroleum products. It produces 1400 m^3 of water per hour as byproduct in the Fisher-Tropsch chemical process, and uses it, after treatment, in the cooling systems.

Figure 5: The Pearl Gas to Liquids complex.

Objective

1. In a nutshell, oil production requires water, and water is scarce.
2. Possible solutions include:
   - Change current technology with one that requires less water.
   - Treat waste water for re-use.
     - Water quality matching: do not over treat water when it is not needed.
   - Find alternative water supplies.

How?

Na
K
Ca
Mg
Fe
Cl
SO_4
CO_3
HCO_3
Br

The important aspects to consider include:

1. Single, or multiple, input and output streams of water.
2. Input and output contamination concentration levels.
3. Integrated water treatment units (TU) with process units (PU).

Na ↓
K ↓
Ca ↓
Mg ↓
Fe ↓
Cl ↓
SO_4 ↓
CO_3 ↓
HCO_3 ↓
Br ↓

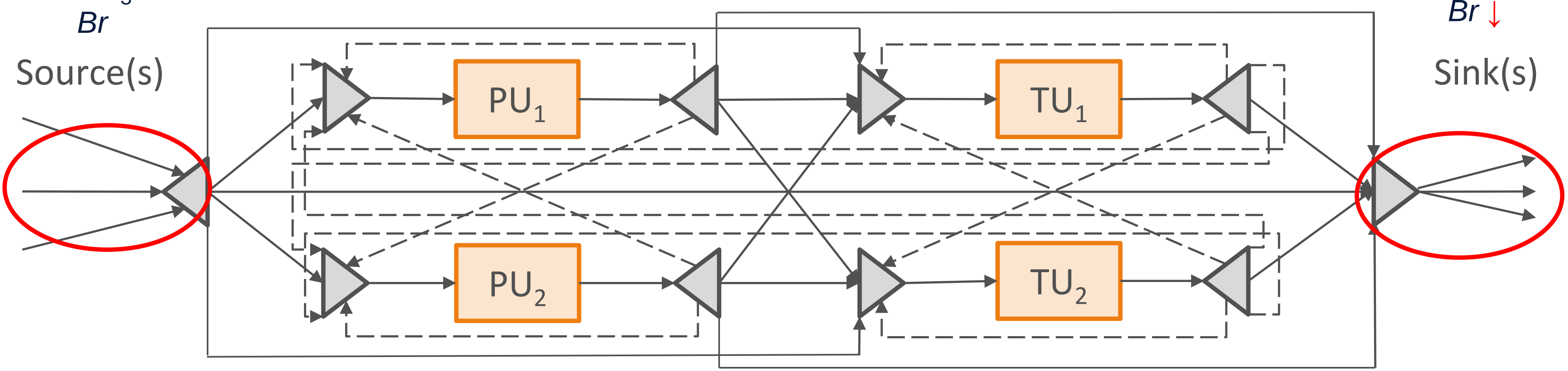


Figure 6: Total waste water treatment network.

The important aspects to consider include:

4. Possible re-cycles in TUs.
5. Treatment and processing takes time (scheduling problem).
6. Mixer units have bilinear functions between inputs and outputs.

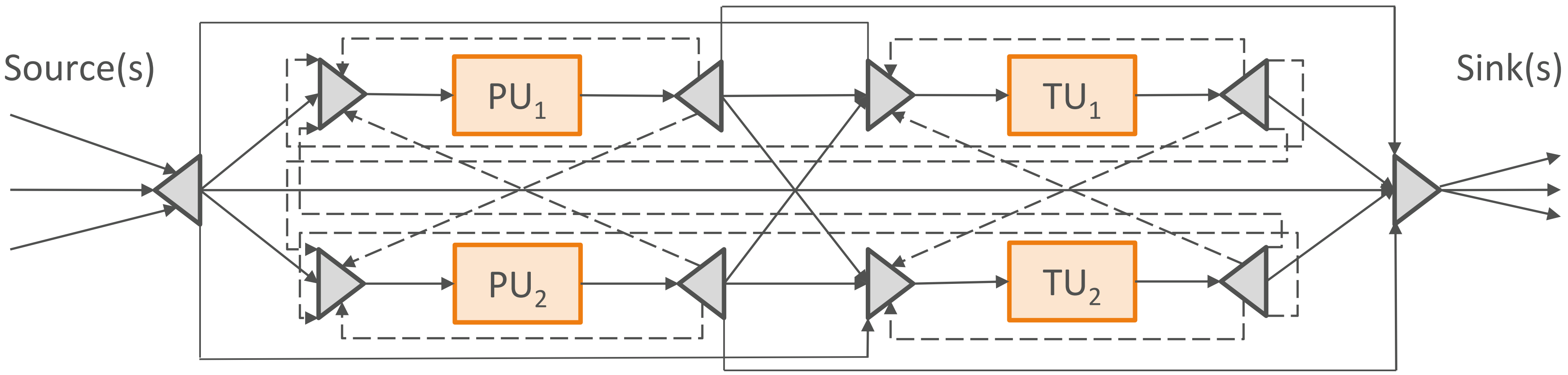


Figure 6: Total waste water treatment network.

Problem description

Objective:

Minimize the cost of designing and operating a total waste water treatment network.

1. A mathematical programming model is MINLP, with bilinear terms in the mixer units.

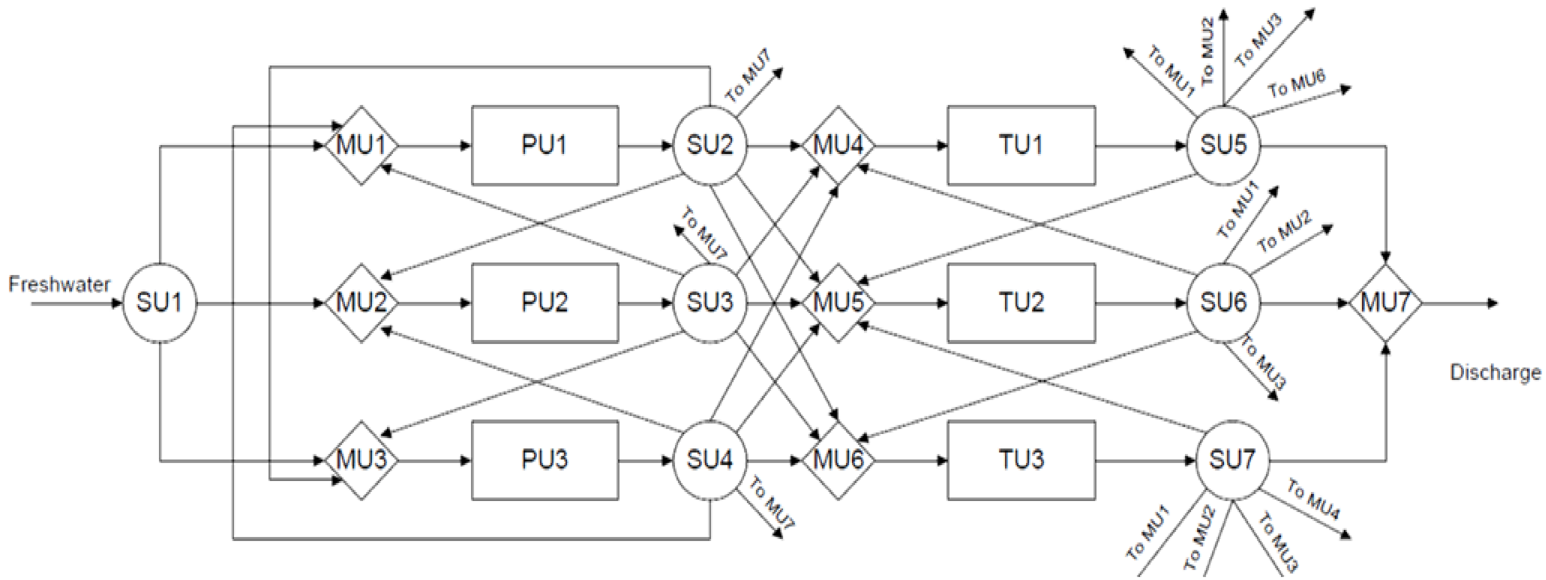


Figure 7: An example of water network with three PUs and three TUs taken from Karuppiah and Grossmann, 2005. The problem was solved with BARON to optimality.

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1. A mathematical programming model is MINLP, with bilinear terms in the mixer units.

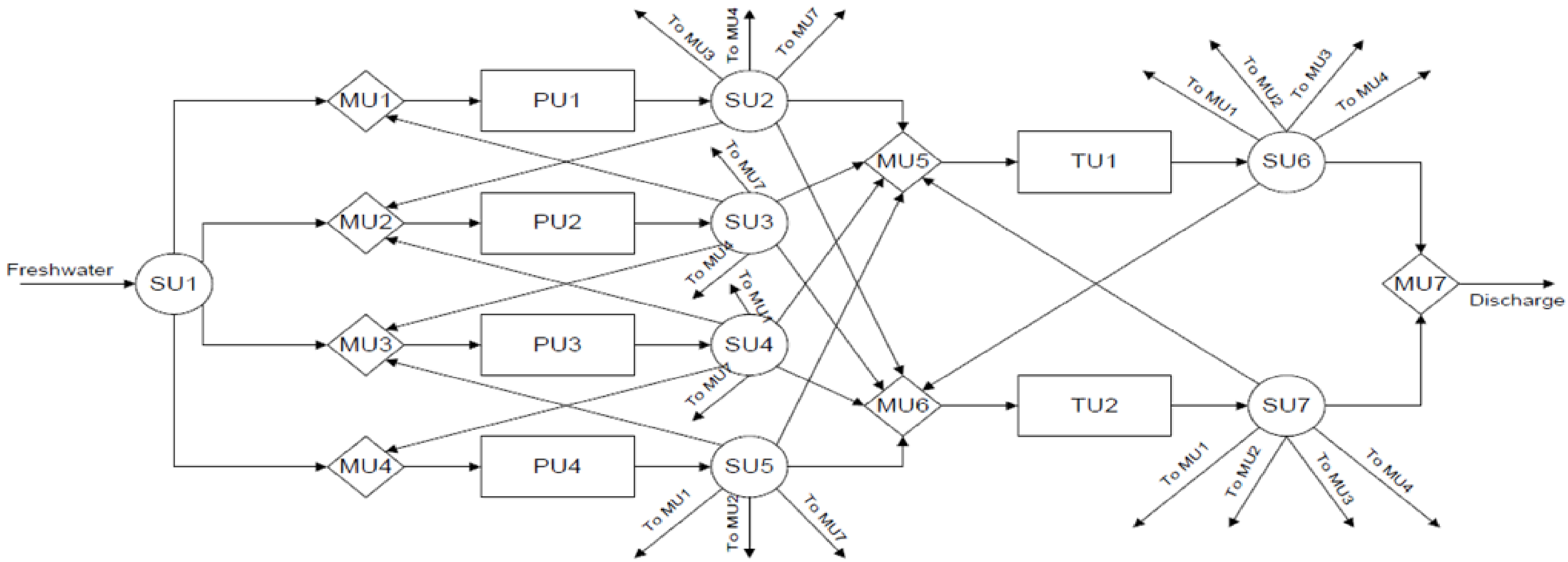

Figure 8: An example of water network with four PUs and two TUs taken from Karuppiah and Grossmann, 2005. The problem was *not* solved to optimality with BARON.

1. A mathematical programming model is MINLP, with bilinear terms in the mixer units.

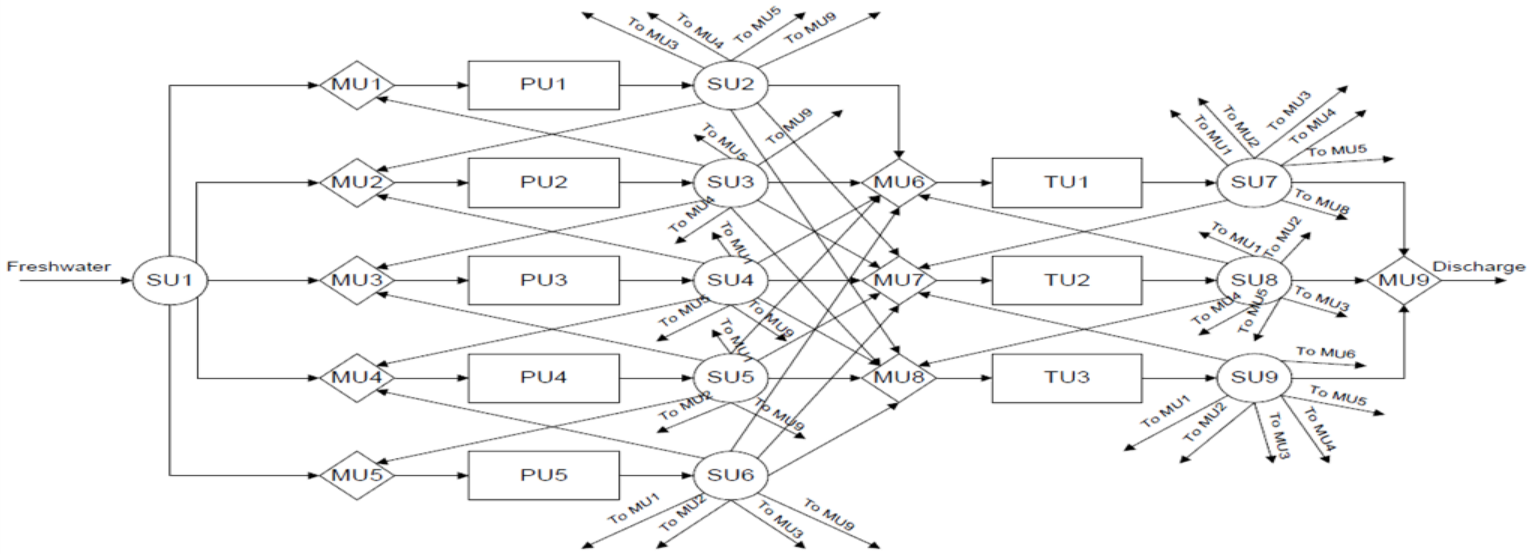

Figure 10: An example of water network with five PUs and three TUs taken from Karuppiah and Grossmann, 2005. The problem was *not* solved to optimality with BARON.

Challenges

2. Accounting for all the important aspects, presented earlier, in one mathematical model is challenging, and perhaps is non-existent.
3. Simulation modeling is an option, but we do not know how it compares to the mathematical modeling approach, at least for this problem.

Initial tackling of the problem

1. ORTEC teamed up with Shell to investigate which aspects of the problem can accounted for, perhaps all.
2. We are organizing a competition where we provide problem instances, inspired by real-life scenarios, and leave it to the competitors to choose the proper modeling and optimization approaches.
3. Based on the results, the best solution(s) will be considered for implementation.

Thank you!

Questions?