Complex System Modelling: Application to Imperial Oil's Cold Lake Oil Sands Facilities

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At Cold Lake, Alberta, Imperial Oil uses a cyclic steam stimulation process to produce heavy oil from oil sands formations. High pressure steam is generated at central plant facilities. The steam is distributed through a pipeline system and injected into the reservoir at wells located at a distance from the central plant facilities. Steam injection continues until the oil viscosity is such that the oil can be pumped to surface. Oil, water and gas are produced during the production part of the cycle and are returned to the central plant facilities. Produced water is mixed with make-up water and is treated and reused as feed water for the steam generators. The produced gas supplements the purchased natural gas used as fuel for the steam generators. The produced oil is processed to remove sand and water. It is then diluted with a lighter hydrocarbon ("diluent") to meet pipeline viscosity specifications. The diluted bitumen is sold to refiners.

There are three central plant facilities at Cold Lake. A total of 3500 wells have been drilled to date of which 3200 are still active. Each well is associated with a single plant. The older wells have completed up to 10 cycles of steaming and production. New wells are periodically added. The duration of the steaming and production phases depends on the age of the well. The steaming phase lasts from 28 to 150+ days. The production cycle lasts from 100 to 1600 days.

Figure 1 is a description of the physical components of the system:

Table 1 provides a more general list of the system inputs, outputs and processes.

The Challenge:
Imperial Oil would like to be able to optimize the performance of the overall Cold Lake system. Given the interdependencies of the system and the fact that the time delays vary, we believe that dynamic system modelling is the answer. How would you approach this problem?

System Description & Diagram:
Because of the complexity of the Cold Lake system, it is difficult to summarize everything in a diagram. The following chart lists system inputs and outputs and the processes that should be considered within the scope of the project. Note that items shown in italics are not included on the system diagram.

Inputs	*Processes*	*Outputs*
fuel gas	steam generation - LM, MS, MH	heat to reservoir
diluent	steam injection - LM, MS, MH	dilbit for sales
heavy oil reservoir - LM, MS, MH	bitumen production - LM, MS, MH	disposal water
groundwater	water treatment - LM, MS, MH	emissions
fresh water	gas treatment - LM, MS, MH	solid waste
brackish water	produced water balancing	
people	brackish water balancing	
technology	groundwater balancing	
ideas	fresh water balancing	
price forecast	diluent blending - LM, MS, MH	
strategic business considerations	waste management - LM, MS, MH	
operating budget	forecasting	
capital budget	corporate plan development	
	pad addition management	
	volume addition management	
	surveillance/optimization	
	maintenance planning	
	safety	
	environmental/regulatory	

The following chart defines the abbreviations used on the system definition diagram.

Abbreviation	*Meaning*
BFW	boiler feed water
BW	brackish water
dilbit	diluted bitumen
FG	fuel gas
FW	fresh water
GW	ground water
HP	high pressure
LM	LM
MH	Mahihkan
MS	Maskwa
PG	produced gas
PW	produced water
Stm	steam