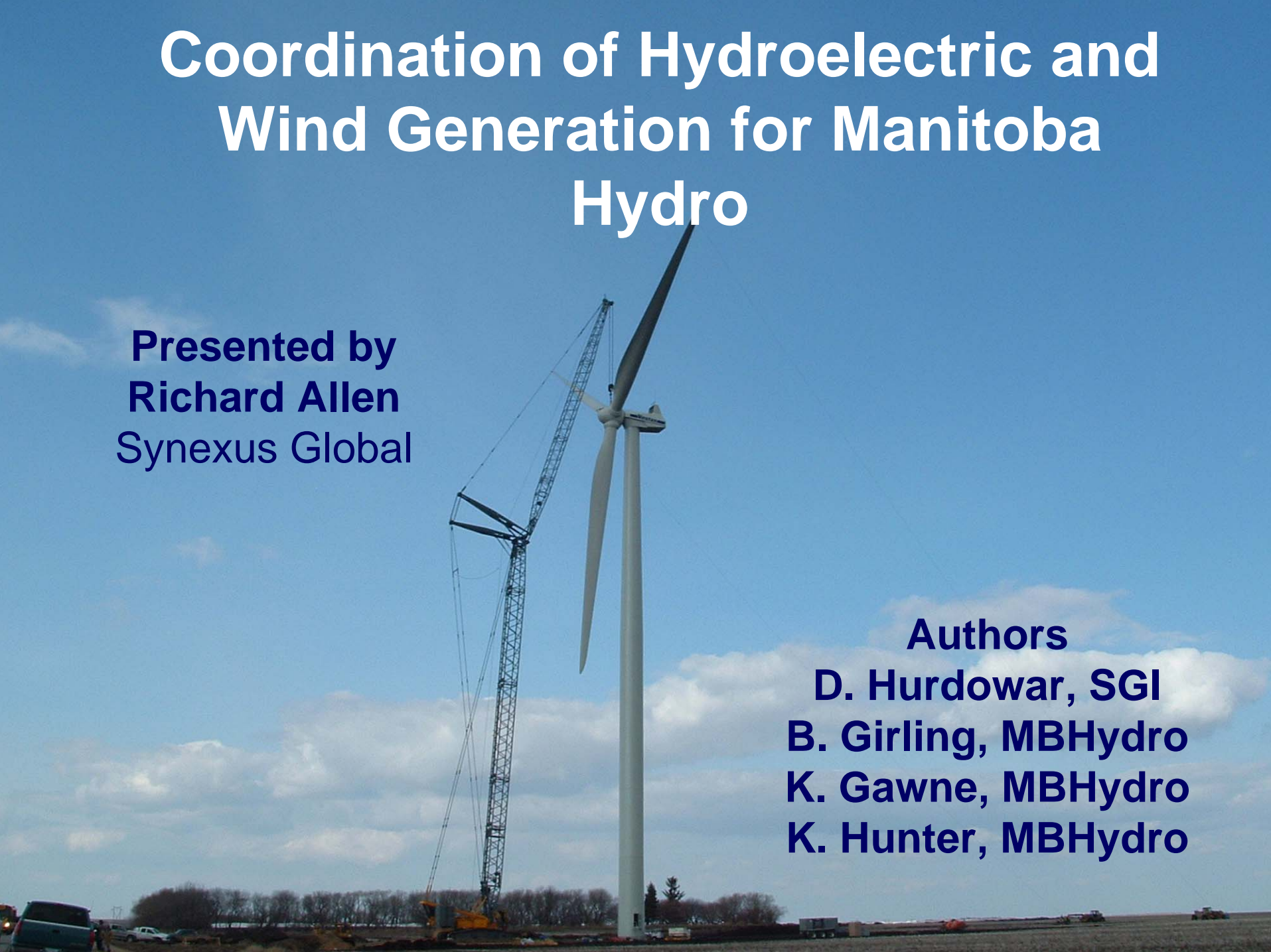


Coordination of Hydroelectric and Wind Generation for Manitoba Hydro

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Why is Manitoba Hydro Studying Wind Power?

- Serve domestic load (not required until around 2020).
- Increase firm supply for export.
- Offset high cost imports or thermal generation during drought.
- Short lead time.
- Need to know value of wind power to Manitoba Hydro – **how much should we pay independent wind developers?**



Wind – Hydro Synergies

- Use reservoir flexibility to shape wind energy into a high value export product.
- Hydro generation is adept at responding to rapid load changes (*generally*).
- Hydro can provide the necessary reserve requirement to support a variable wind supply



Short-Term Modeling To Estimate Cost of:

1. Sub-optimal hydro operations due to variability and uncertainty of wind generation.
2. Lost opportunity cost from increased capacity reserve requirement for wind
 - Regulation reserve for uncorrelated minute to minute variations in net load (AGC control).
 - Load following reserve for sub-hourly ramp in net load.
 - Reserve to backstop against next 1-2 hr wind generation forecast error.
3. Short-term hydro operations planning tool used to compare economics of integrating wind into the Manitoba Hydro System.

“Vista” Analysis Tool

A DSS is an computer tool that uses

- Forecasting
- Optimization and Simulation

to find cost effective solutions for :

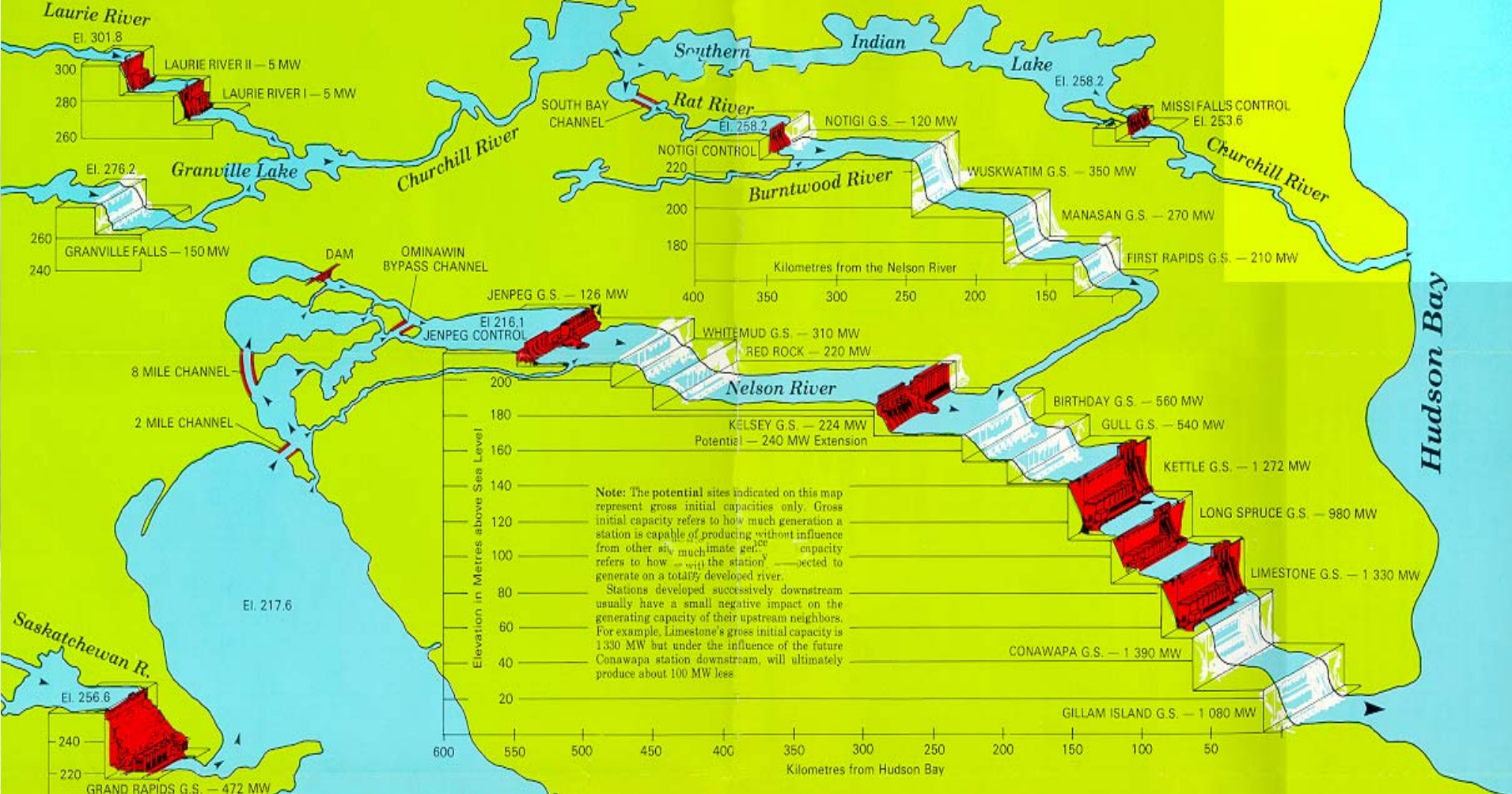
- Long term energy management
- Short term scheduling
- Facility upgrading
- Strategic Planning
- Water Management Planning

Operations

Studies

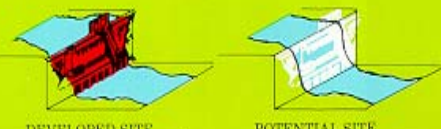
Vista Short-Term Model

- ⇒ *Vista* can model the hour-to-hour, day-to-day operations of the Manitoba hydro system
- ⇒ Reservoirs can redistribute wind energy to peak hours and/or offset off peak imports or both because it models market opportunity. (Energy reshaping)
- ⇒ Can model multi-reservoir systems and their hydraulic considerations (*Vista* is ideal)
- ⇒ To model wind we need to capture the effects of wind variability and uncertainty on reservoir operations.

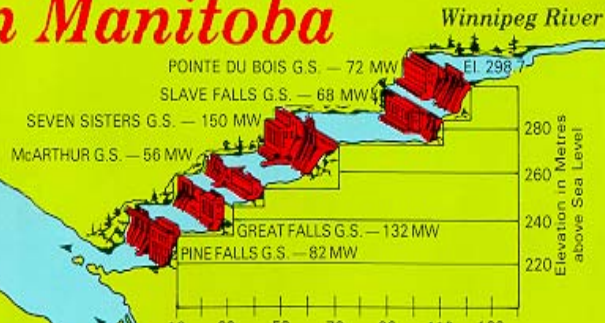


Water power has been the main source of electric generation in Manitoba since 1906. As of March 31, 1985, the province's developed hydraulic capacity amounted to 3 644 megawatts (MW).

Beyond 1985, further hydraulic development is possible at a number of Manitoba sites — Nelson, Burntwood and Churchill Rivers — promising another 6 270 MW of additional generating capacity.



Hydro-Electric Power in Manitoba



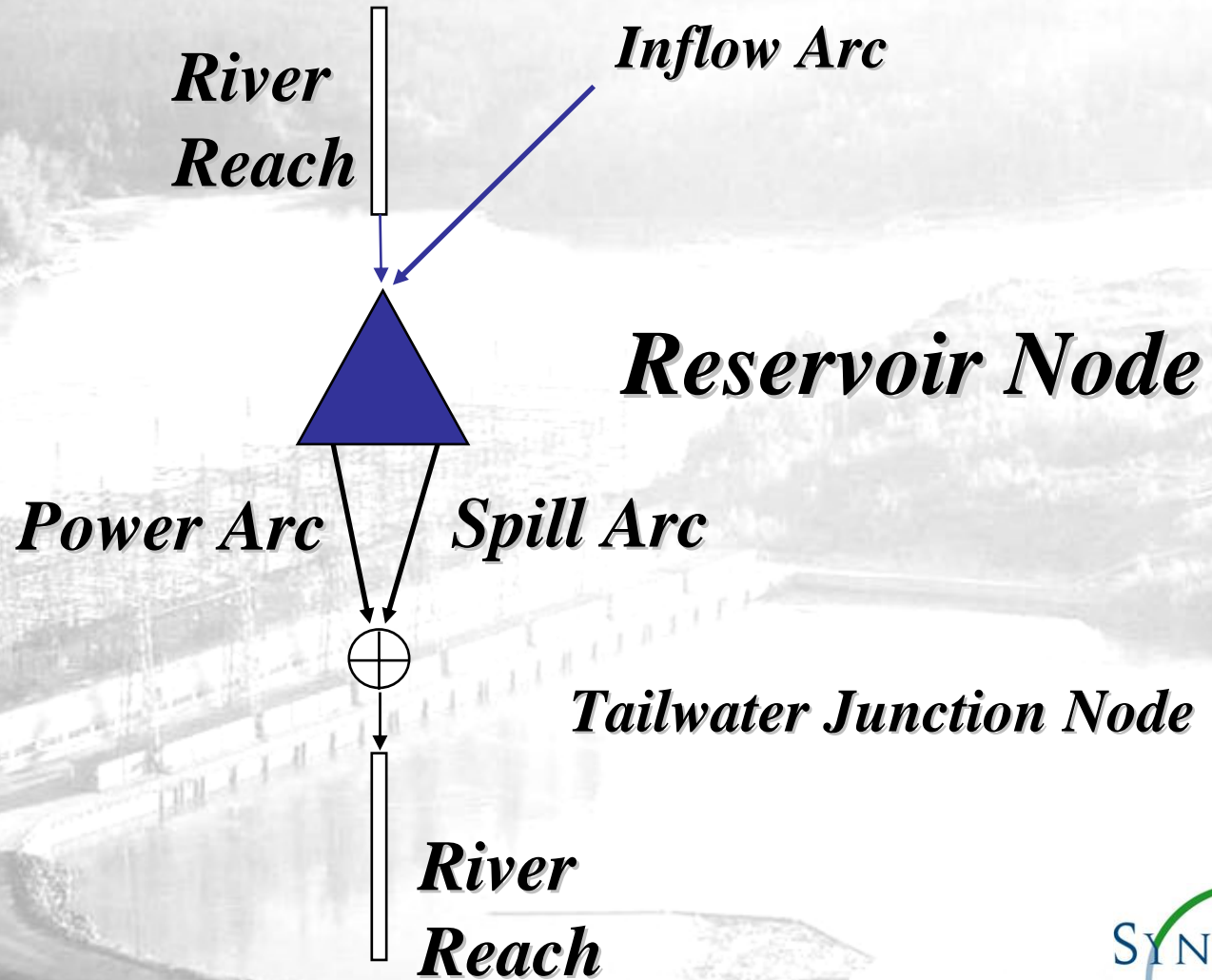
Modelling Wind Hydro Integration

- System Related (Manitoba Hydro)
 - Uncontrolled Lakes and channels
 - Long river reaches and lag times
 - Ice conditions in winter
- Wind Related
 - Uncertainty in wind forecasts
 - Variability in wind energy delivery

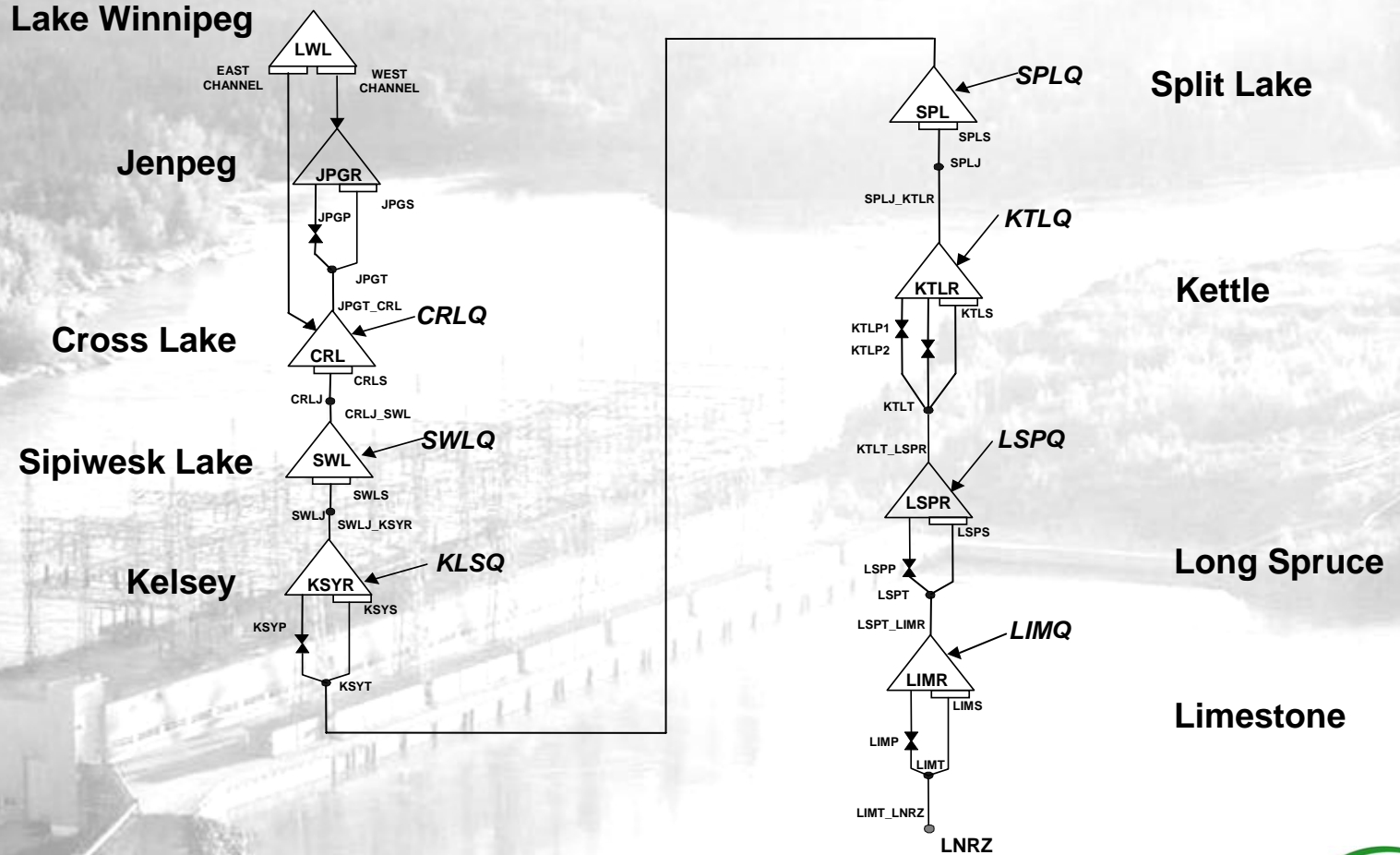
Vista Workings

- Model workings
 - Physical/hydraulic/transmission characteristics and constraints
 - Market Price forecasts
 - Firm Contracts
 - Historical/forecast Inflow sequences
 - Load demands
 - Within-plant dispatch (Unit Operations)
 - Transaction opportunities
 - Reserves
- *AUTO Vista*
 - Performs analysis over 1 year

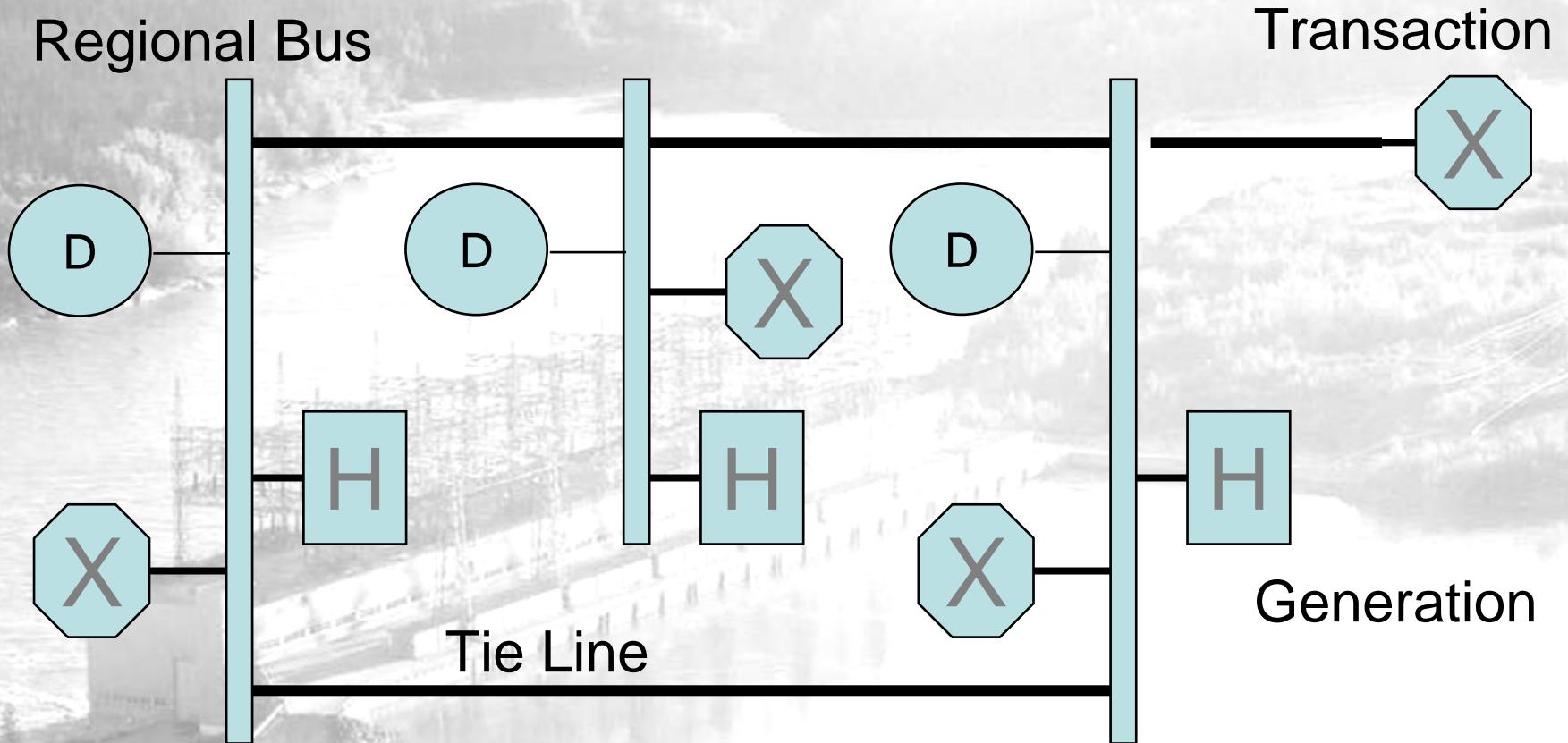
Vista Hydro System Components



Nelson River

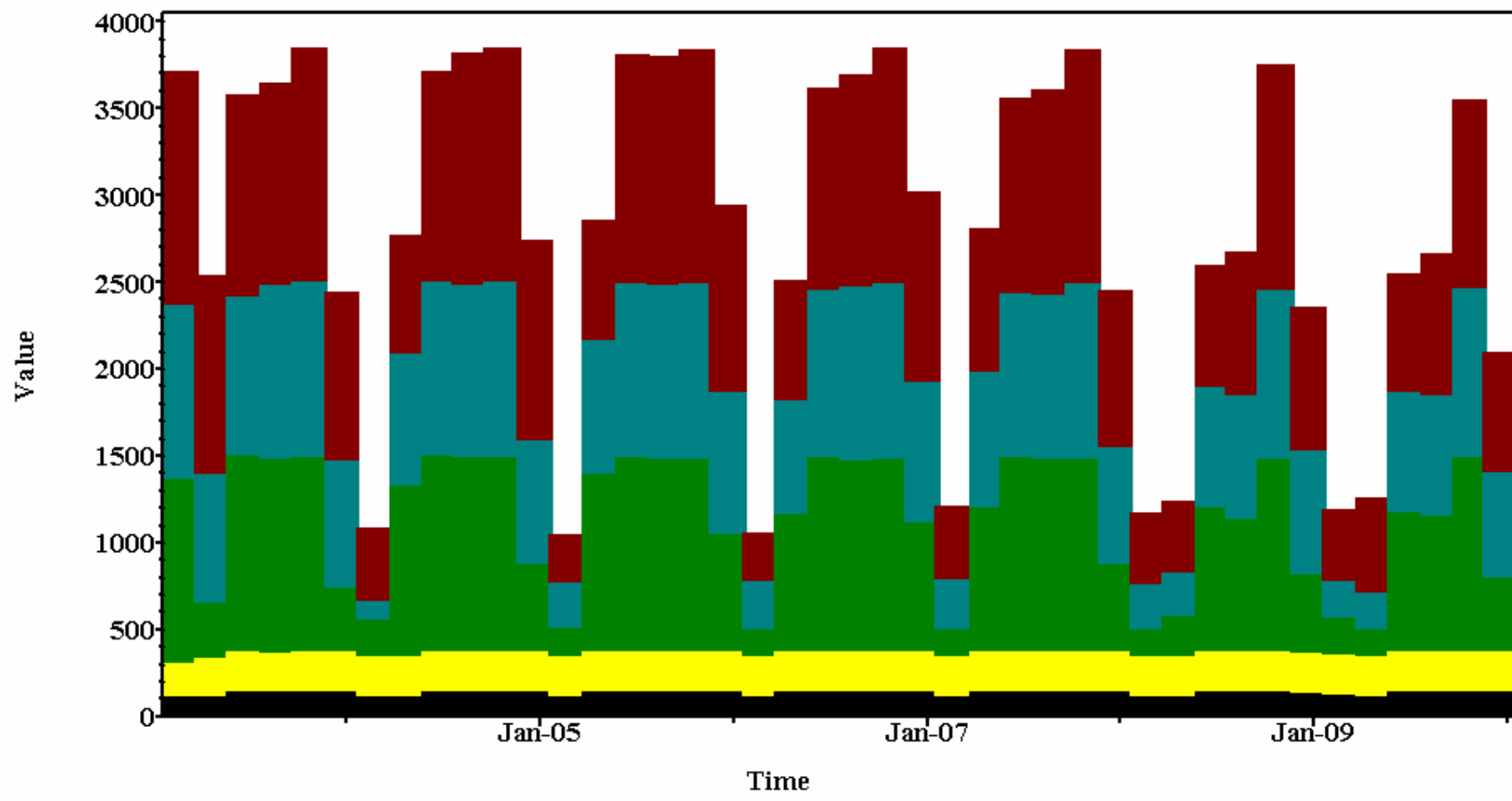


Vista Transmission System Components



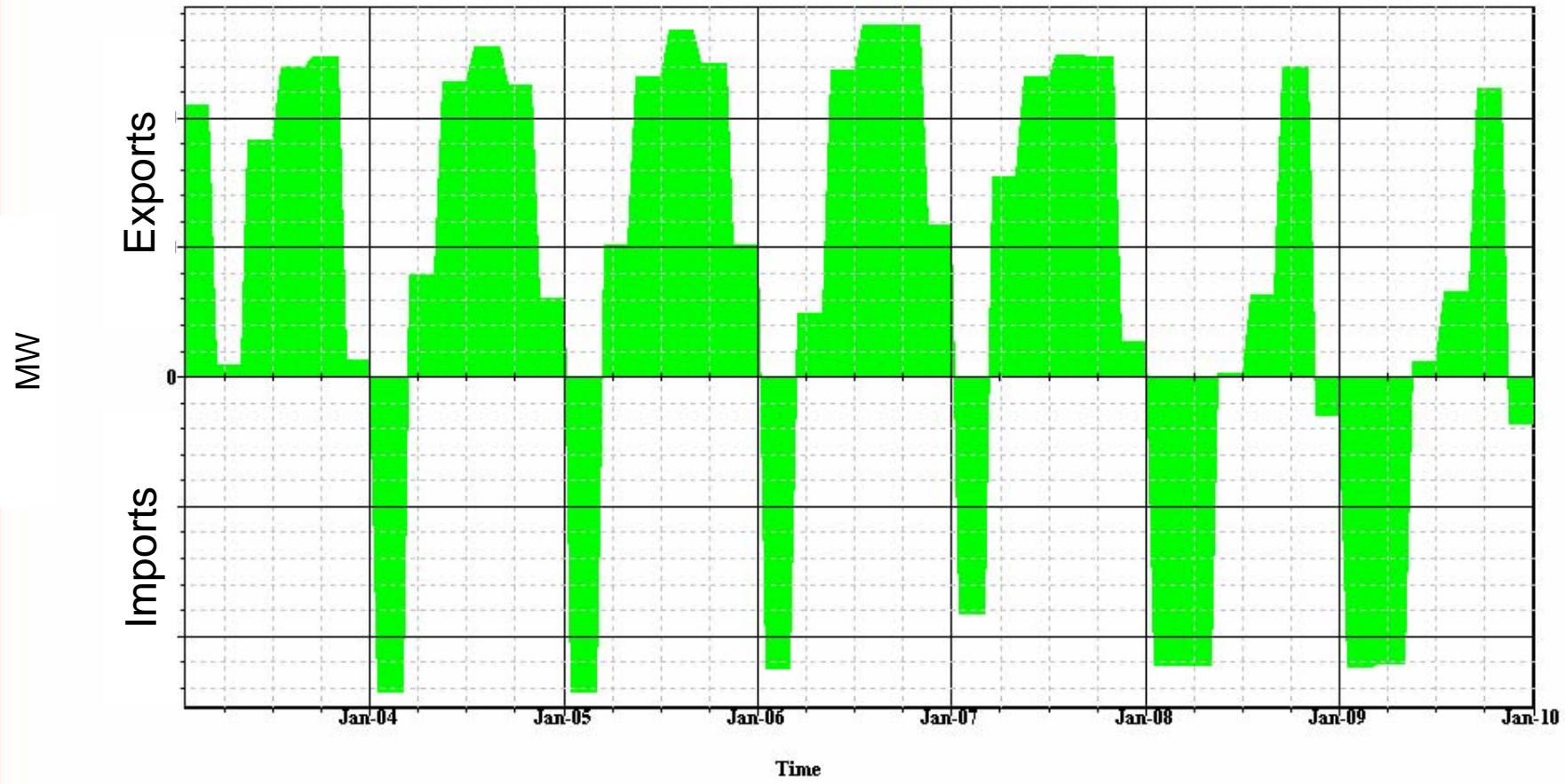
Nelson River Plants Generation

Wednesday, November 09, 2005
Ref Time: Monday, January 03, 2011 01:00:00



Net Transactions **Wednesday, November 09, 2005**
System **Ref Time: Monday, January 03, 2011 01:00:00**
From Mon Jan 03 2011 01:00 to Sun Jan 09 2011 24:00

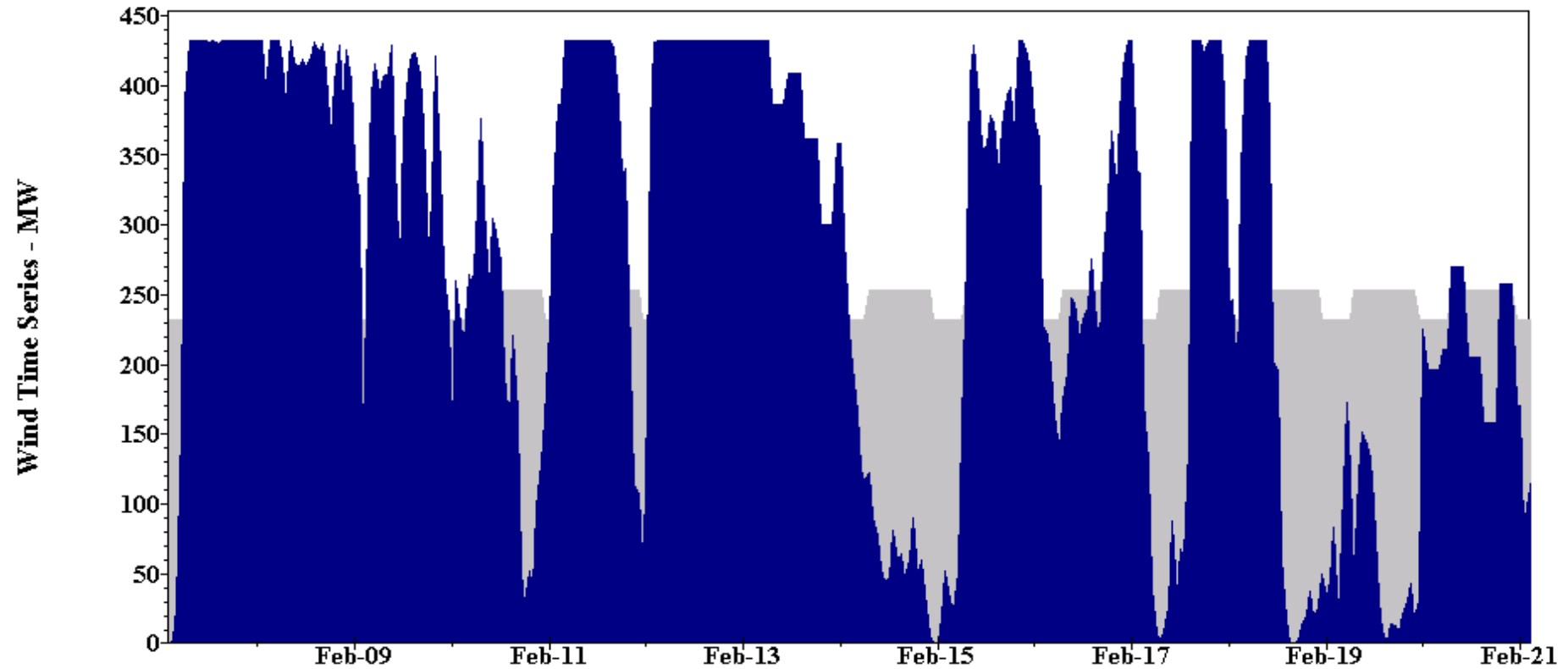
■ SYS_TRANS(MW)



Sample St. Leon Wind Time Series

■ Average Wind

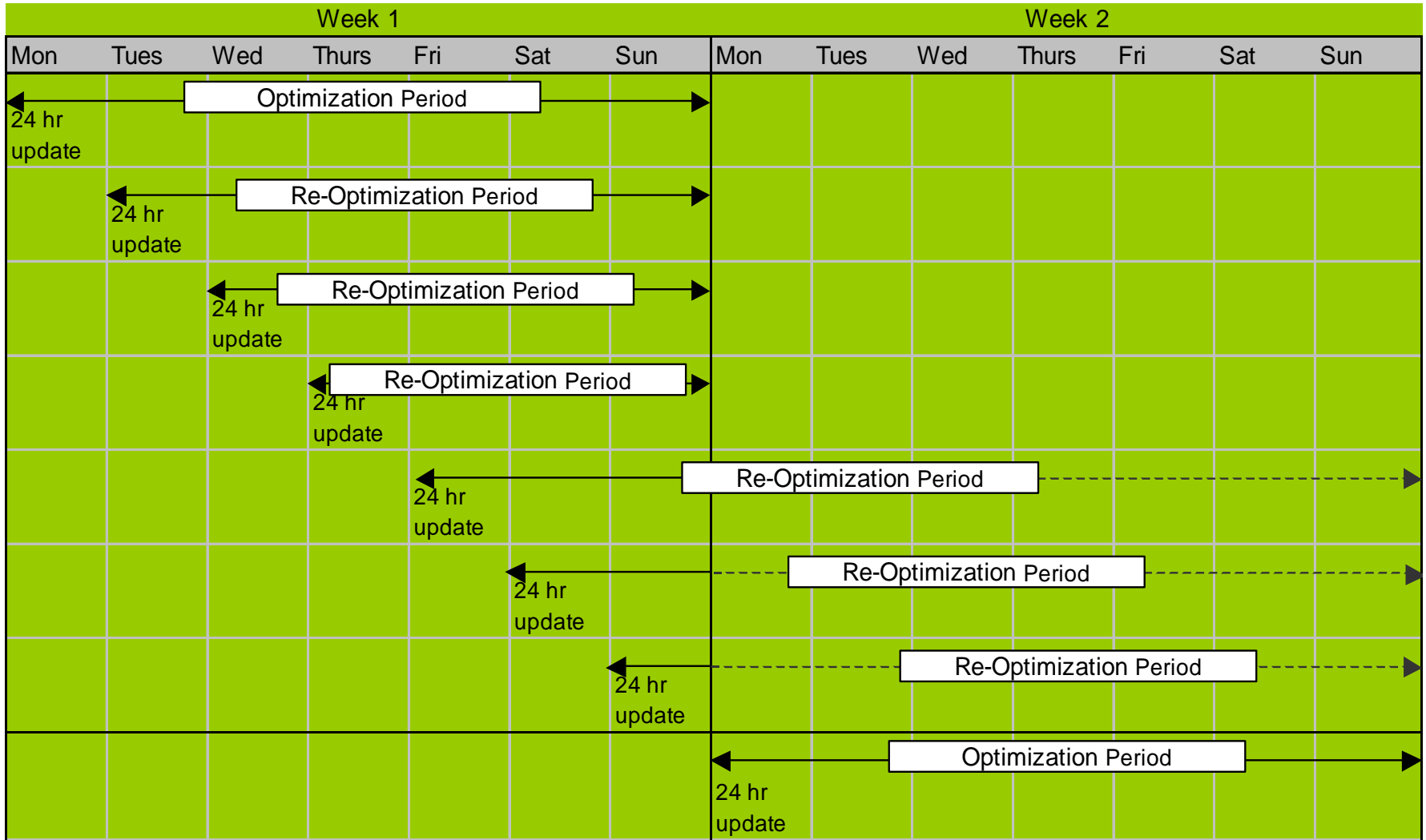
■ Actual Wind



Modeling Wind

- Could assume perfect foreknowledge of wind much like we do for hydrology – does not capture the uncertainty
- Could assume an average energy for the week, derived from the wind time series – does not capture wind variability
- Adopt perfect foreknowledge for the first 24 hours and average for the remainder of the week.
- *AUTO Vista* enhanced to re-optimize periodically (e.g. daily); new wind forecast for the current day

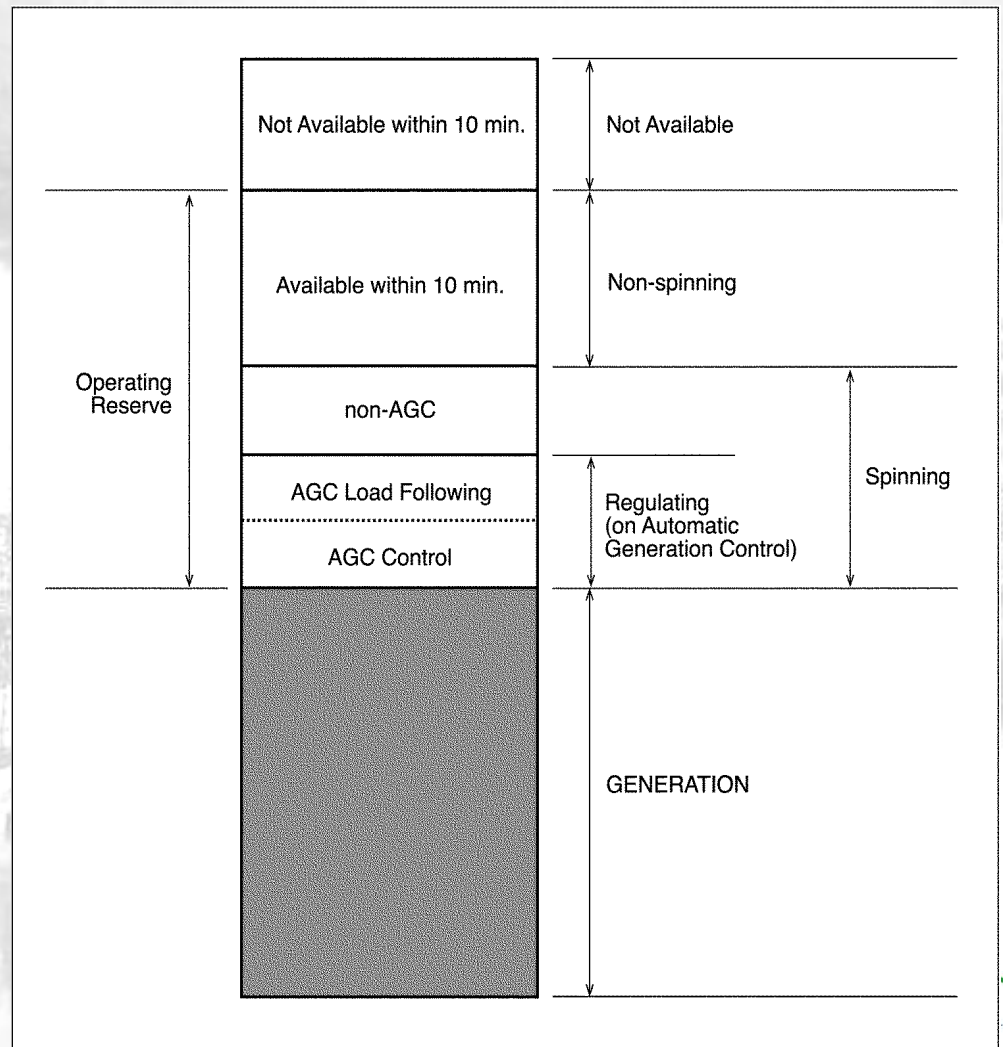
Wind Updating

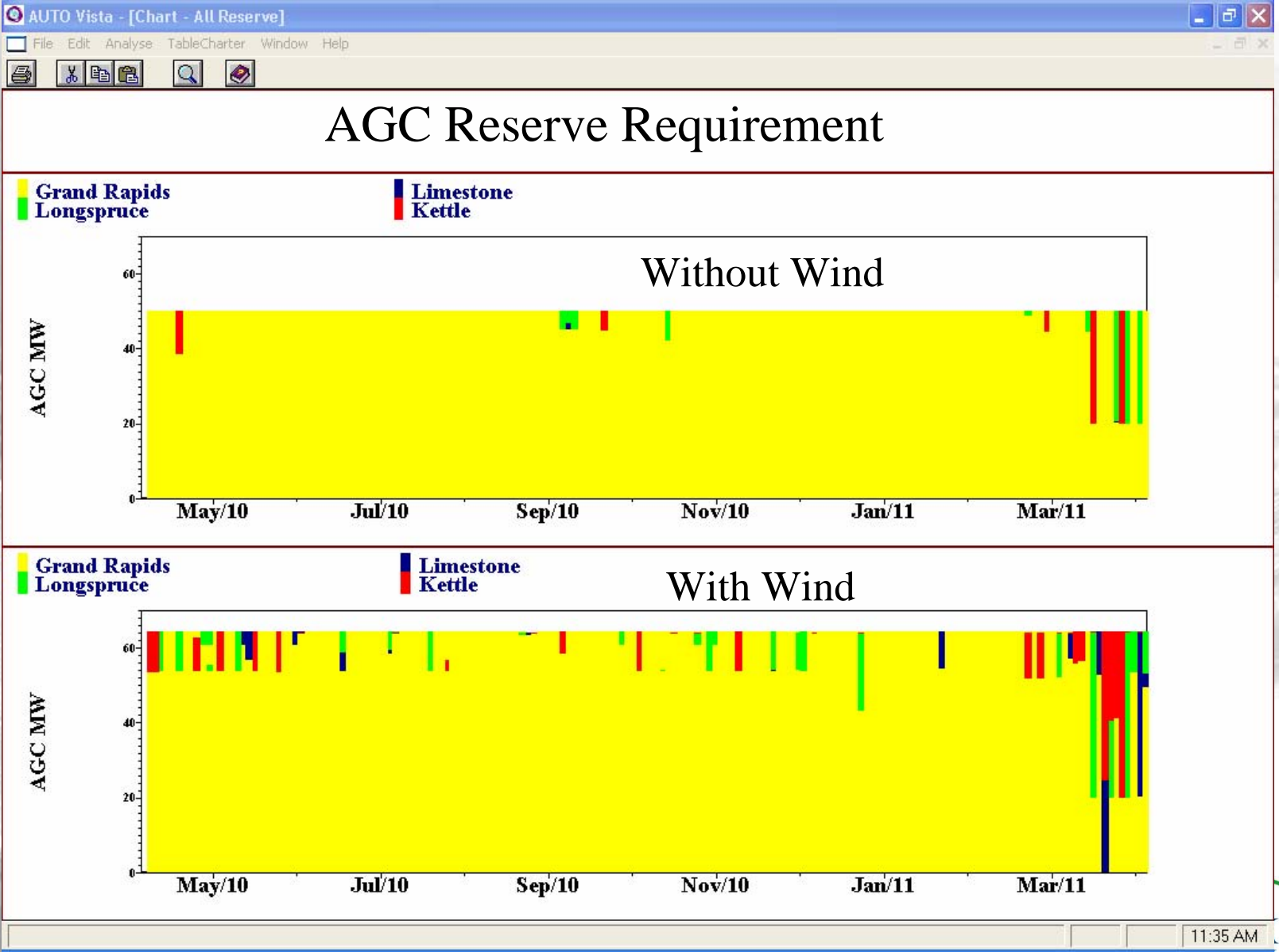


Modelling Reserves

Can model both the variability and uncertainty of wind and the associated reshaping of operations.

Need to incorporate additional reserve requirement

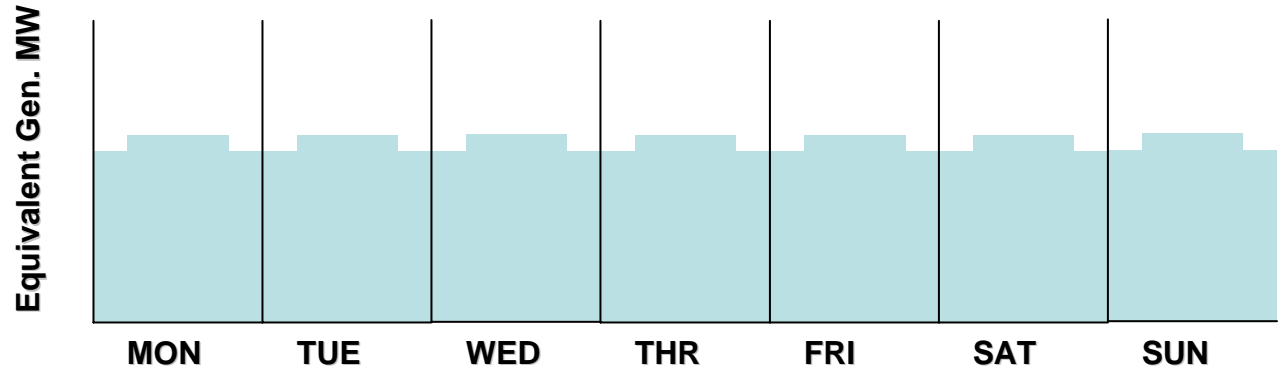




Modeling short-term Wind Uncertainty/Variability

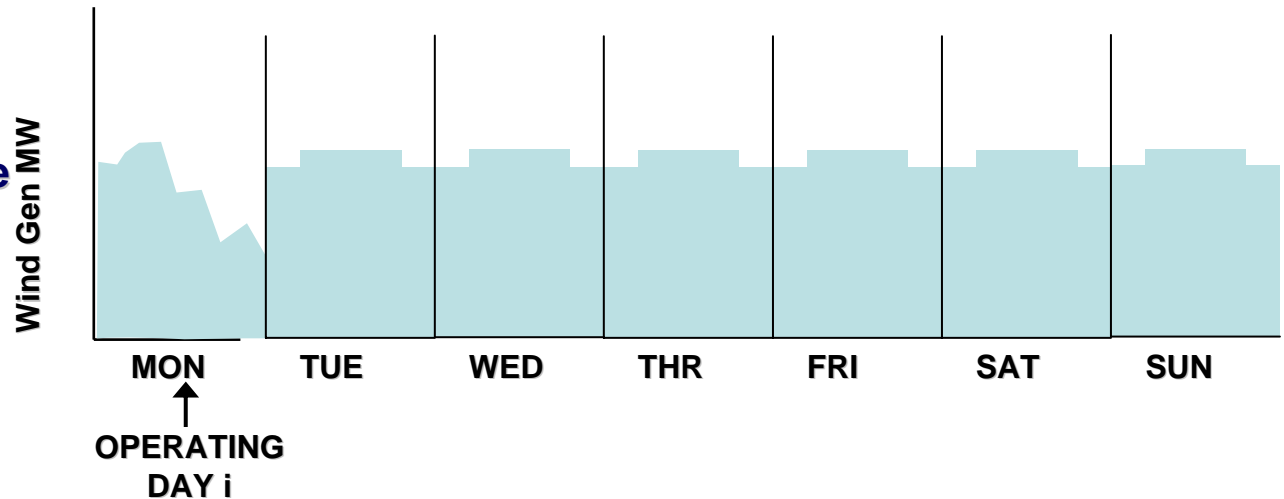
CASE 1

- Monthly average energy
- No added reserves

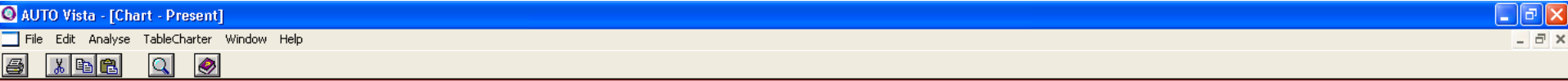


CASE 2

- Perfect foreknowledge on operating day
- Assume monthly average for subsequent days
- Advance daily
- Added reserves

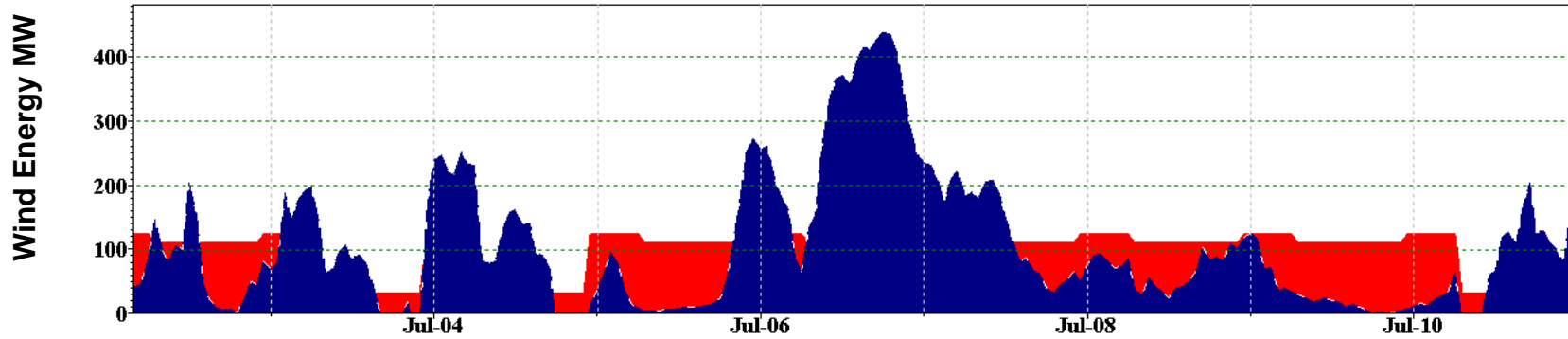


Net Transactions



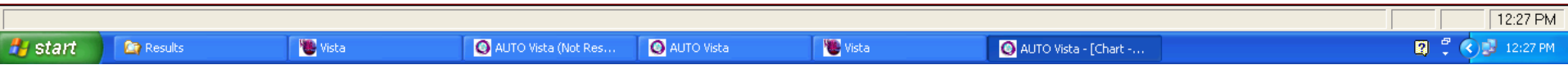
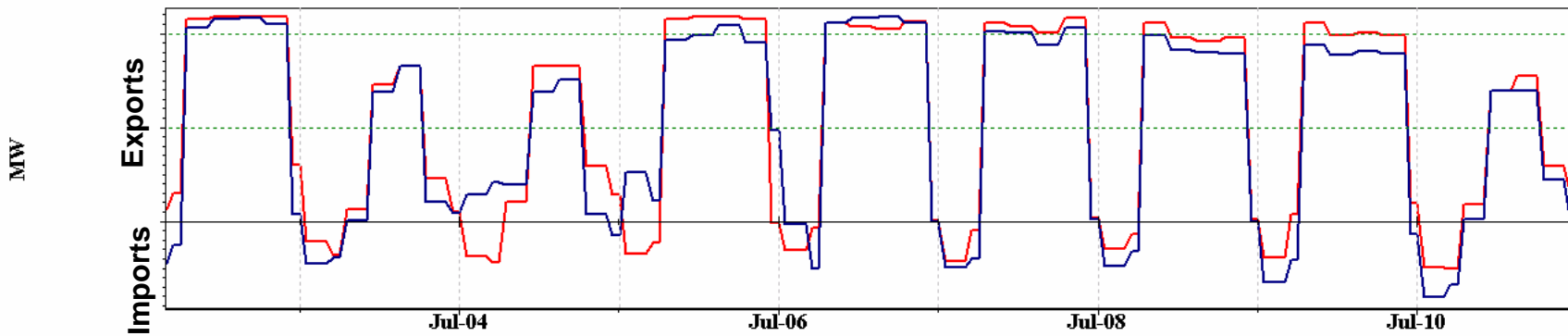
Equivalent Energy Case

With Wind



- Equivalent Energy Case

- With Wind



Brief Results

Results are Manitoba Hydro specific but general comments on the incremental cost associated with reshaping wind energy and providing reserves is provided

- Incremental cost was smallest under low flow conditions and incrementally increased under median and high flow conditions
- The 1000 MW wind farm yielded a cost that was slightly higher on a per MWh basis than the 500 MW case under high flow conditions.
- Under low and median hydrology Total Incremental Cost = 65% reshaping reservoir + 35% additional reserve requirement.
- Under high hydrology Total Incremental Cost = 30% reshaping reservoir + 70% additional reserve requirement.

In Summary

- Using MOST (ST *Vista*) for Manitoba Hydro
 - Modeled the hourly hydro operations in conjunction with a variable and uncertain wind supply over a one year period.
 - Determined the incremental cost of a wind supply source in terms of \$/MWh for each of the low, median and high hydrologies.
 - Provided a breakdown of this incremental cost in terms of reserve and reservoir reshaping.
 - Provided the detailed analysis for both a 500 MW and 1000 MW wind supply.
 - Determined the impacts of additional energy supply on the existing transmission system.
 - Quantified the additional spill associated with integrating the wind supply source into the Manitoba system.
 - Assessed the increased usage of existing contracts for the wind supply.
 - View the hourly change in Hydro operations in terms of reservoir levels, flows, spills and power output at each of the hydro plants to accommodate wind.