Renewable energy consultants

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Layout Optimization – what are we optimizing and how?

30th January 2013

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Introduction

Layout optimization – working out where to place your turbines for best effect - is a complex, multi-disciplinary task.

Considerations are by turn (in no particular order):

- Geographical;
- Environmental;
- Political;
- Regulatory;
- Subjective;
- Aesthetic;
- Scientific;
- Commercial.
- …

What are we optimizing?

Within the constraints of the physical situation of the project and the regulations in effect at that location, we seek to optimise the following:

- Financial returns (high):
  - ✓ Energy yield (high)
  - ✓ Construction and running costs (low)
  - ✓ Tax and other incentives
- Local acceptance of the project (“good”).
- Environmental impact of the project (low).

An iterative process that may not have a single “best” solution.

Fixed constraints to layout design - challenge

Generally fall under Acceptance and Environmental categories; factors not affected by the layout itself:

- **Physical**: Slopes, vegetation/fauna, land ownership, existing structures
- **Regulatory**: Typically, exclusion zones of fixed dimensions from some dwellings, roads, water bodies, electromagnetic communications, flight paths sites of archeological significance etc.
- **Expectation**: straight rows of turbines may be expected and fit in better with local land use patterns (along field boundaries, away from ploughing or other machinery such as Center-Pivot Irrigation systems); land owner X wants Y turbines on his land etc.

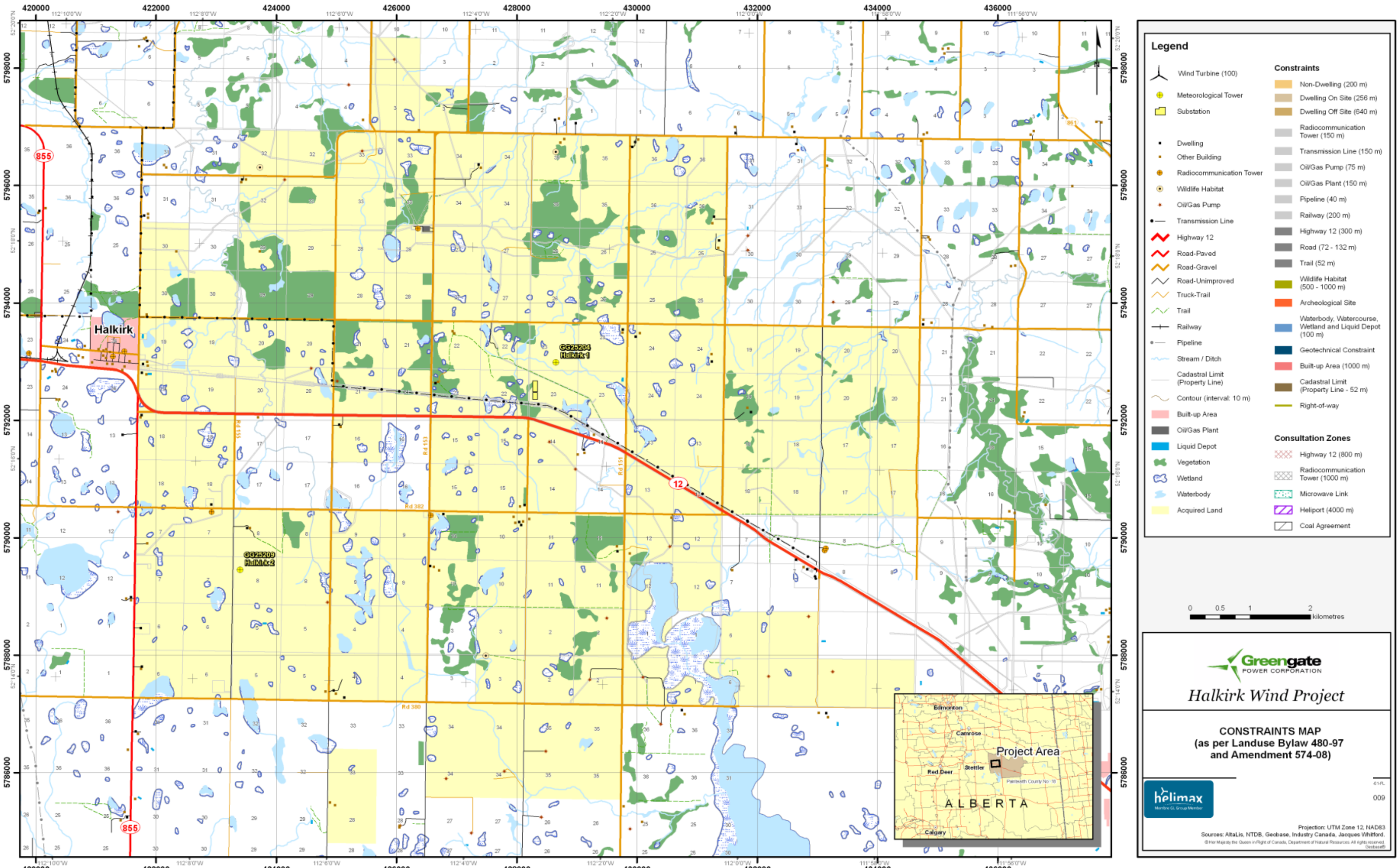
Fixed constraints to layout design - approaches

Fairly straightforward

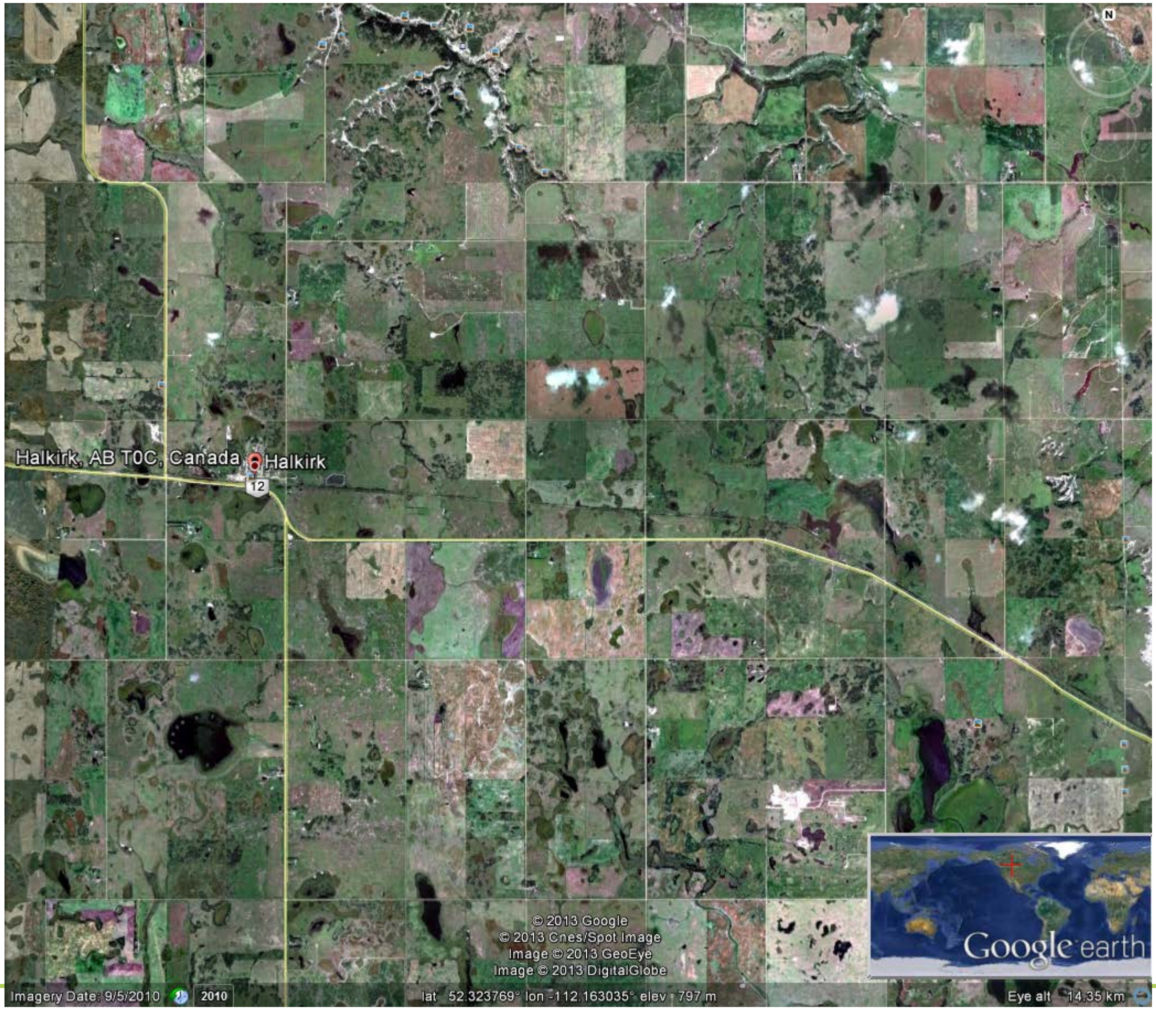
- Early-stage constraint mapping exercise;
- timely Environmental Impact study.

An example from our GIS team:

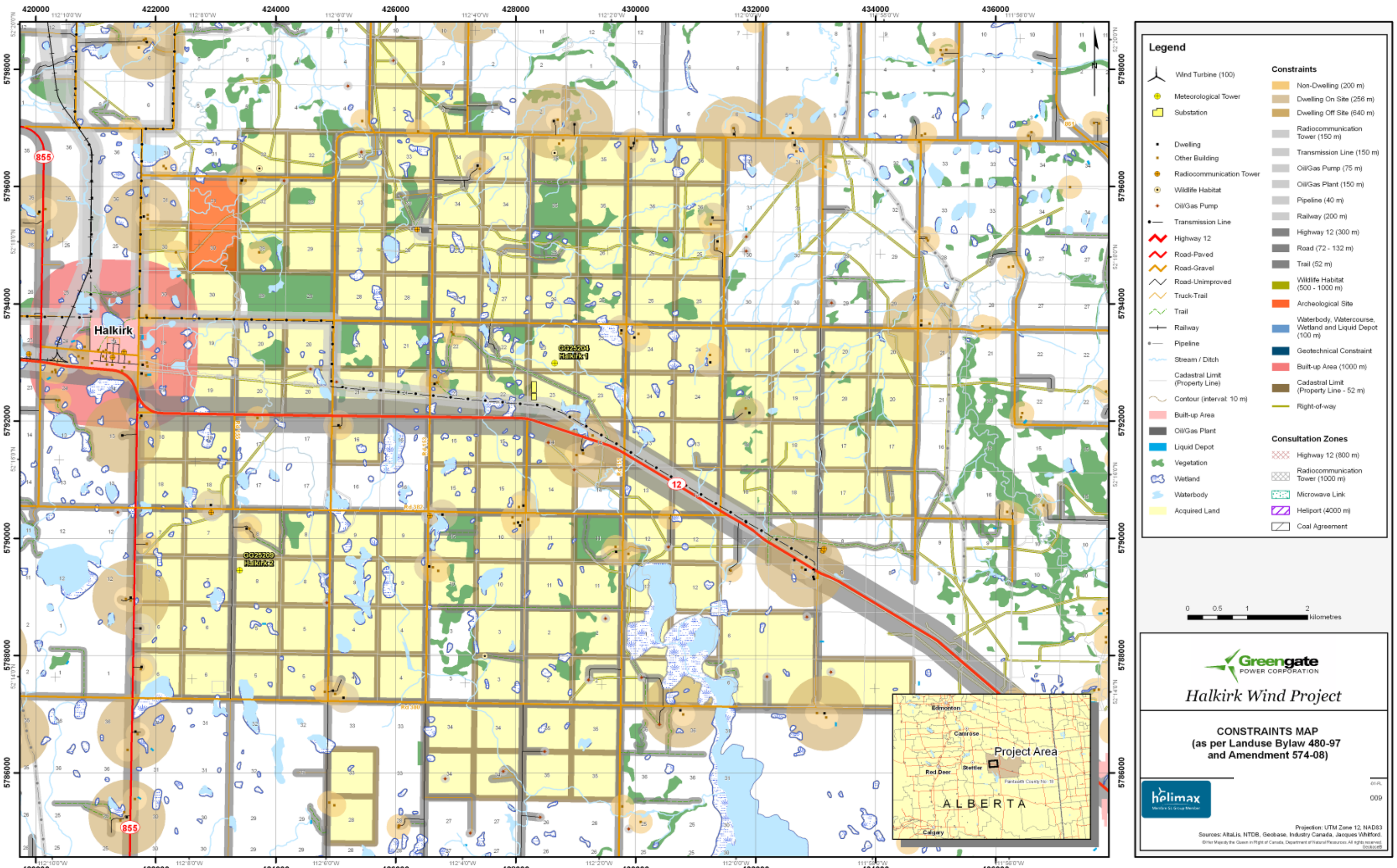
Spatial Analysis Example (1/5) – Base Data



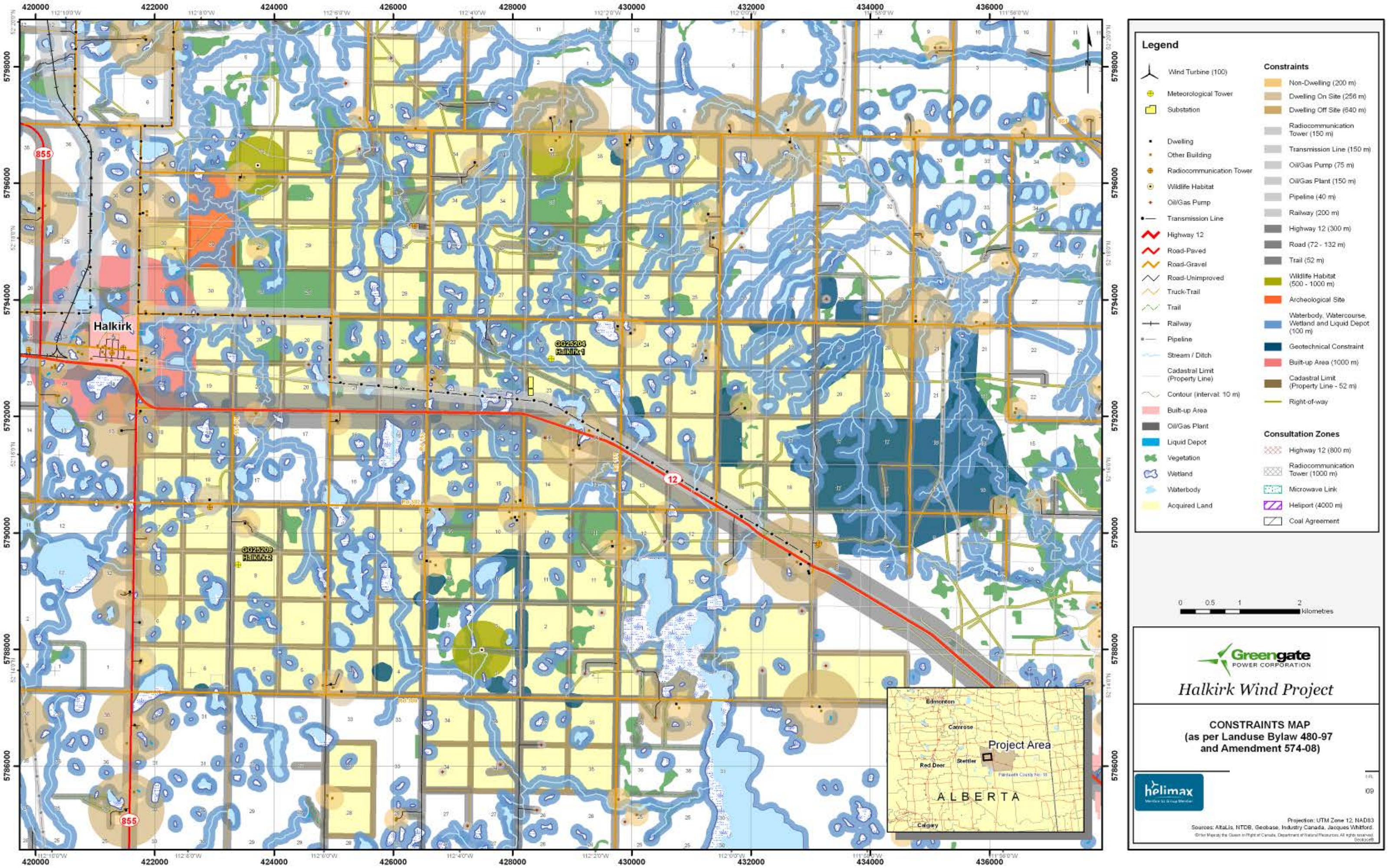
Spatial Analysis Example(1a/5) - Photograph



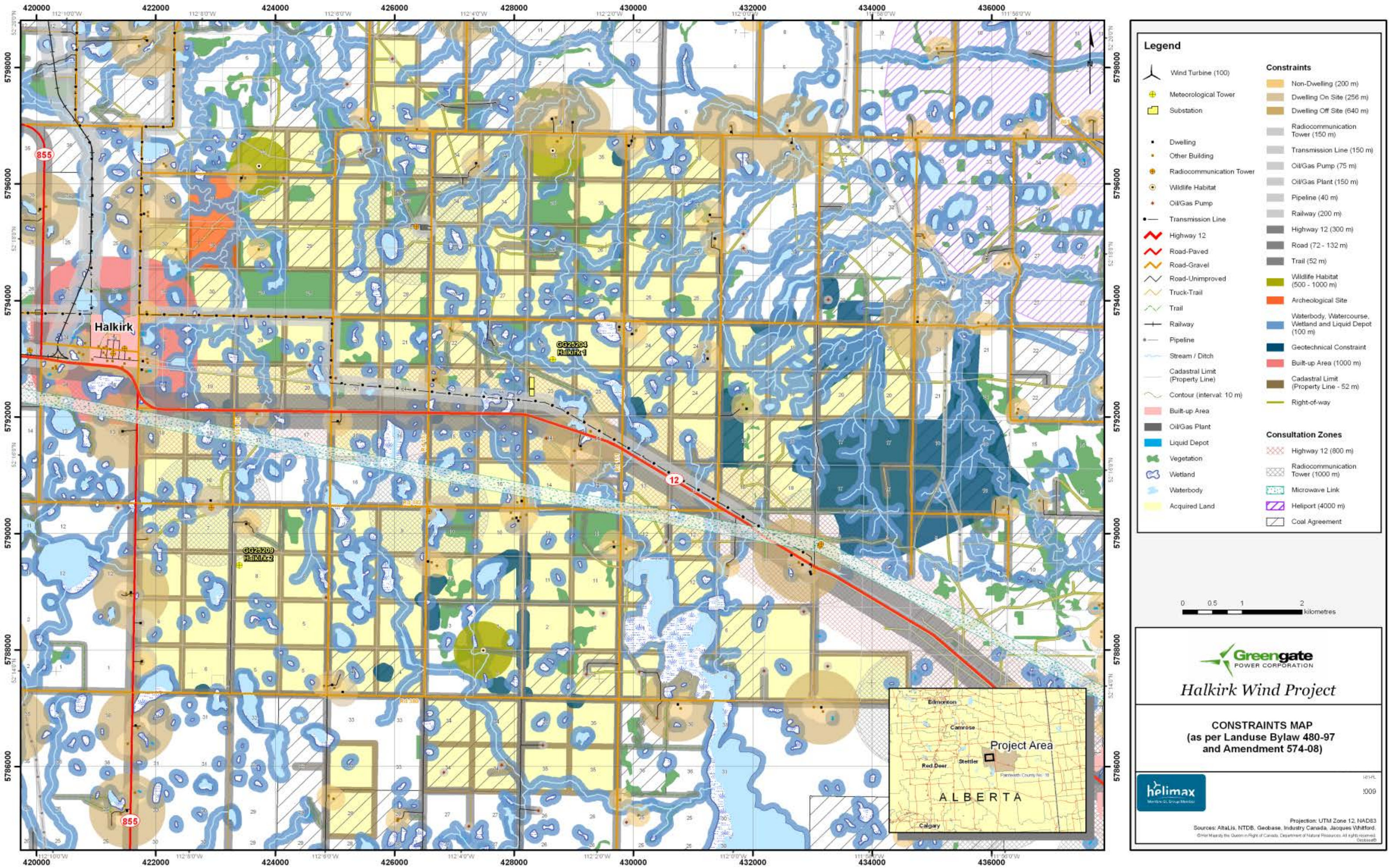
Spatial Analysis Example (2/5) – Human constraints



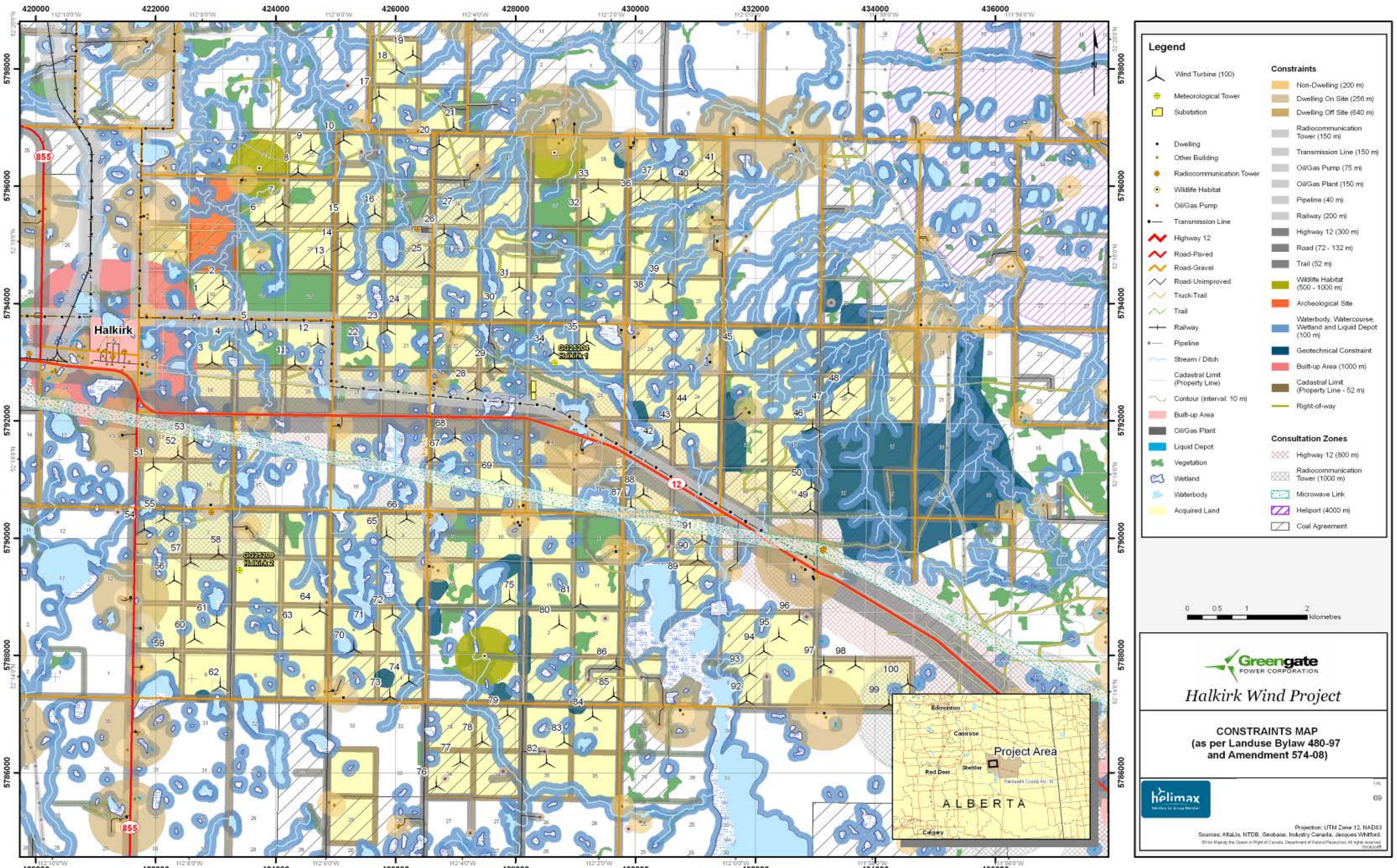
Spatial Analysis Example (3/5) – Biophysical constraints



Spatial Analysis Example (4/5) – Consultation zones



Spatial Analysis Example (5/5) – Layout!

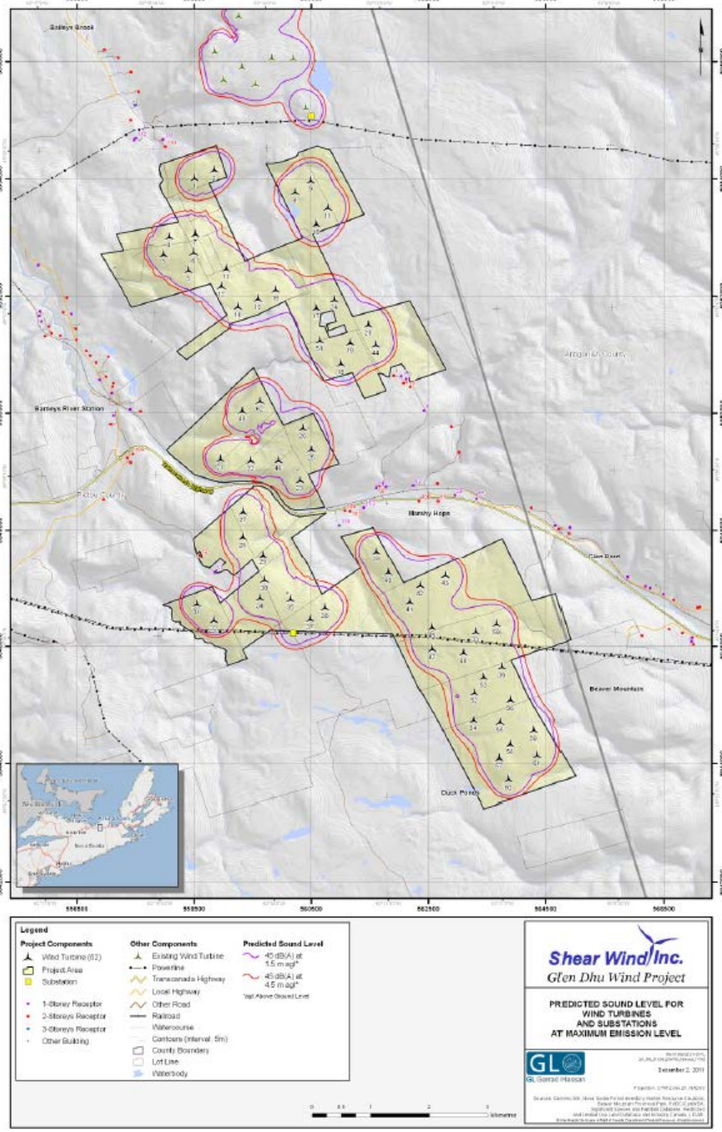


Layout-dependent factors - challenge

Generally relevant to "Acceptance" category above. Typically

- Noise
- Shadow flicker
- Visual influence (ZVI)

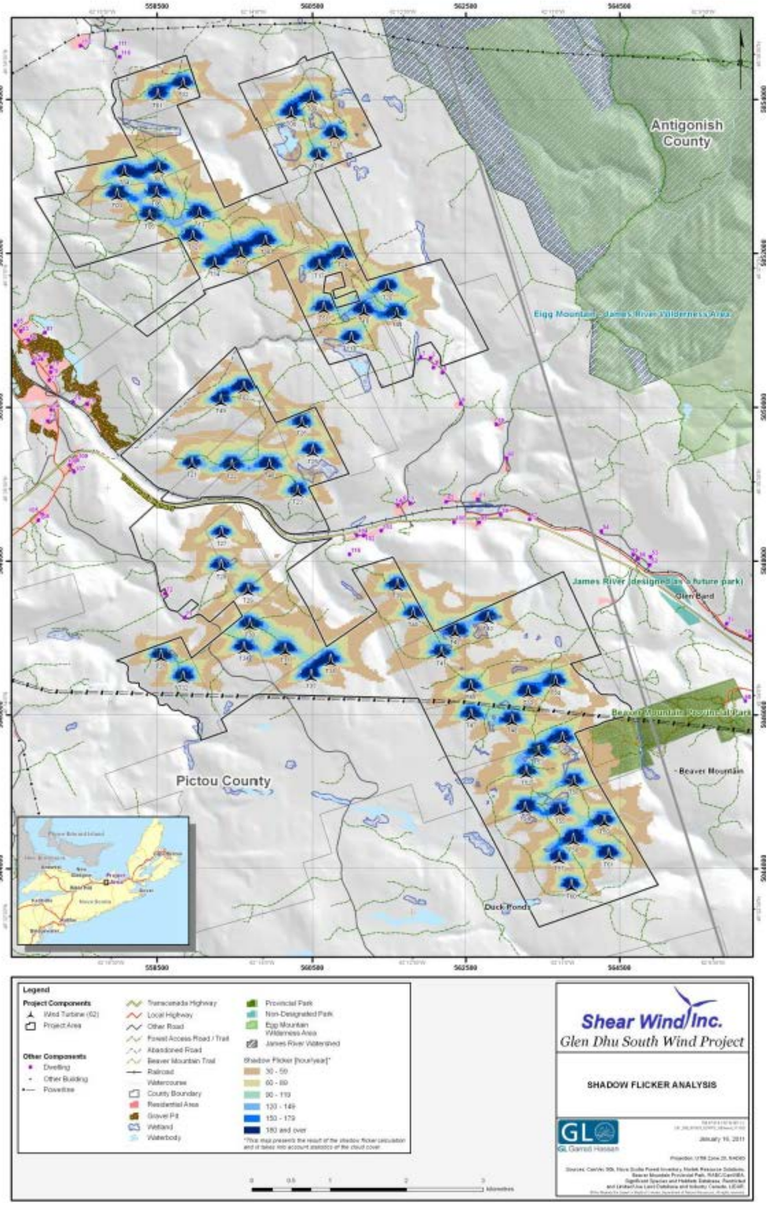
May include effects of other facilities that are planned or already in existence.



Layout-dependent factors - approaches

- Early stage assessments of these factors with various turbine and layout options under consideration to check for compliance with relevant regulations;
- Monitor ongoing changes to the applicable regulations during the project development process up to final approval.
- Local engagement;

Make conservative assumptions at the early stages to try to avoid forced changes later on – layout changes may involve penalties.



Financial aspects of layout optimization - challenge

Relevant to the "Yield/Financial Returns" and "Construction and Running costs" categories above.

- For the same number of turbines, a more spread-out layout could offer higher yields through lower wake losses owing to more widely-spaced turbines and more potential to use the "best" bits of terrain in the area.

But.. More widely spread turbines require longer access roads and cabling, which implies increased costs:

- Construction;
- Maintenance;
- Compensation to land owner.

Financial aspects of layout optimization - approaches

A full financial optimization would be highly involved:

- Highly detailed cost information (both fixed and layout-dependent)
- Optimal BOP design and costing
- Yield and revenue for full life cycle

.. and for this to be calculated for each iteration

- Computational optimization possible with some simplification
- Apply experience-based estimates for construction and maintenance costs with reasonably design assumptions to assess the relative benefits of a layout.

Layout Yield optimization - challenge

In light of fixed and layout-dependent factors and constraints, and local wind climate, position required number of turbines to maximize topographic advantages whilst minimizing energy loss and elevated turbulence levels from wakes, thus achieving maximum energy output.

- Accurate knowledge of wind resource and its variation across the site
- Turbine suitability

Layout Yield optimization - approaches

- Good wind measurements – sufficient and representative
- Accurate flow modelling
- Address turbine suitability through simple spacing principles etc. at this stage (detailed load calculation necessary at some point)

Computational optimization – iterative layout revisions to maximise yield.

- Useful if you have a fairly constraint-free area in fairly simple terrain with good measurements and reliable flow modelling.

Manual layout design

- Depending on other constraints, layout may be effectively fixed.
- May wish to compare with computational results as a check

Layout Yield optimization – flow modelling example

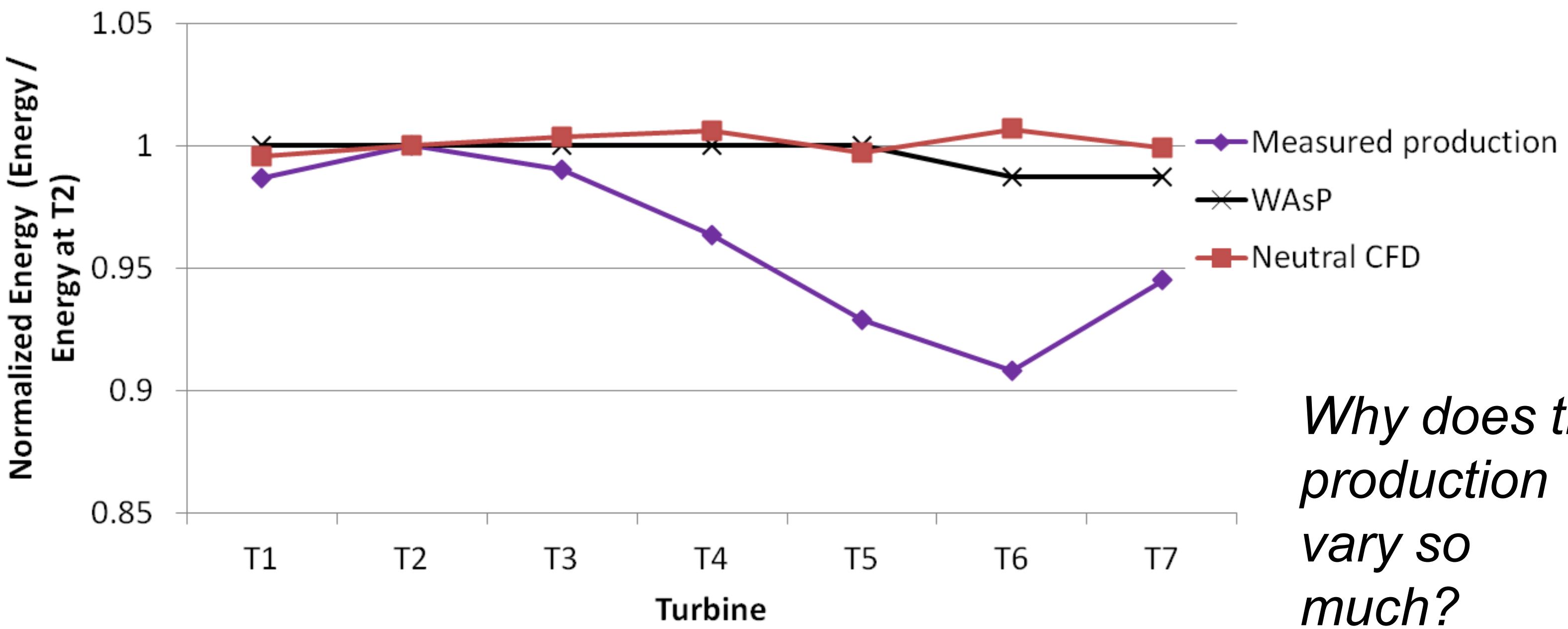
Research suggests that stable atmospheric conditions:

- Exhibit significantly different flows from neutral or unstable conditions;
- Are poorly modelled by WAsP or CFD assuming neutral conditions

GL GH continues to develop our STAR-CCM+ CFD system, and the difficulties in modelling stable conditions were investigated.

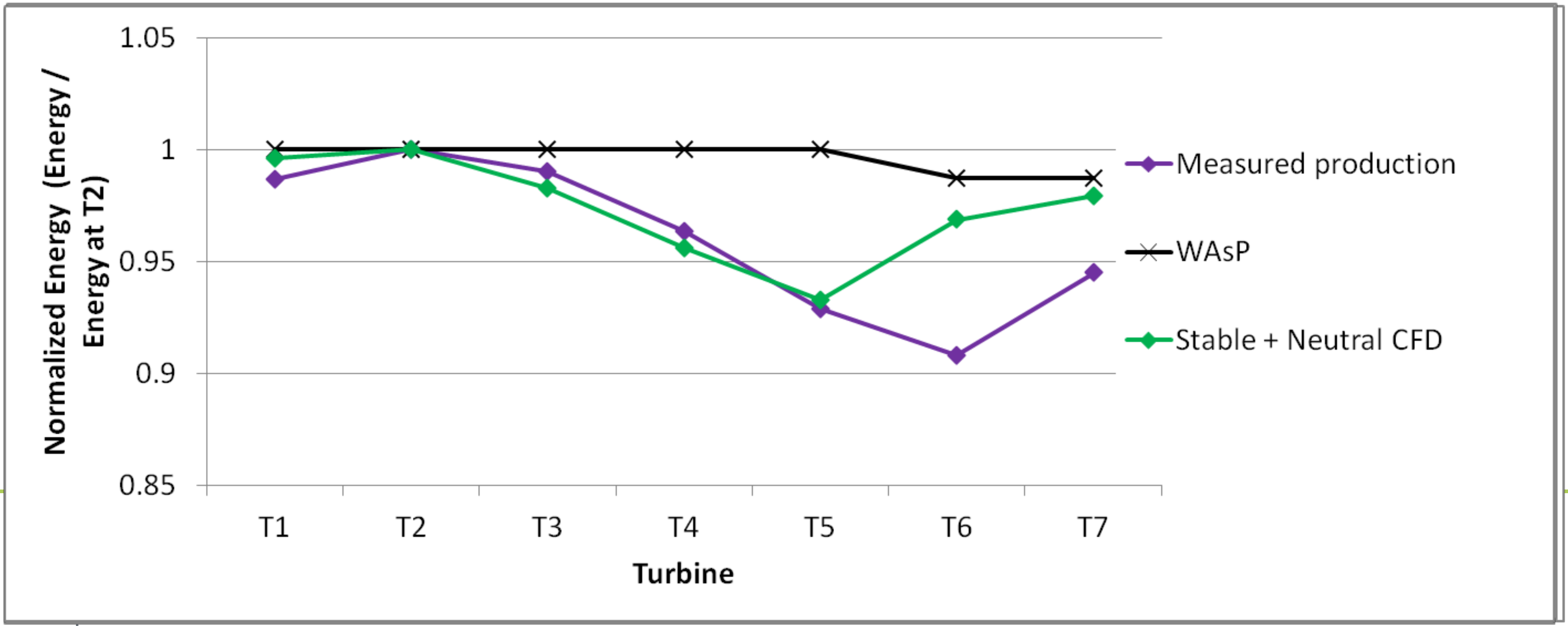
- Turbulence, shear or temperature lapse rate used as proxies for stability.
- Modelling results validated against wind measurements and wind farm production data

A “flat” site in the US Northern Plains



Why does the production vary so much?

Results with Buoyancy term



Thank you!

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