Limnological Research Station
Department of Hydrology
University of Bayreuth

Impact of 90 years of drainage on the hydrology and subsurface biogeochemistry of a northern peatland

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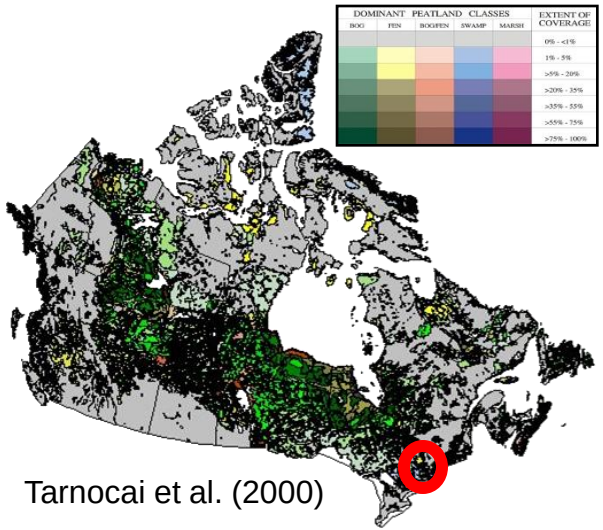
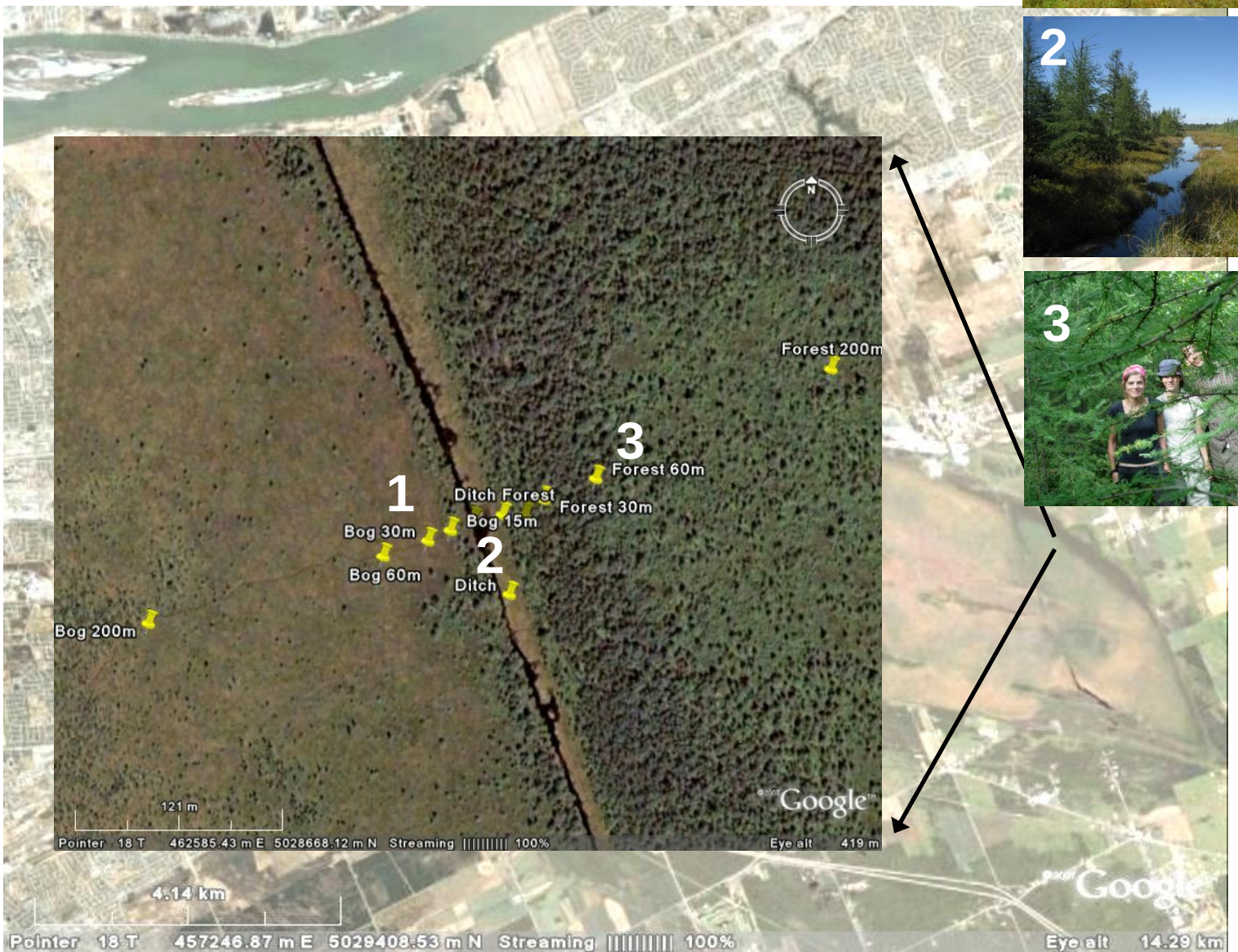


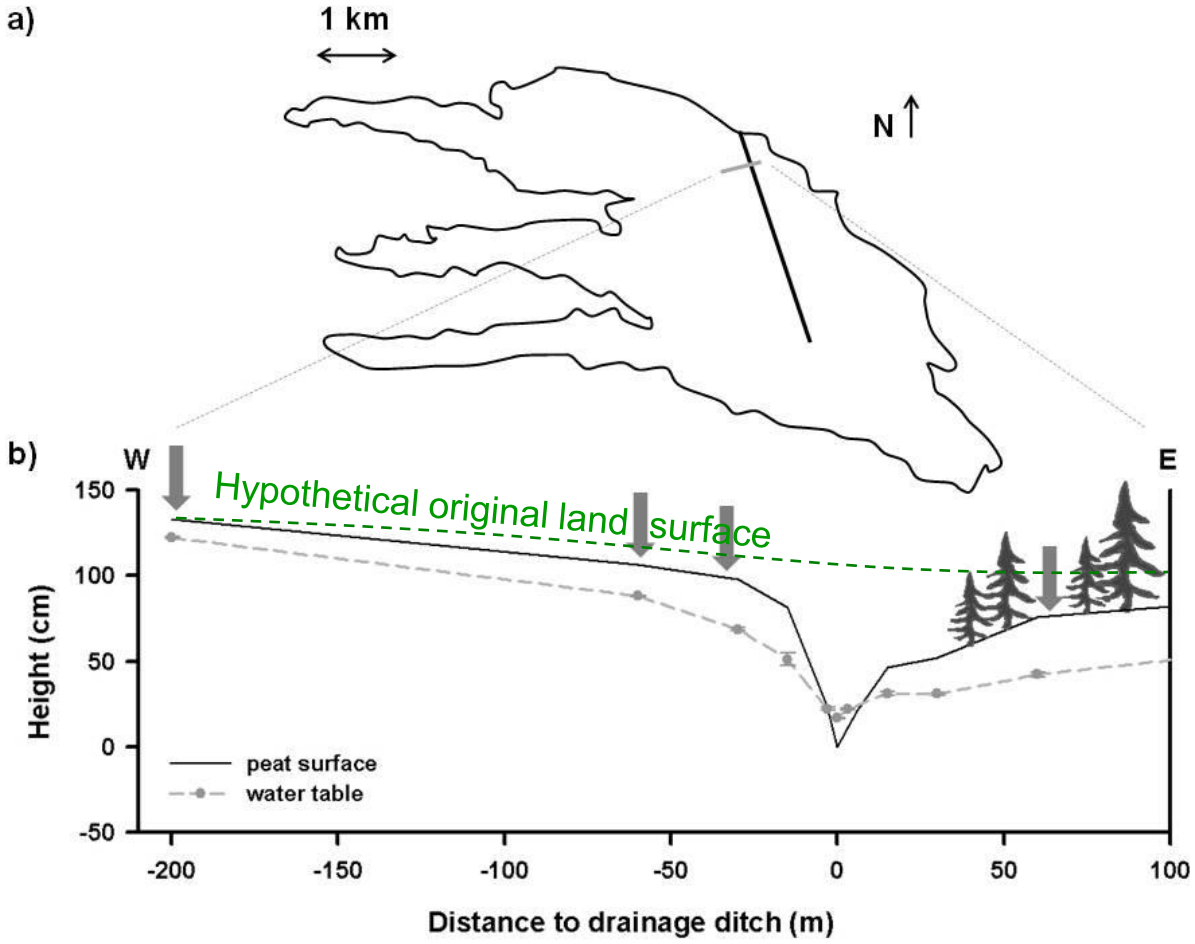
Tarnocai et al. (2000)

Ecohydrology and biogeochemistry



Impact of drainage on below ground carbon biogeochemistry

- Peat decomposition degree
- Peat decomposability
- Groundwater analysis & modelling
- Soil gases and solute chemistry
- Incubation experiments to determine controls



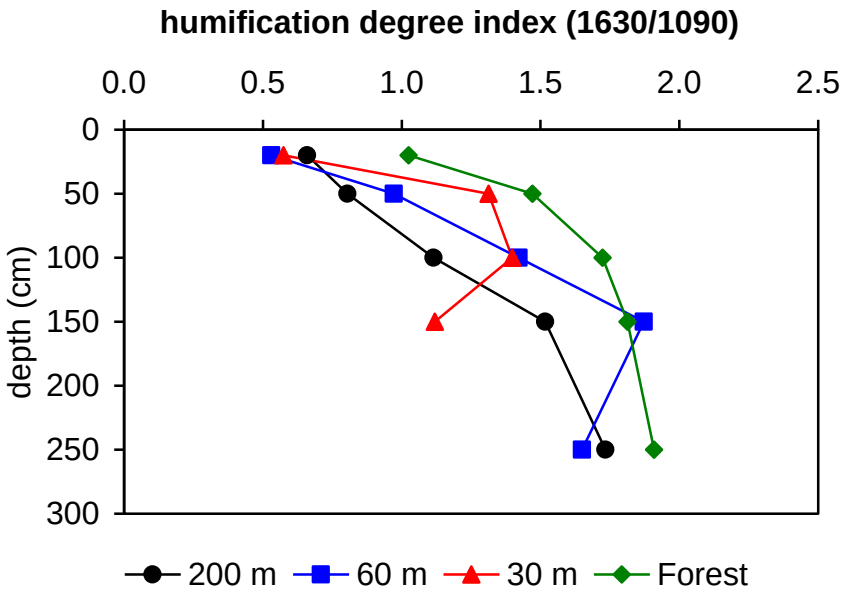
Peat humification

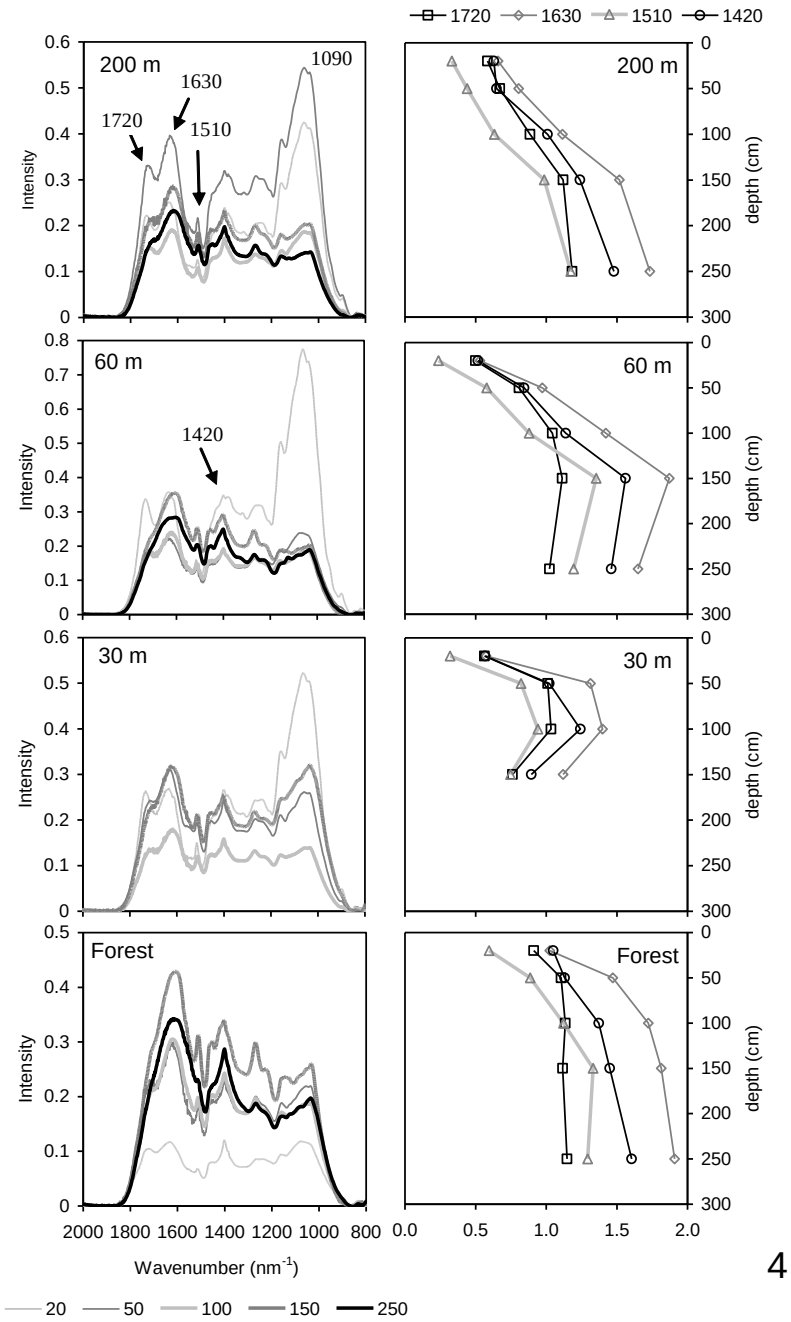
- **Characteristic FTIR band ratios**
  - 1720/1090 carboxylic/polysacharide
  - 1630/1090 aromatic
  - 1420/1090 phenolic
- **Humification**

  ⇒ advances with depth

  ⇒ near ditch

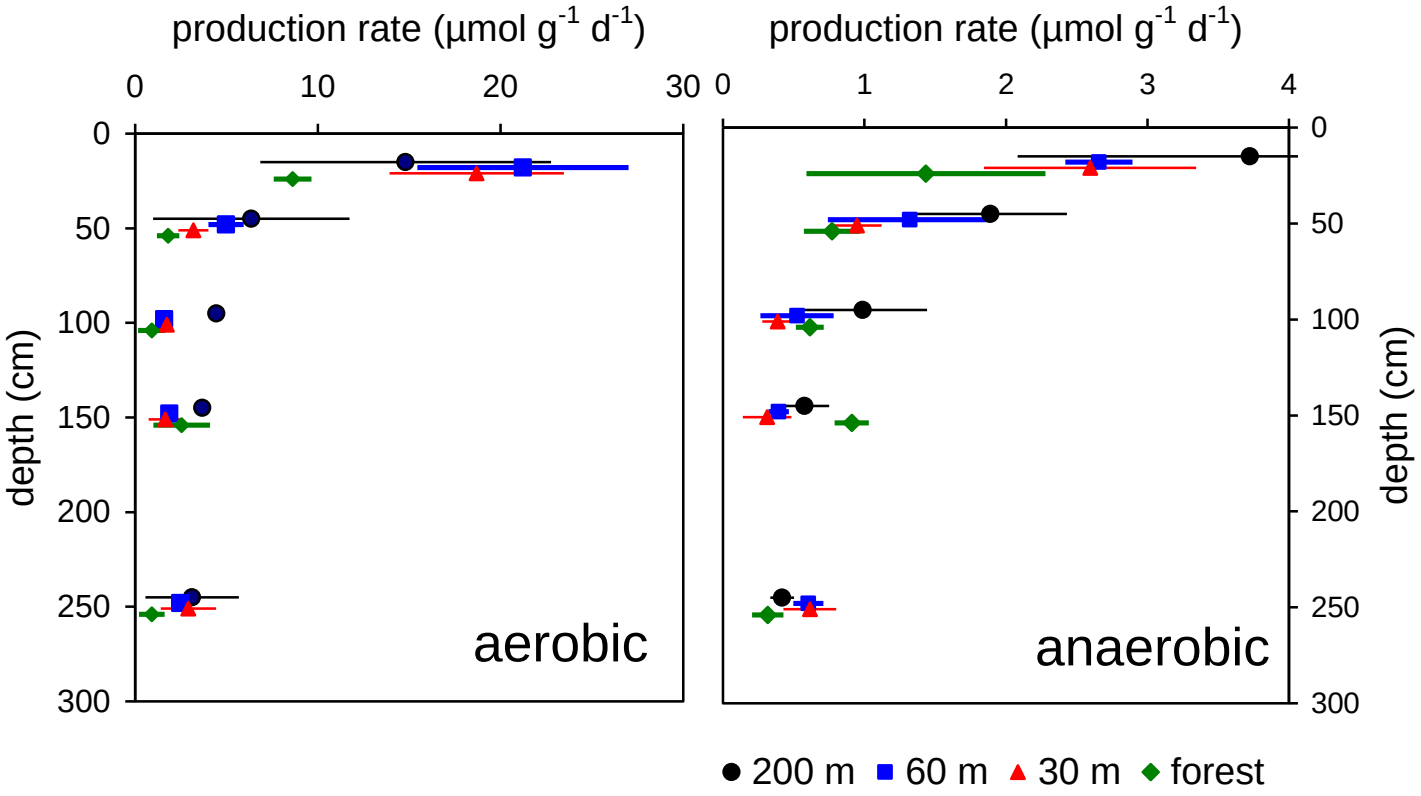
  ⇒ under forest





Blodau, C, Siems, M. (2011) Biogeochemistry.

In vitro respiration



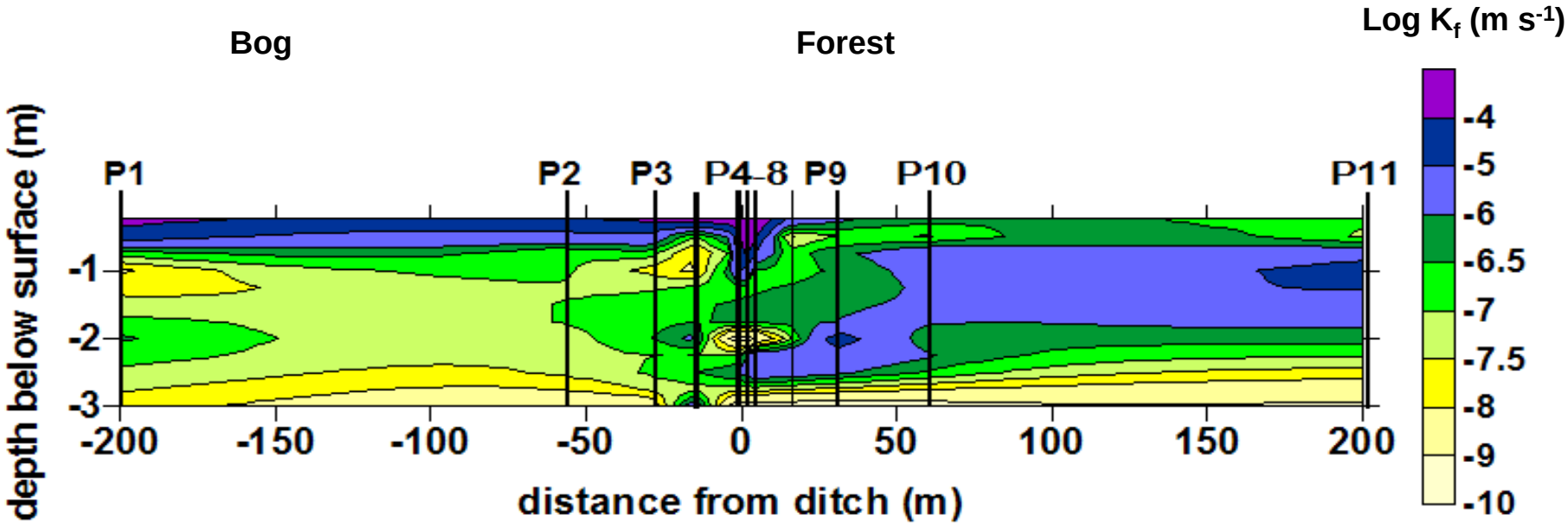
- Peat near ditch and under forest is less ‘decomposable‘
- Advanced humifcation and smaller decomposability deeper than current water table

Blodau, C, Siems, M. (2011) Biogeochemistry.

Hydraulic conductivity

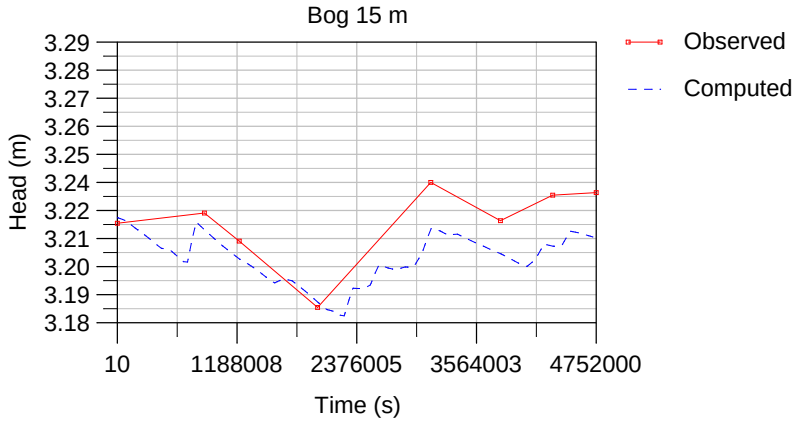
***Slug-tests*:** Hydraulic conductivity strongly altered near ditch and especially under forest

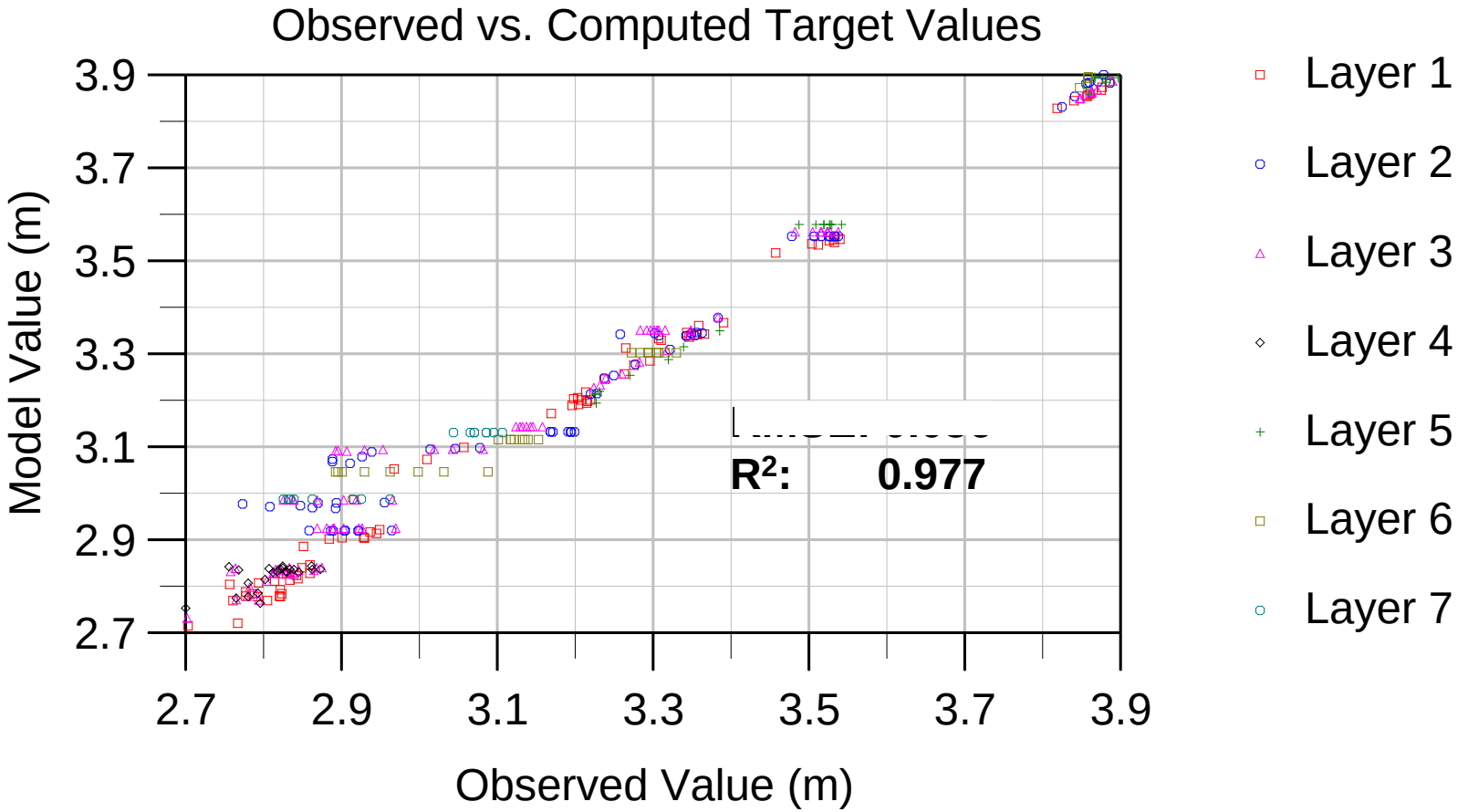
-> inversal of conductivity patterns

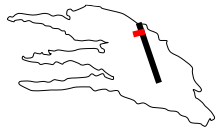


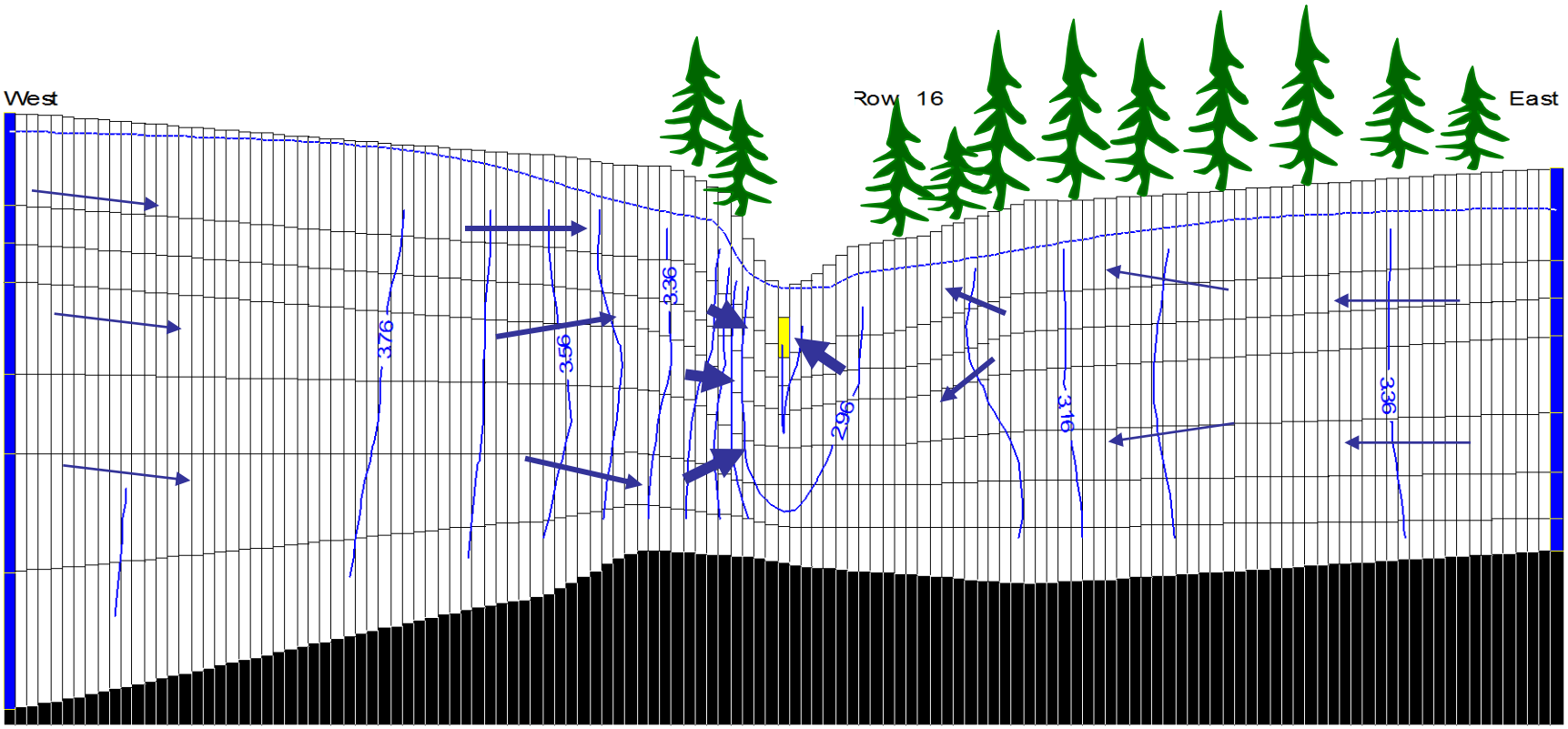
Kopp, B., Fleckenstein, J. Roulet, N.T. Humprehys, E. and Blodau, C. (2011) Hydrologic Processes , in revision.

Groundwater flow modelling

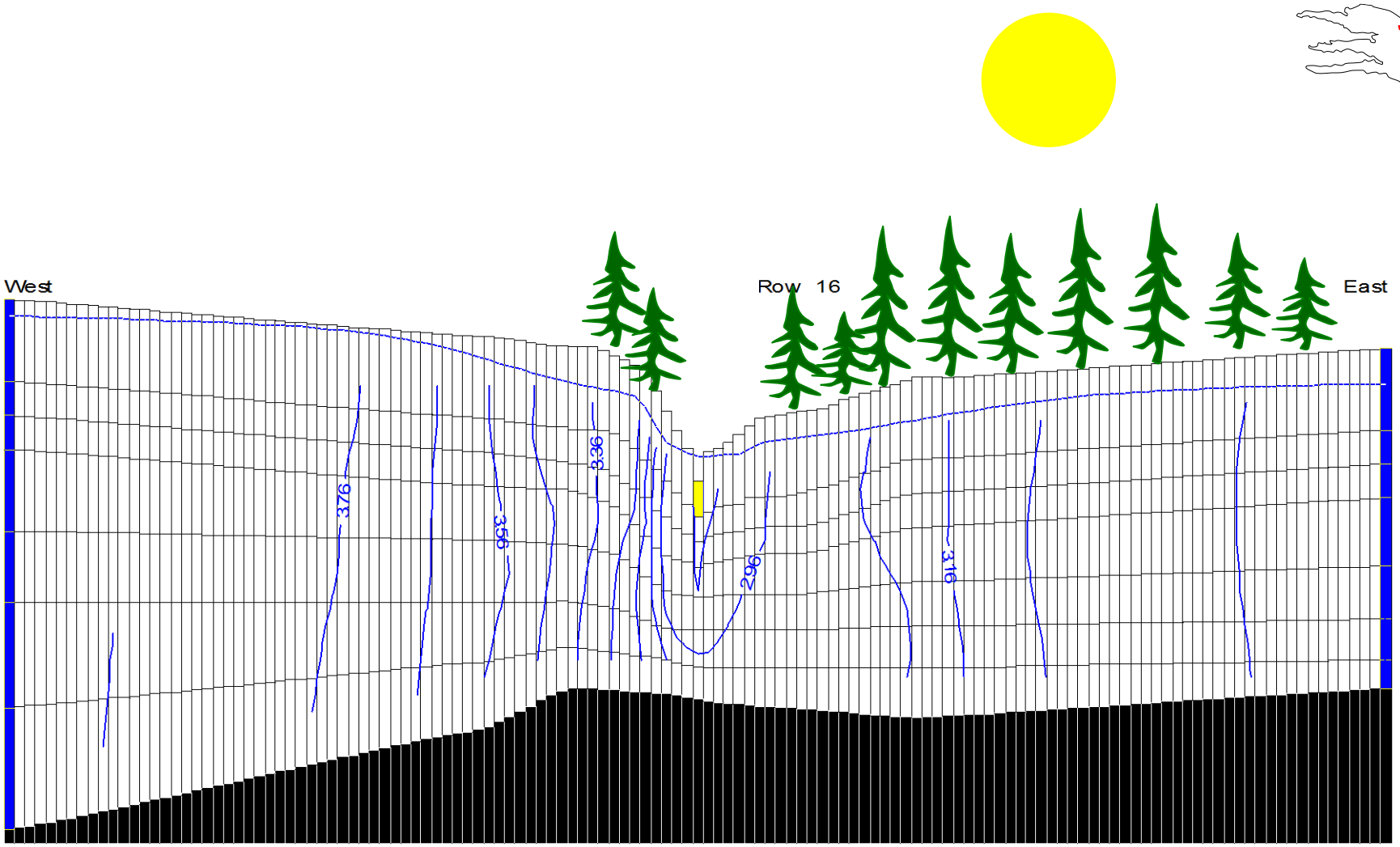








Assumed Steady State



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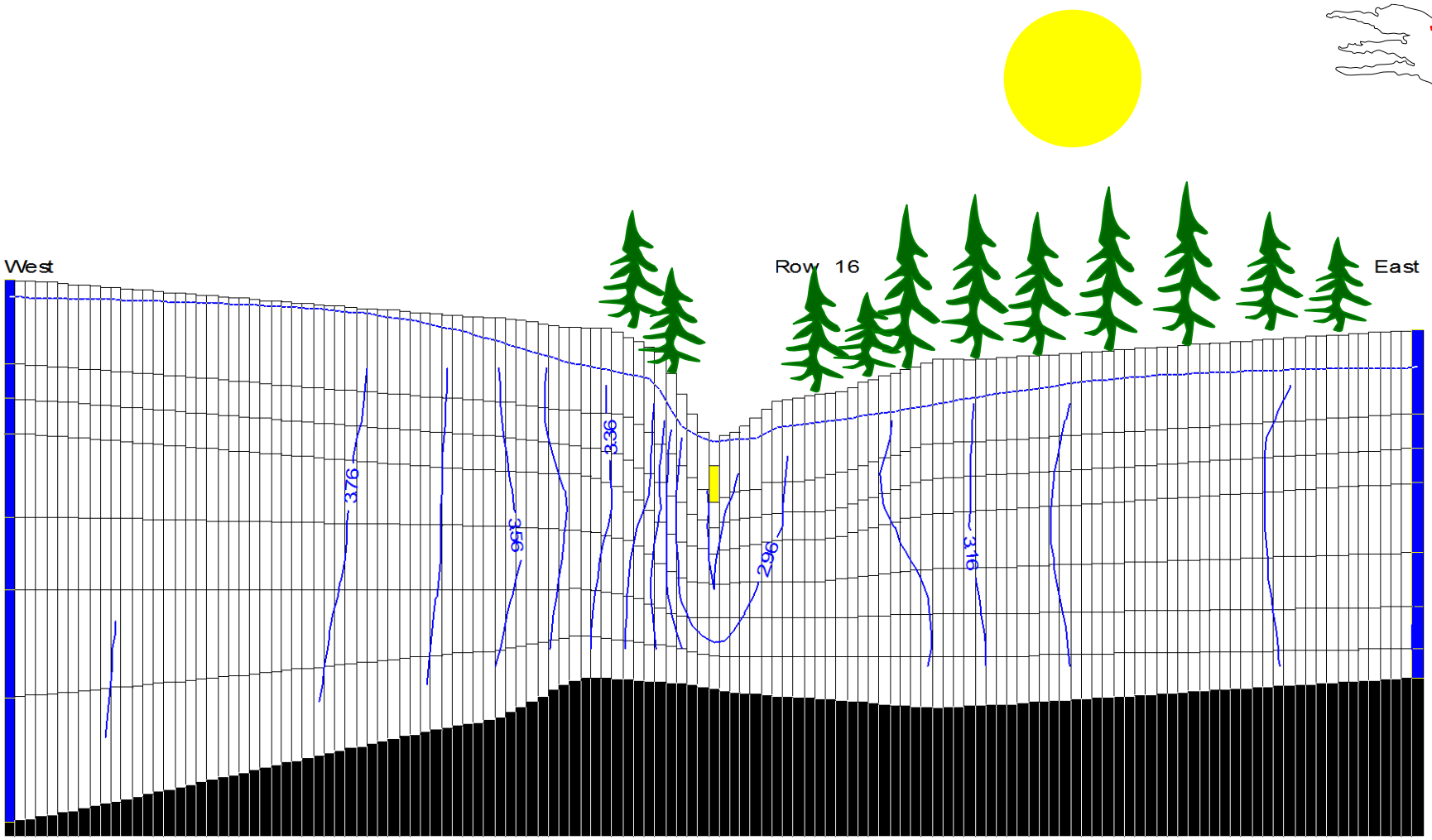

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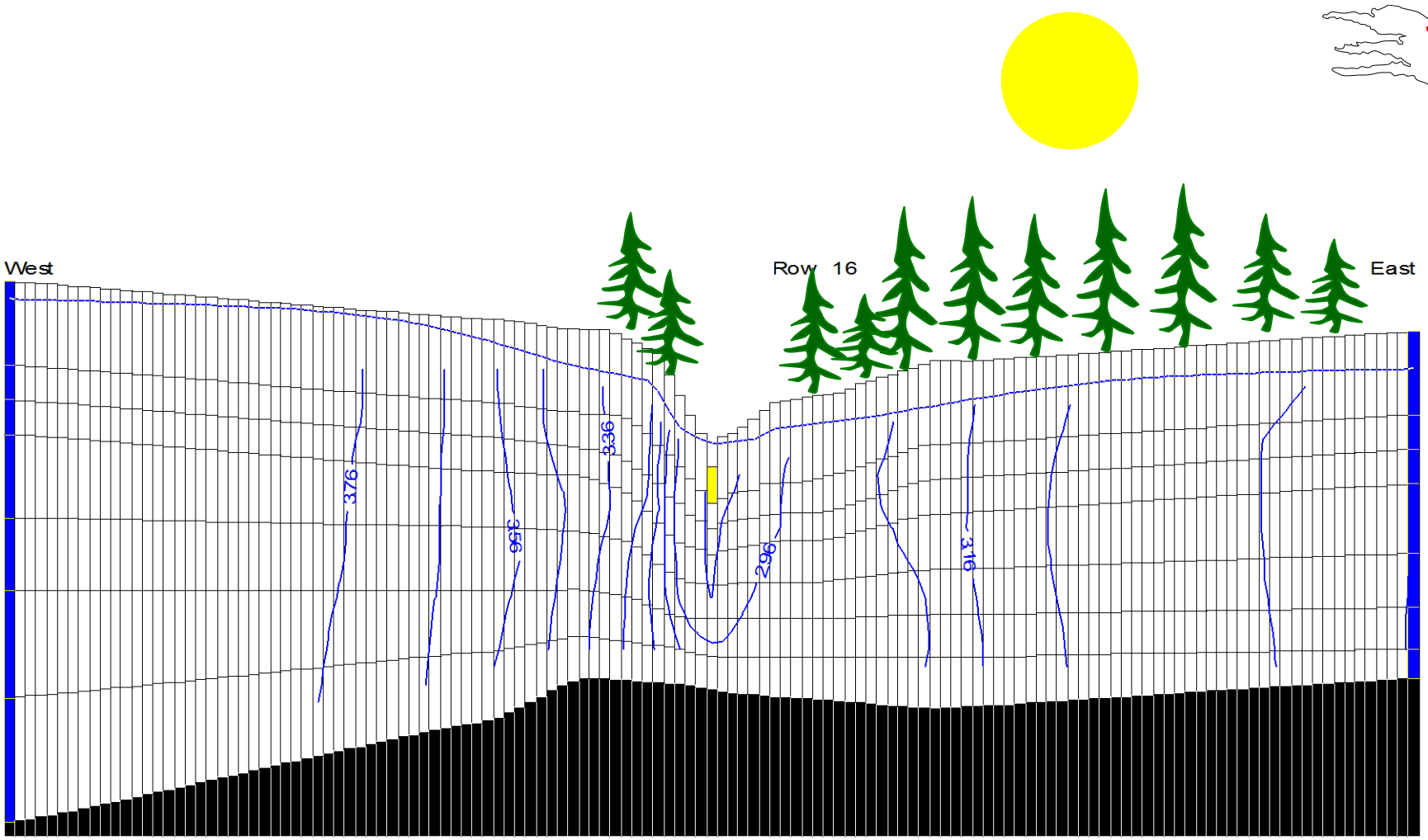

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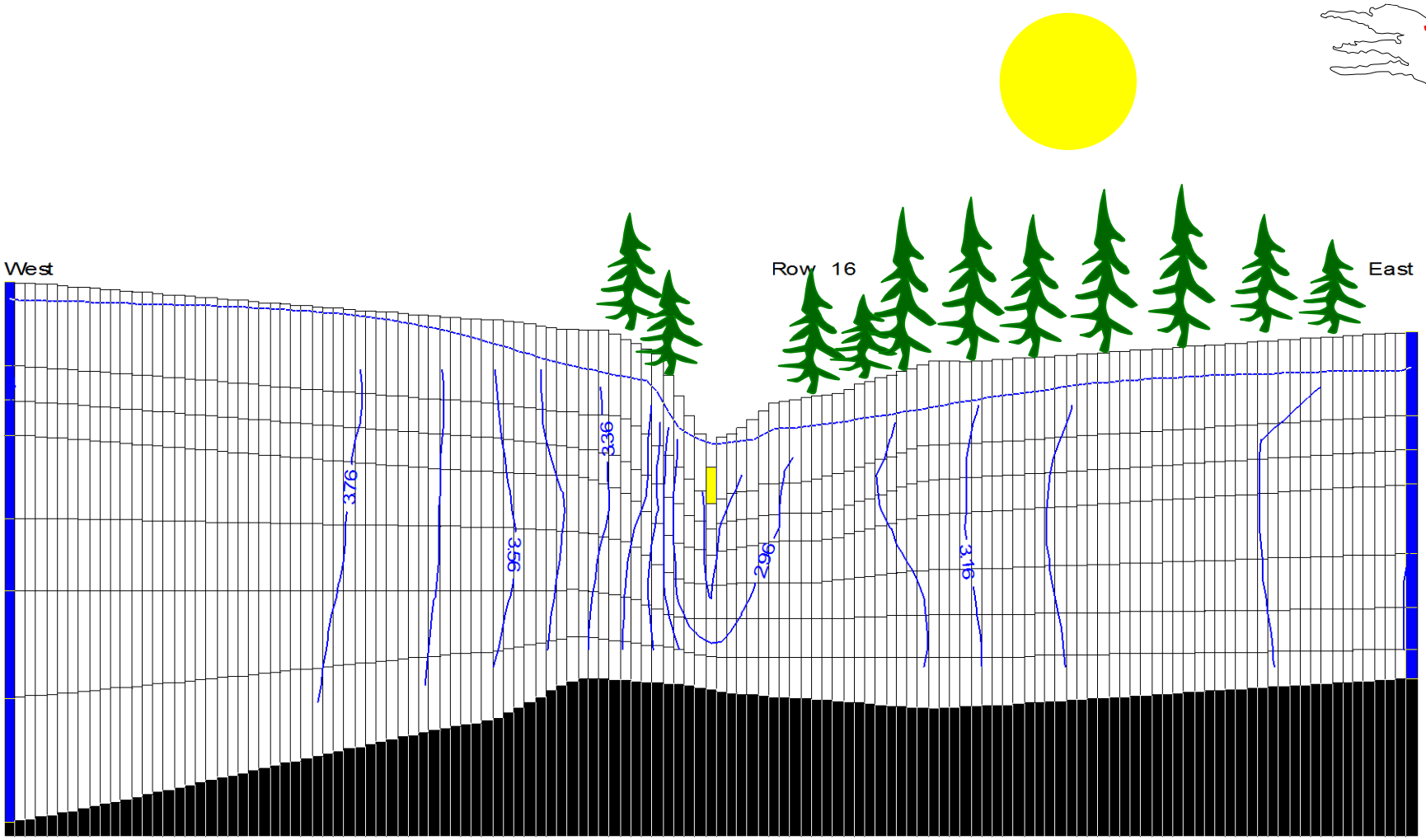

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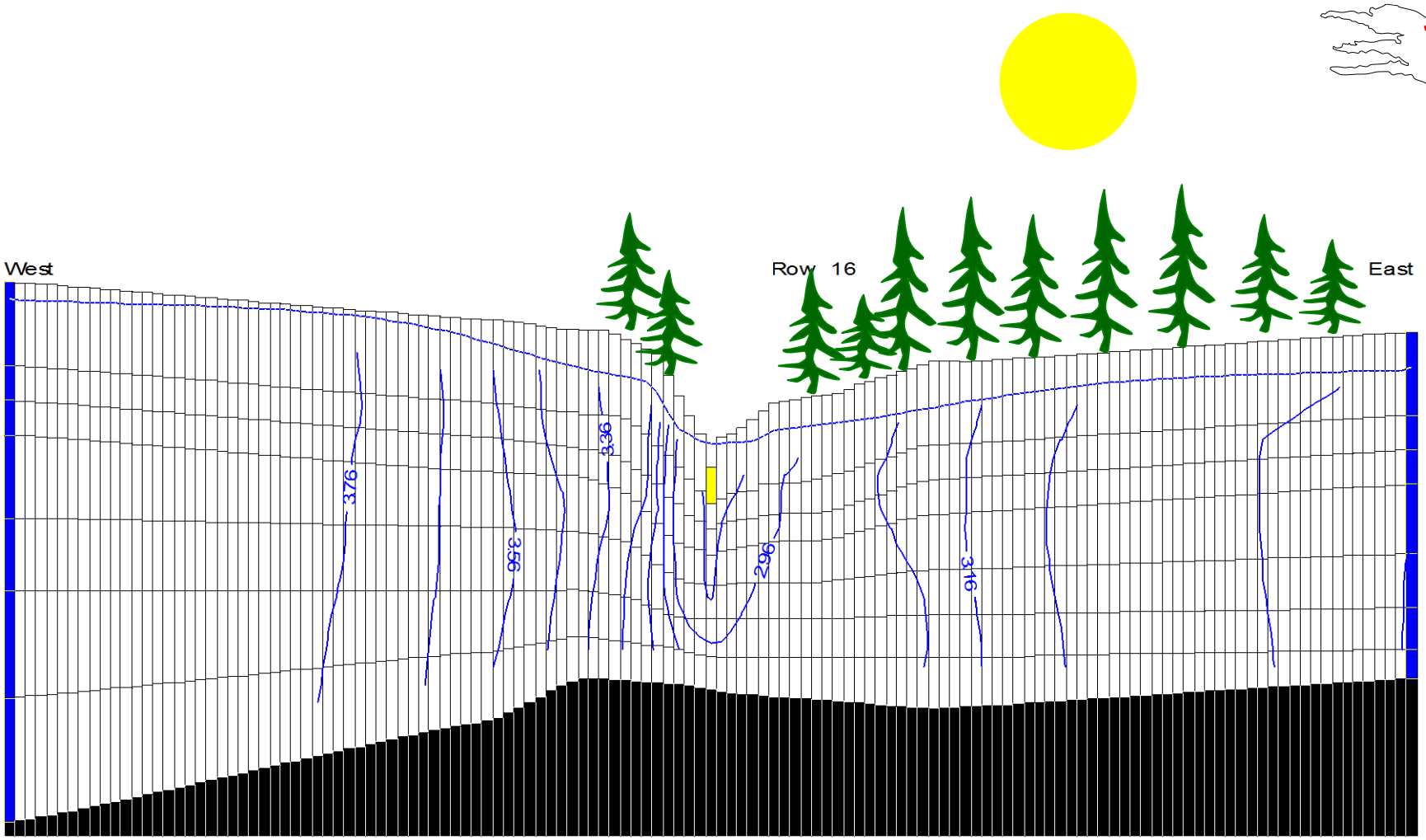

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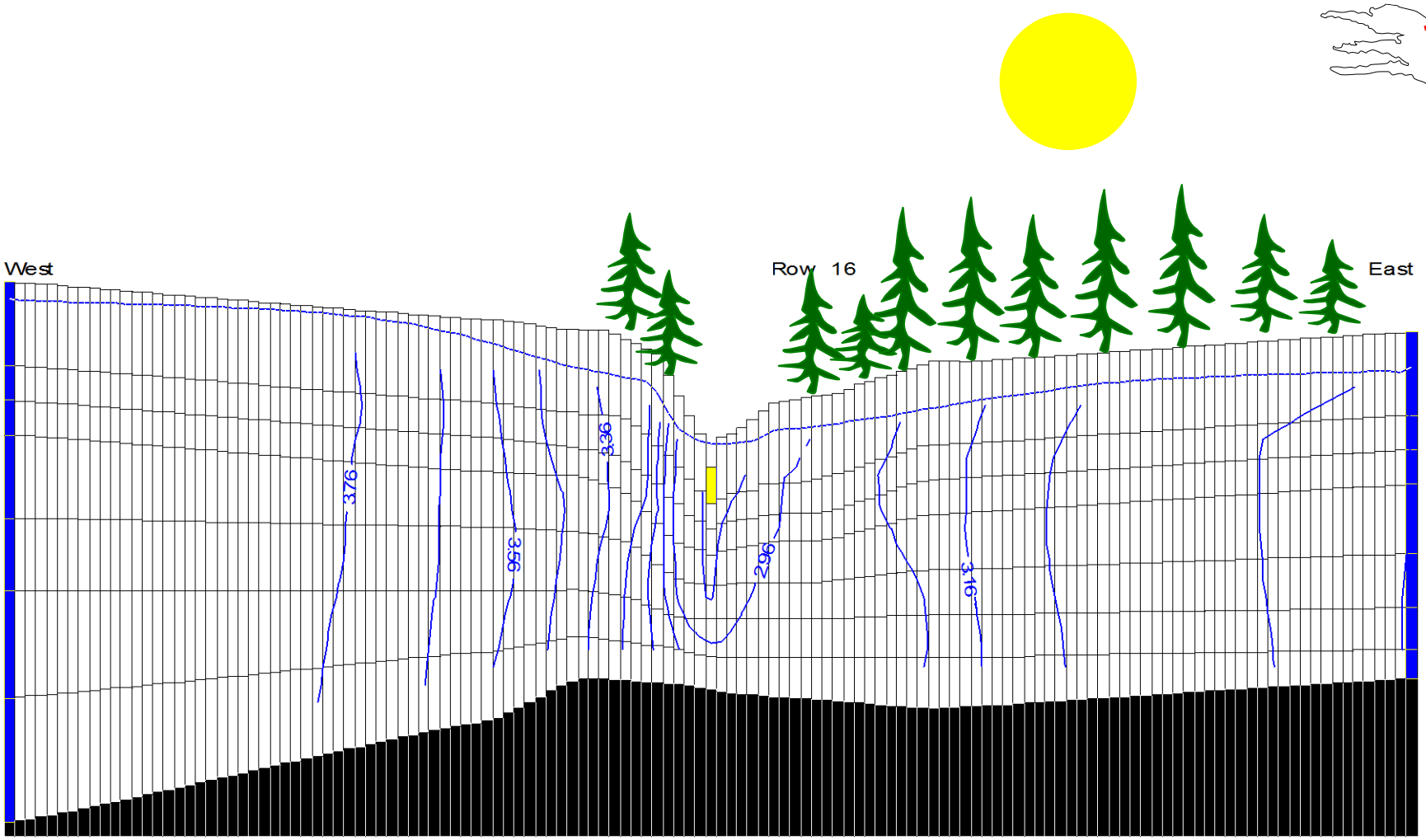

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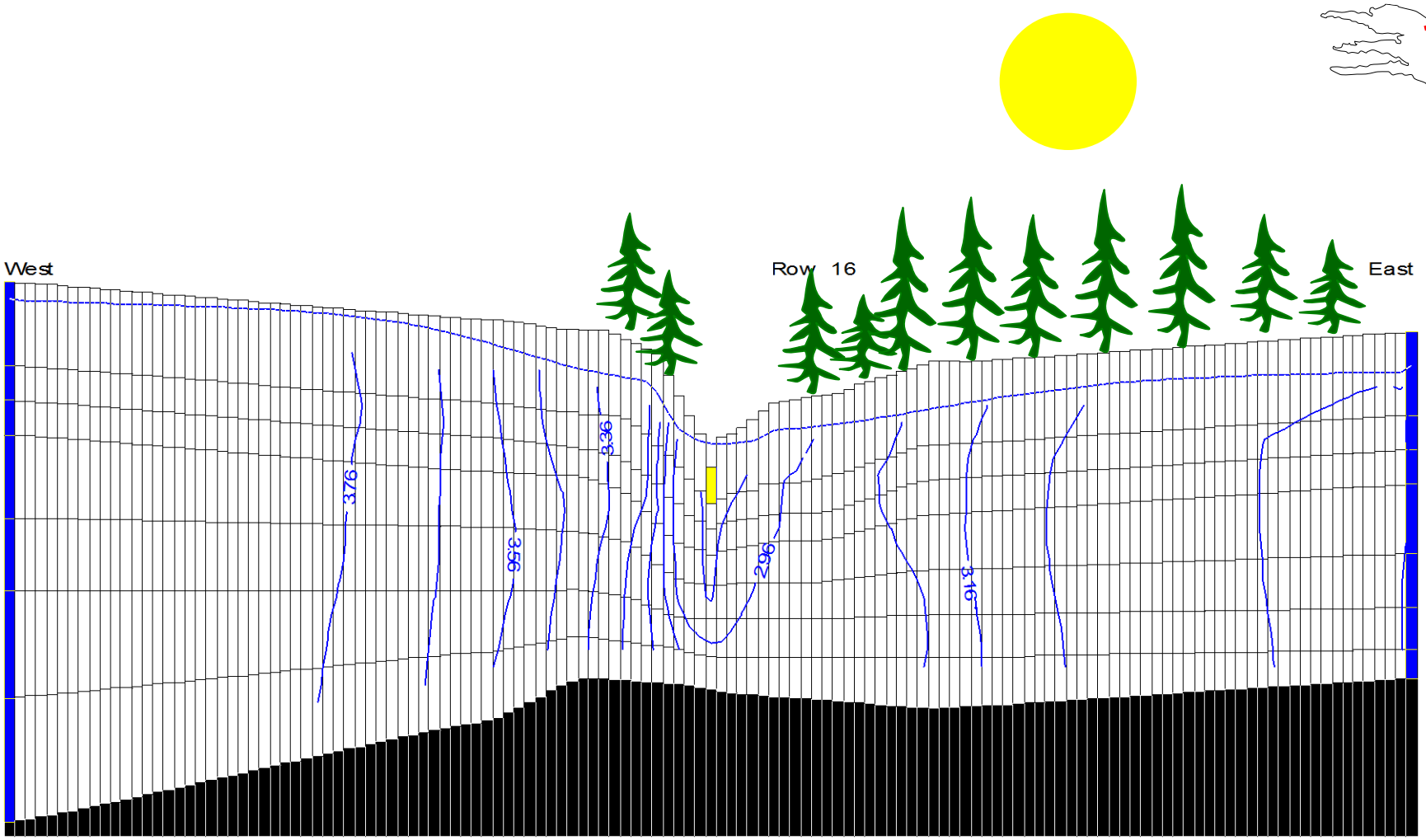

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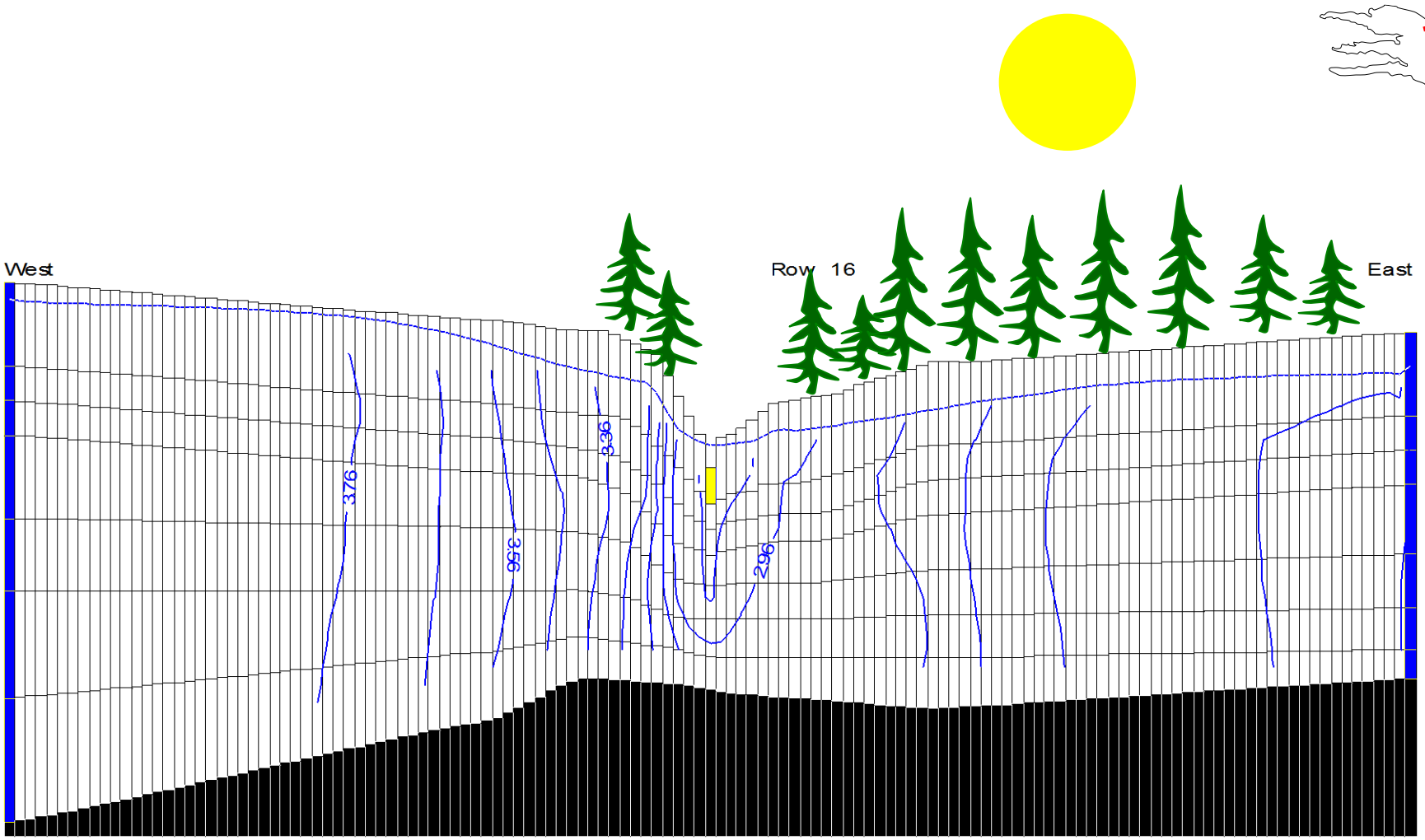

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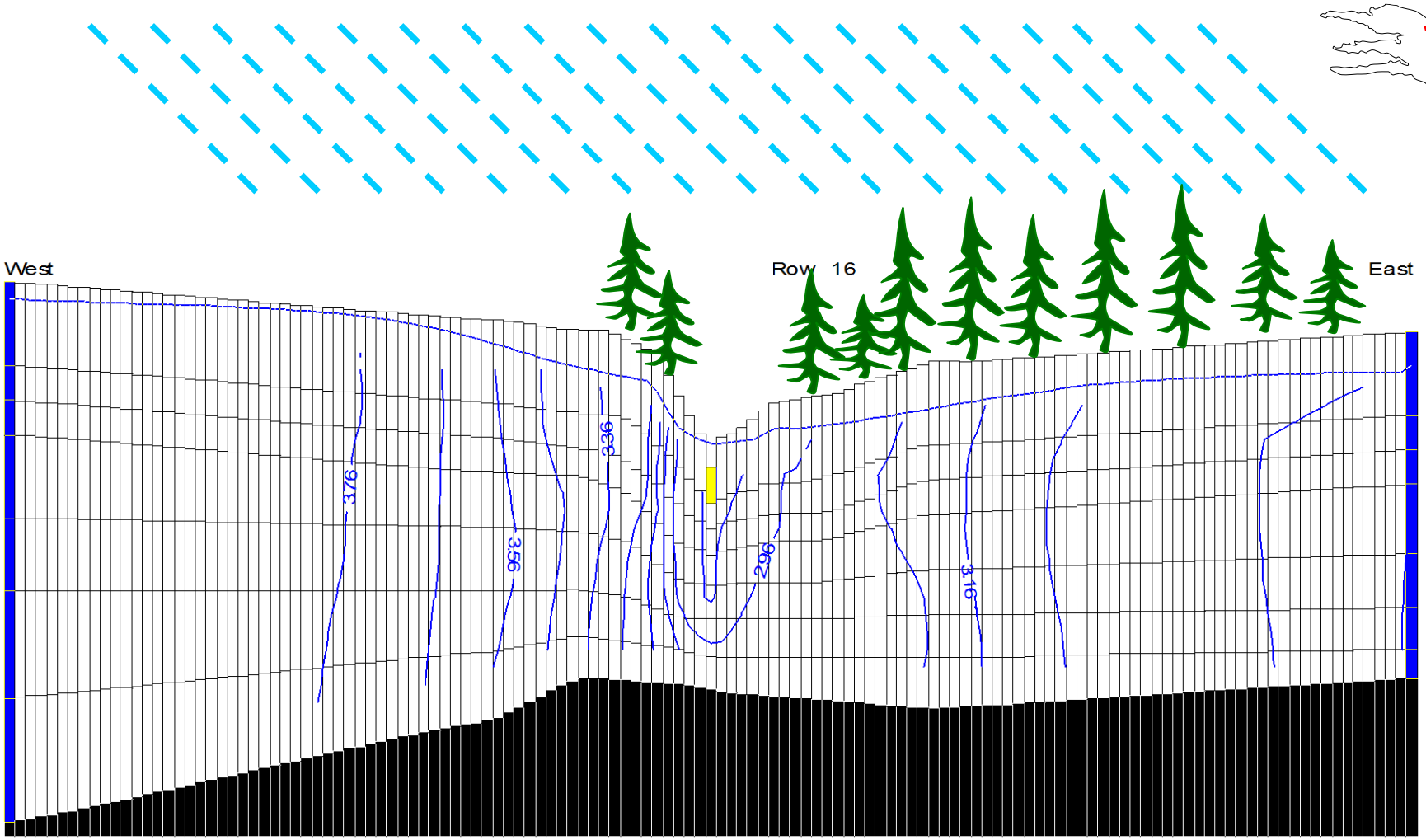

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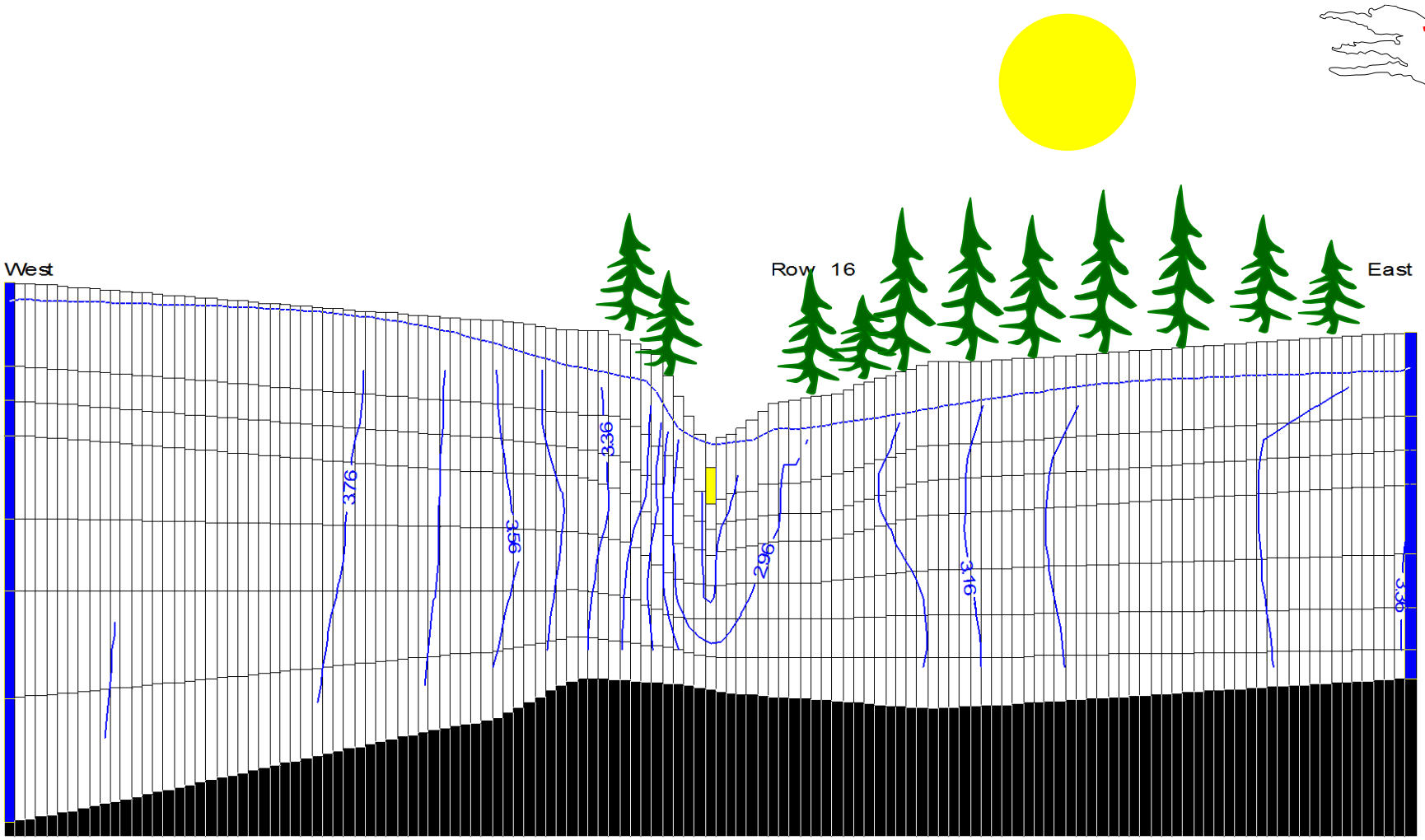

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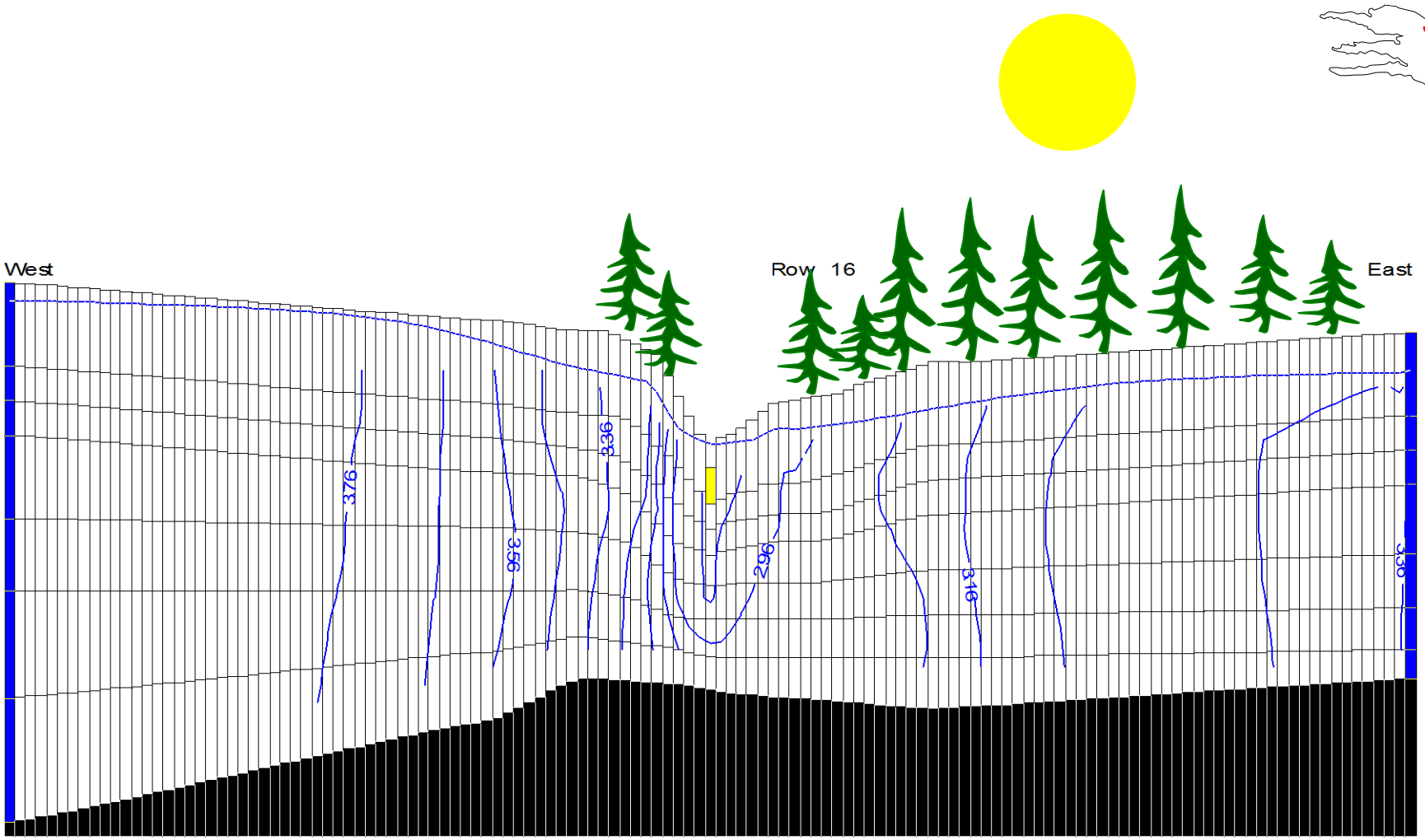

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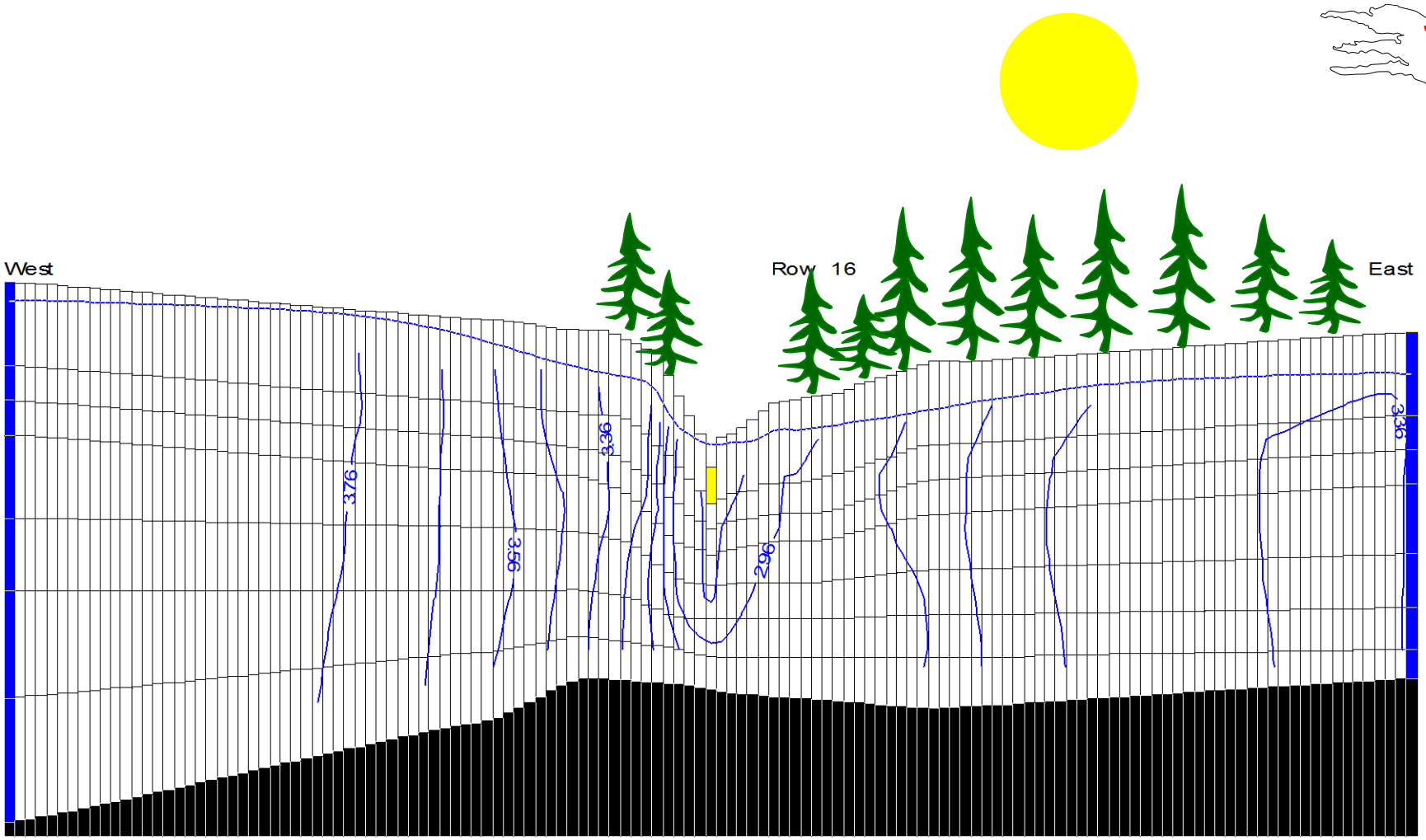

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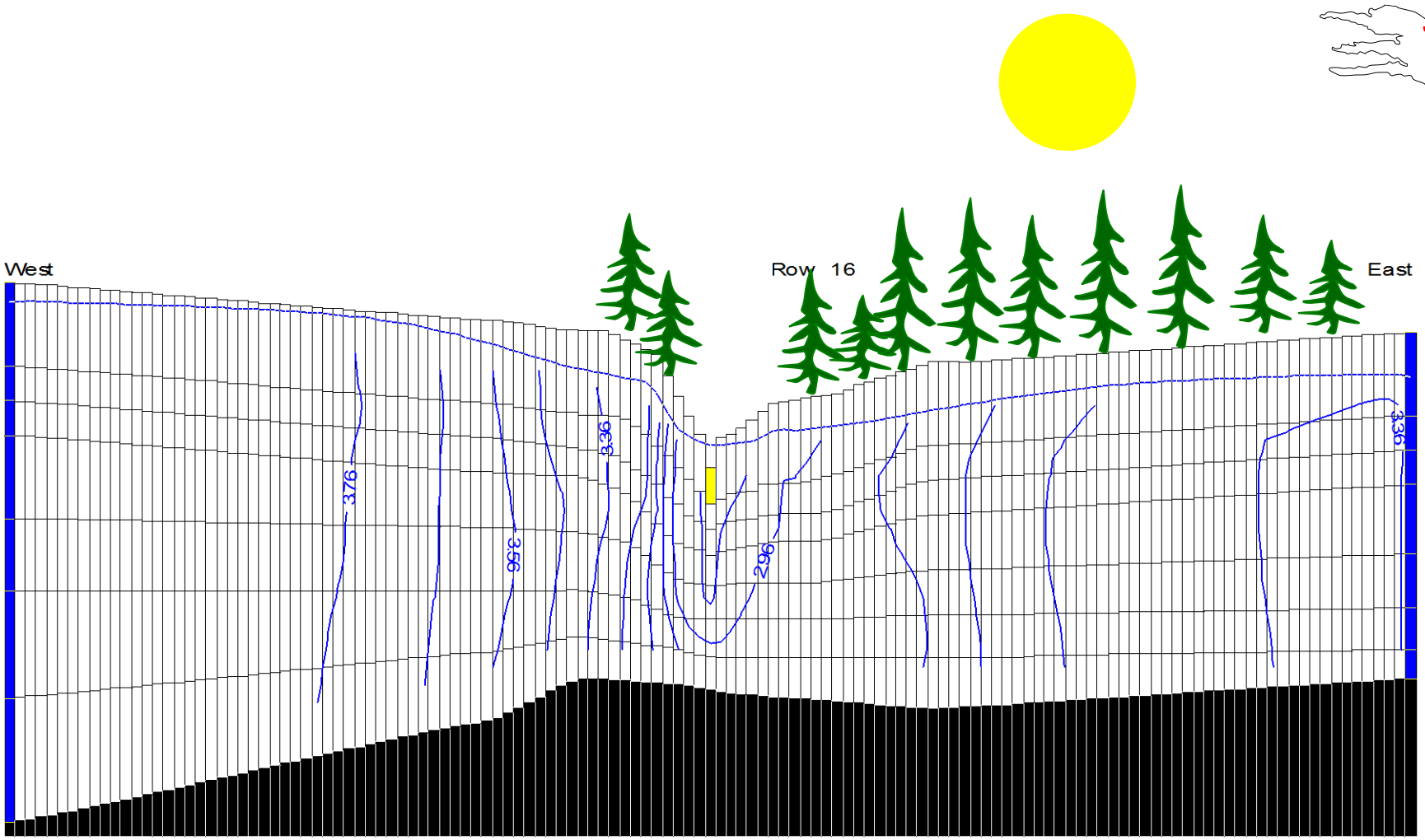

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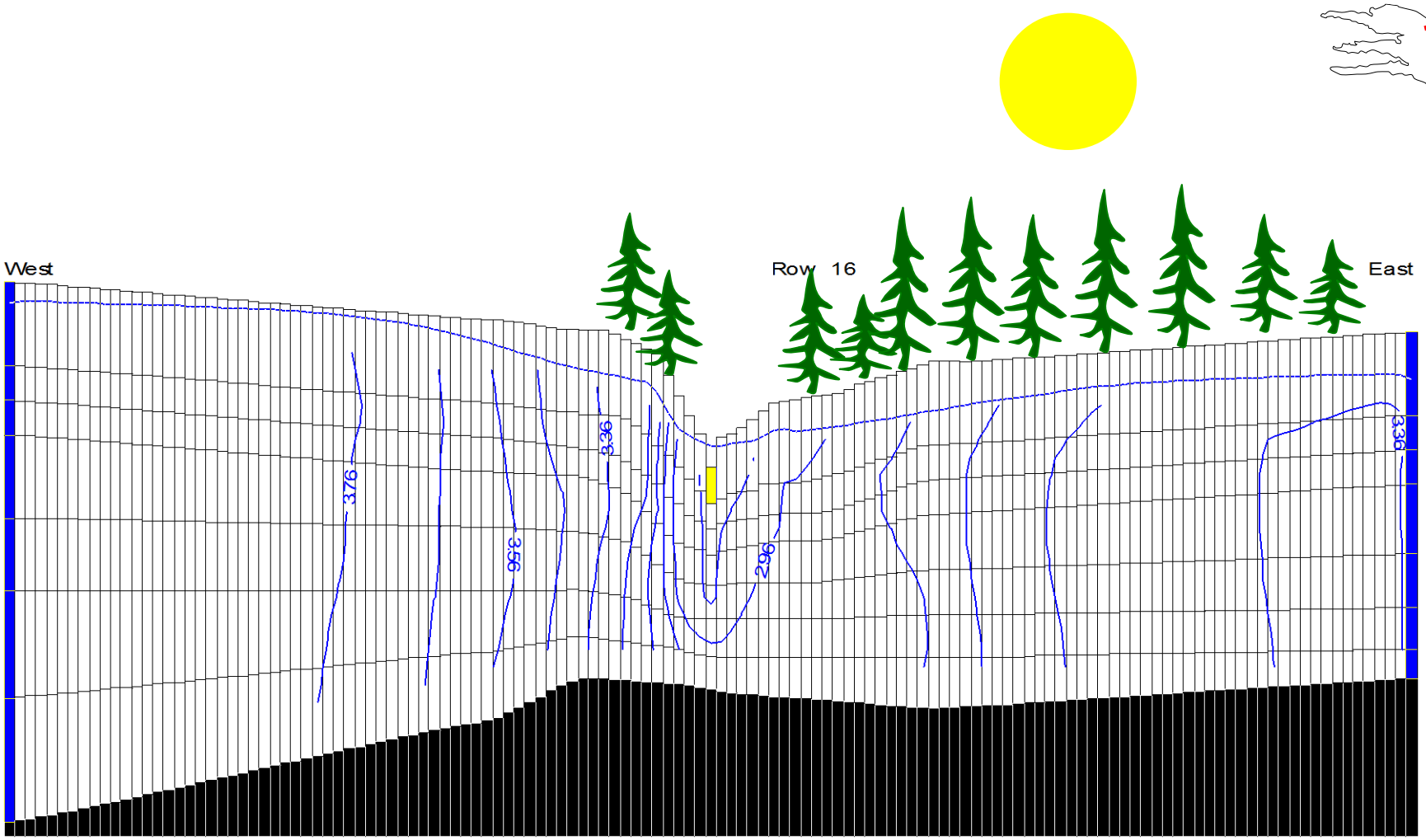

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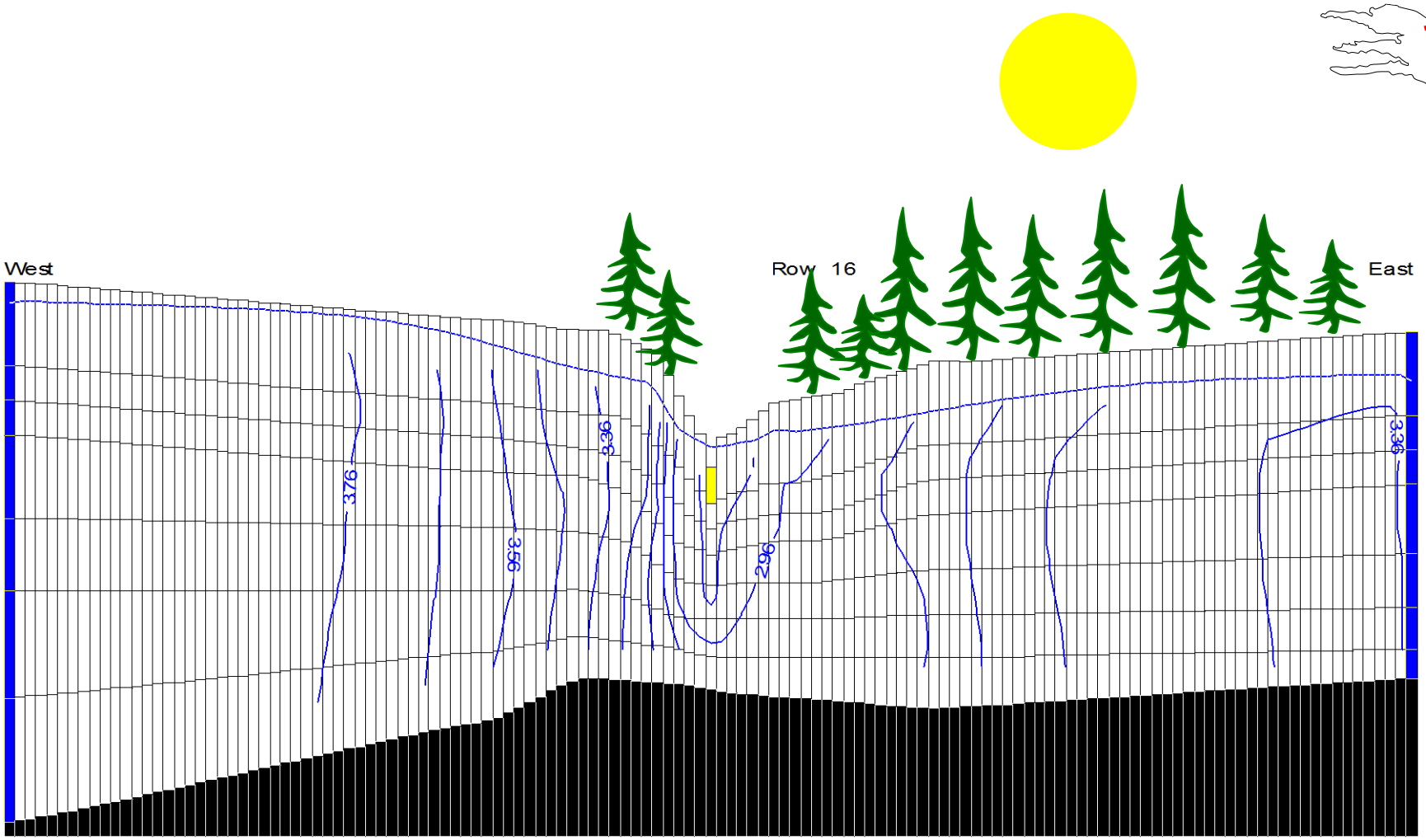

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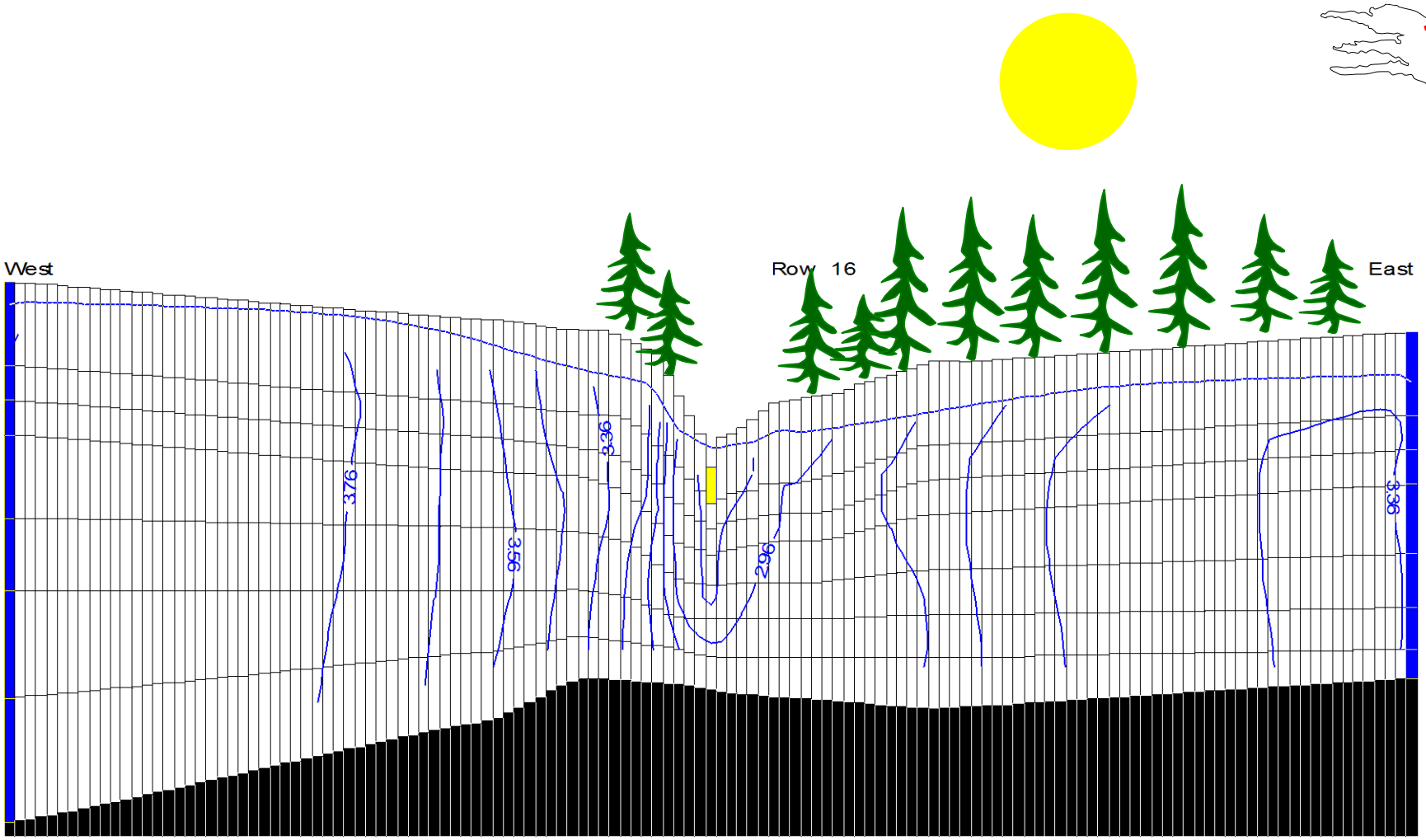

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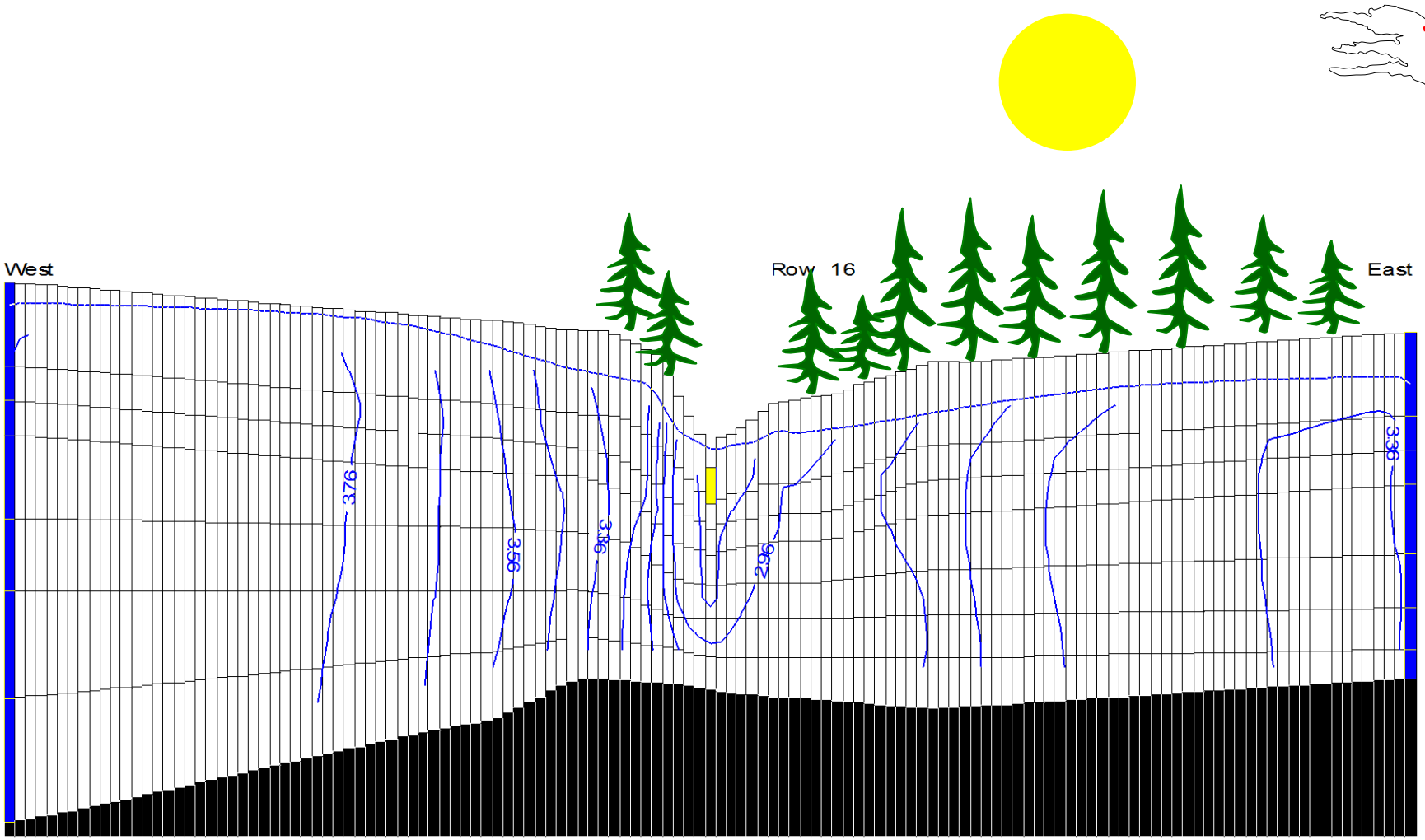

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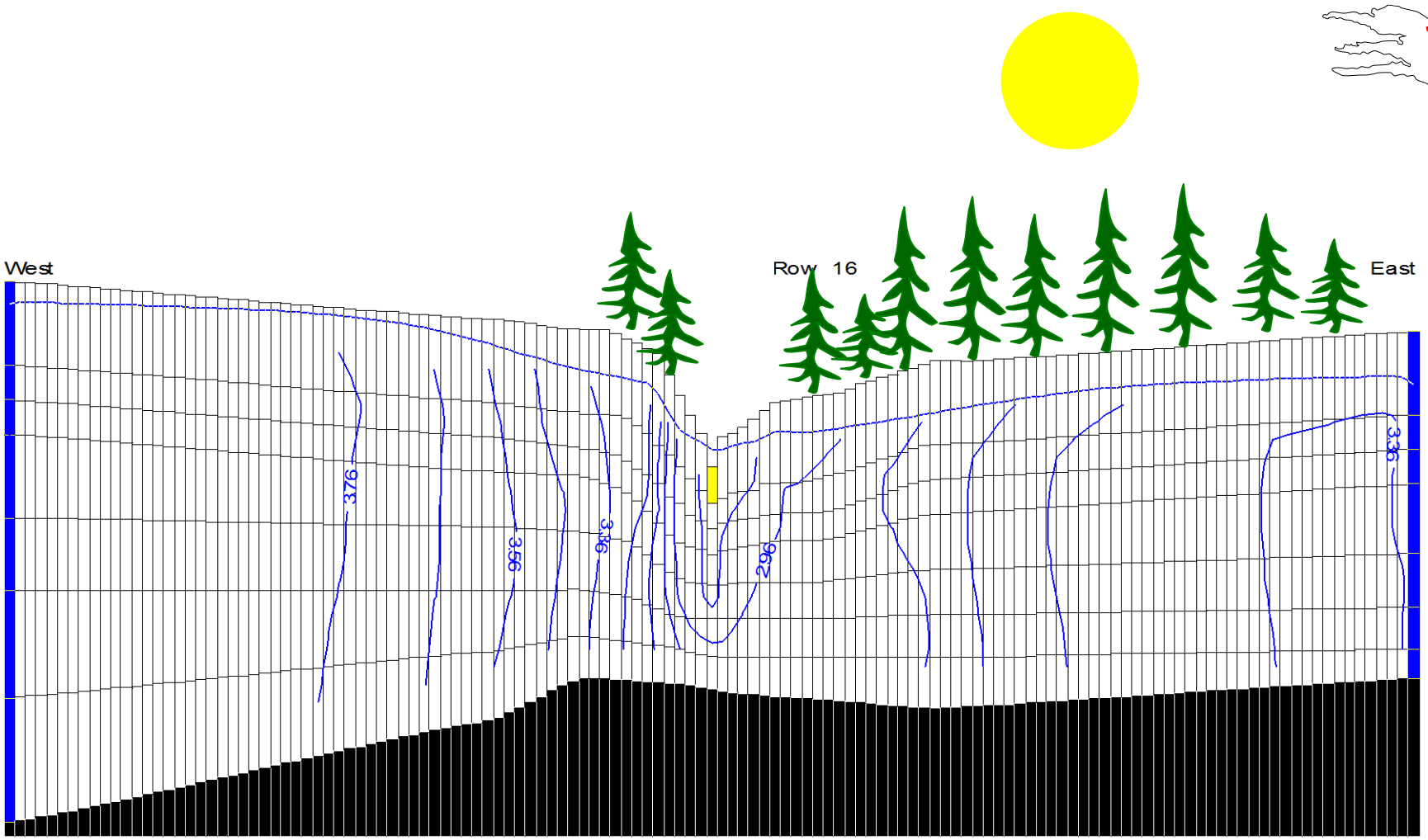

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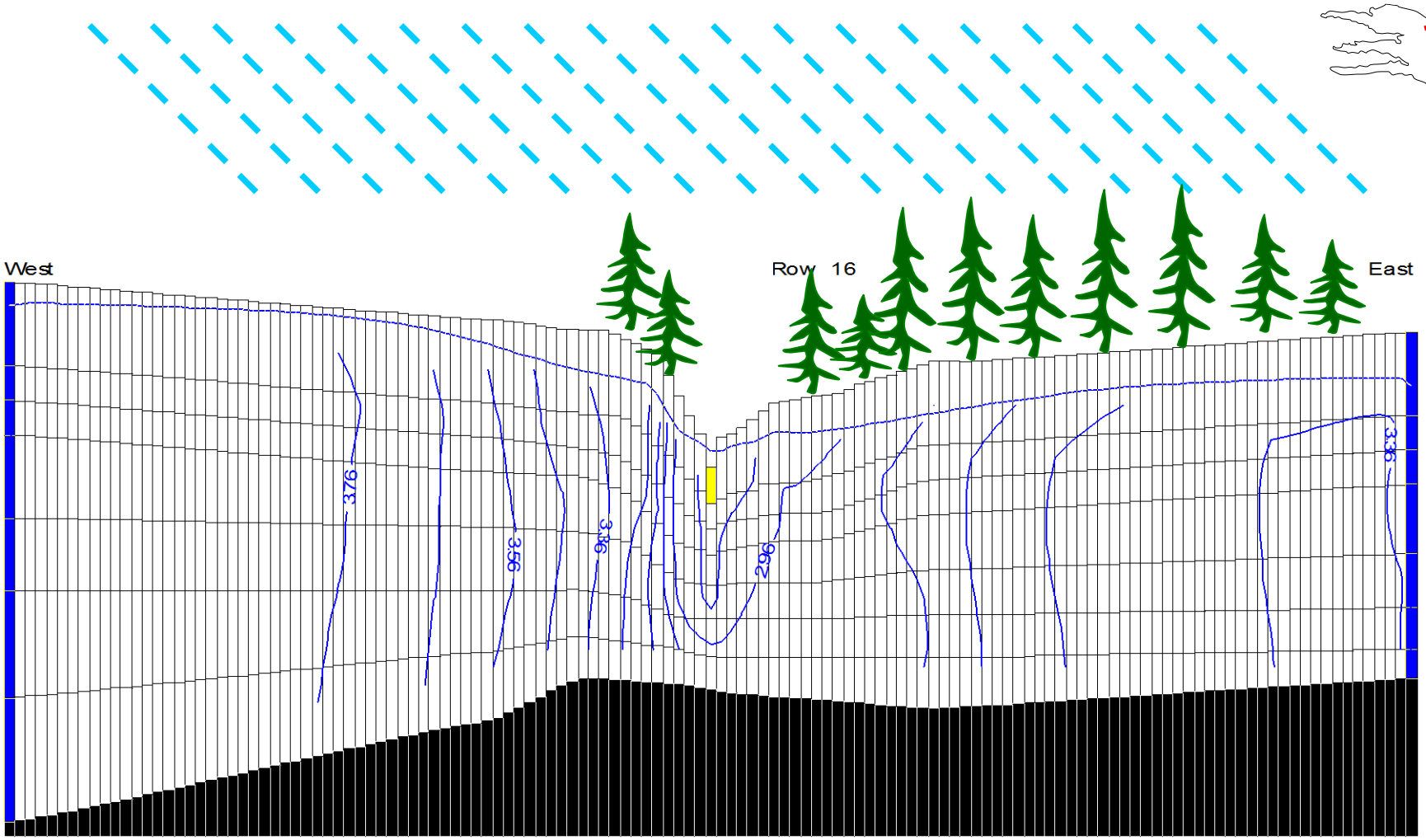

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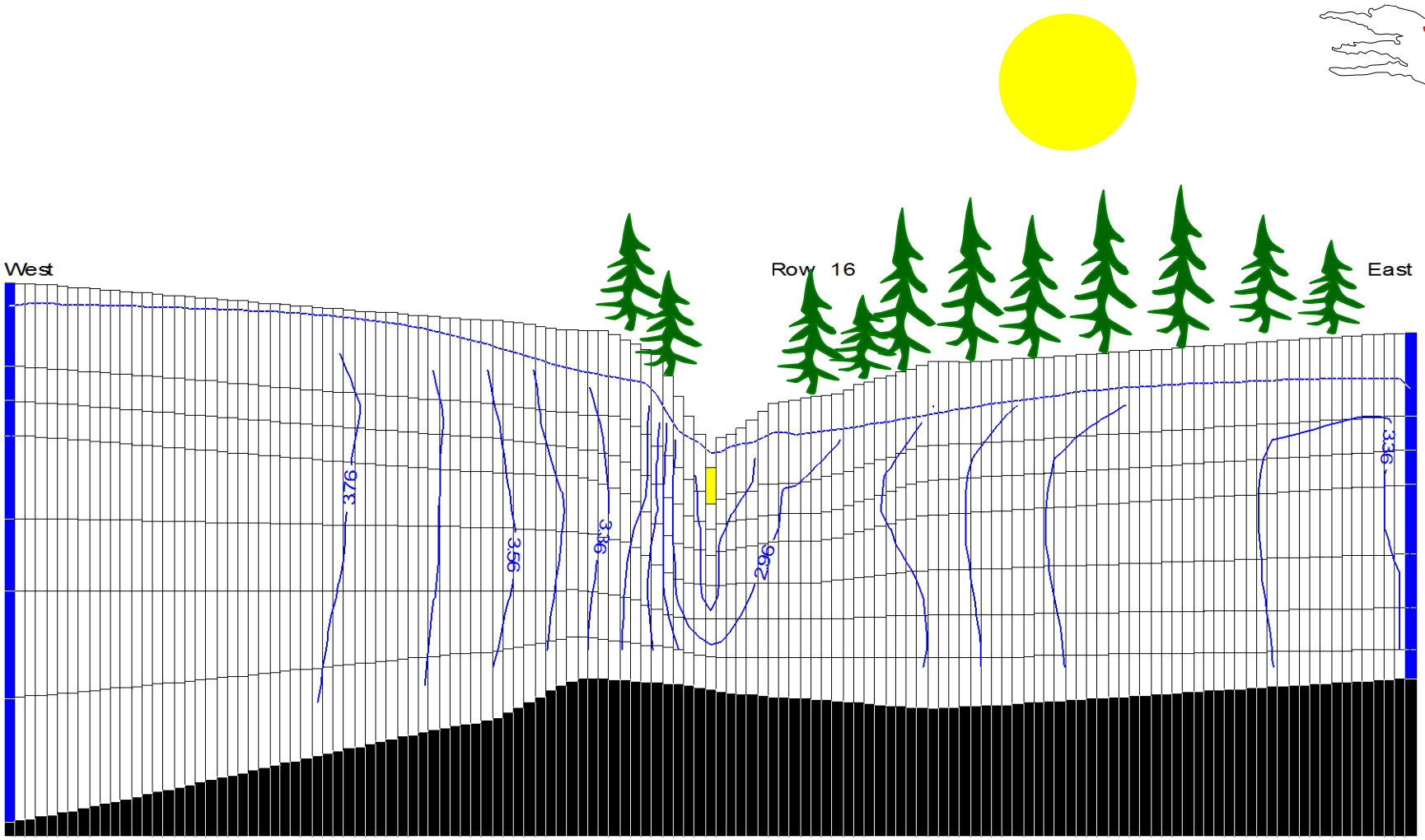

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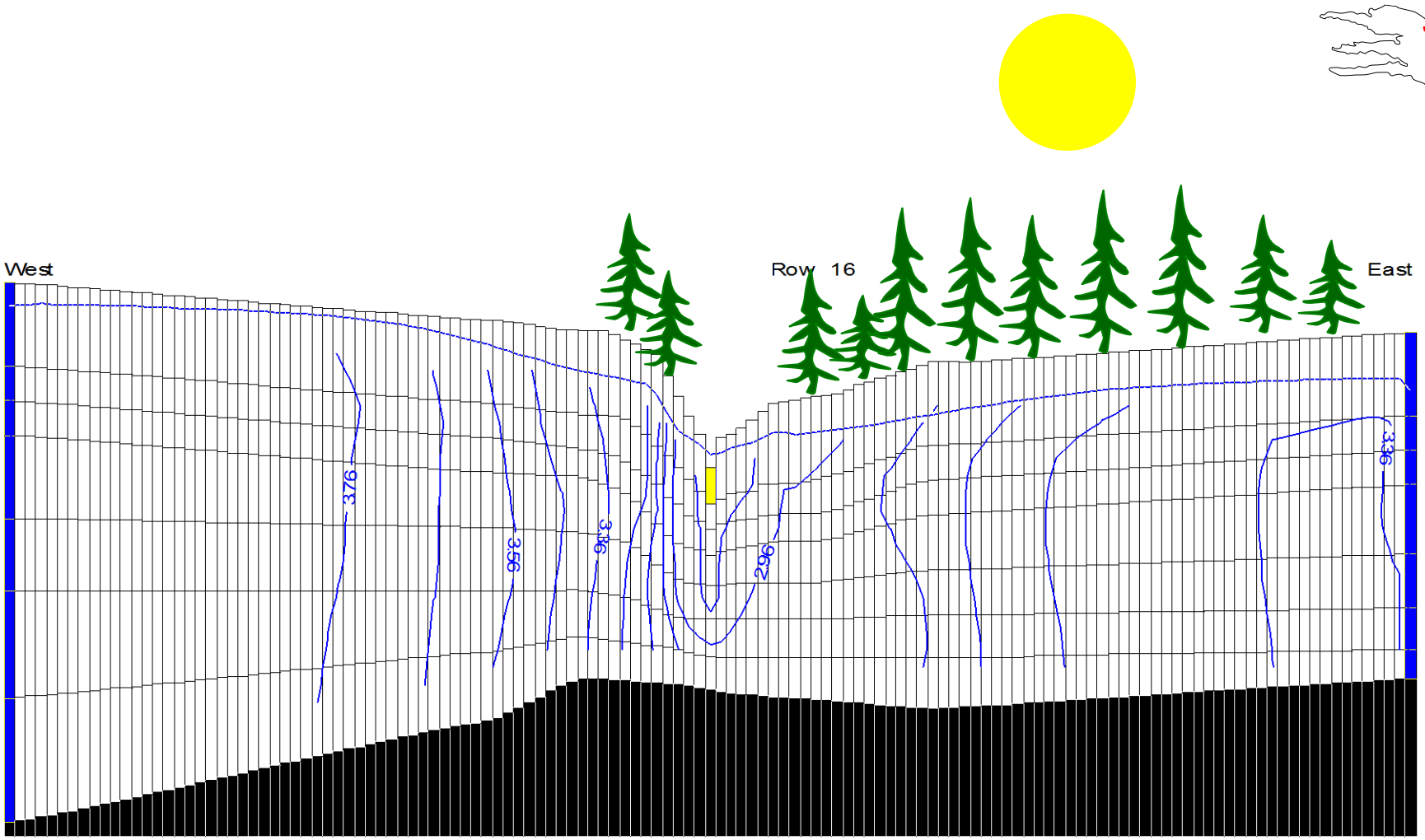

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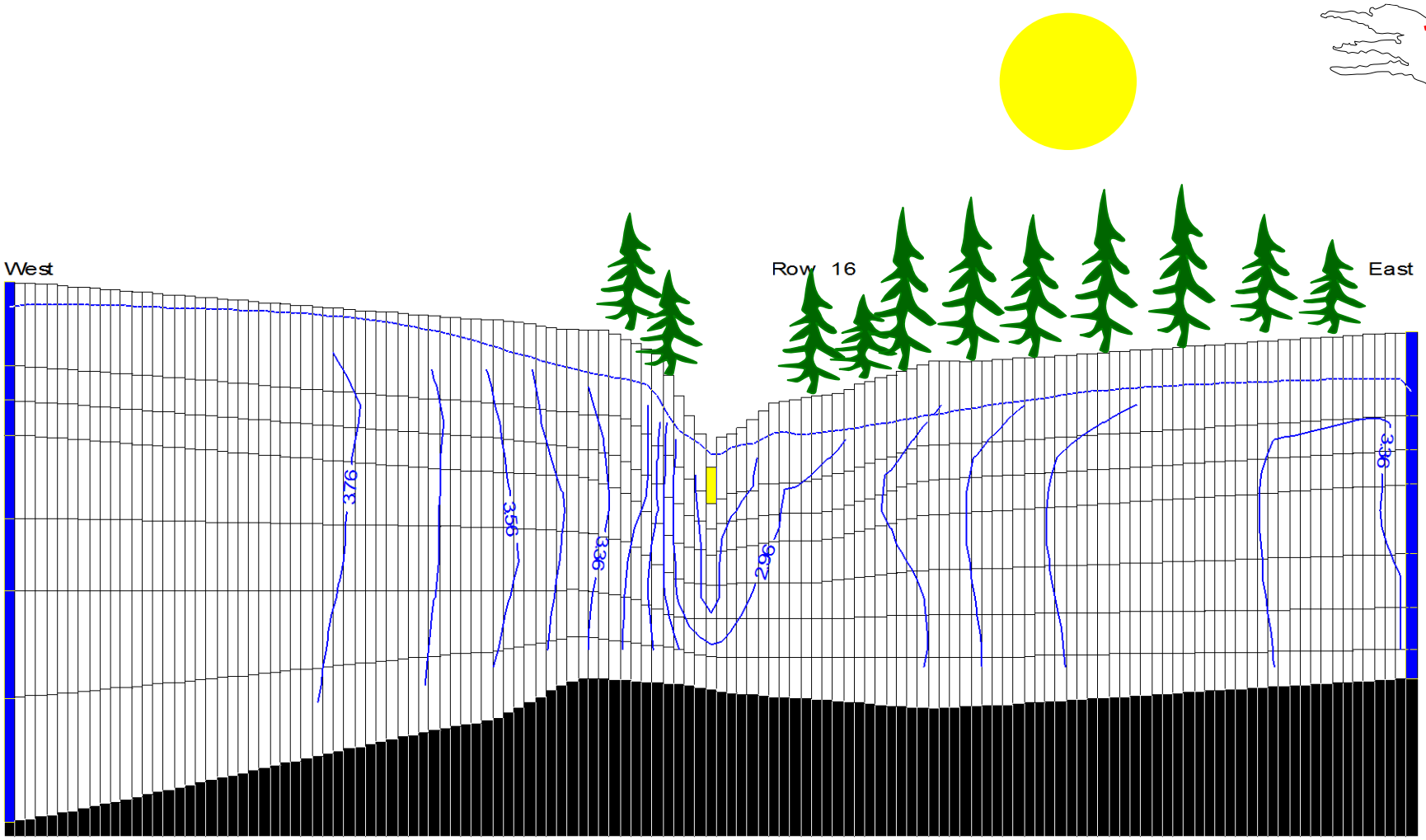

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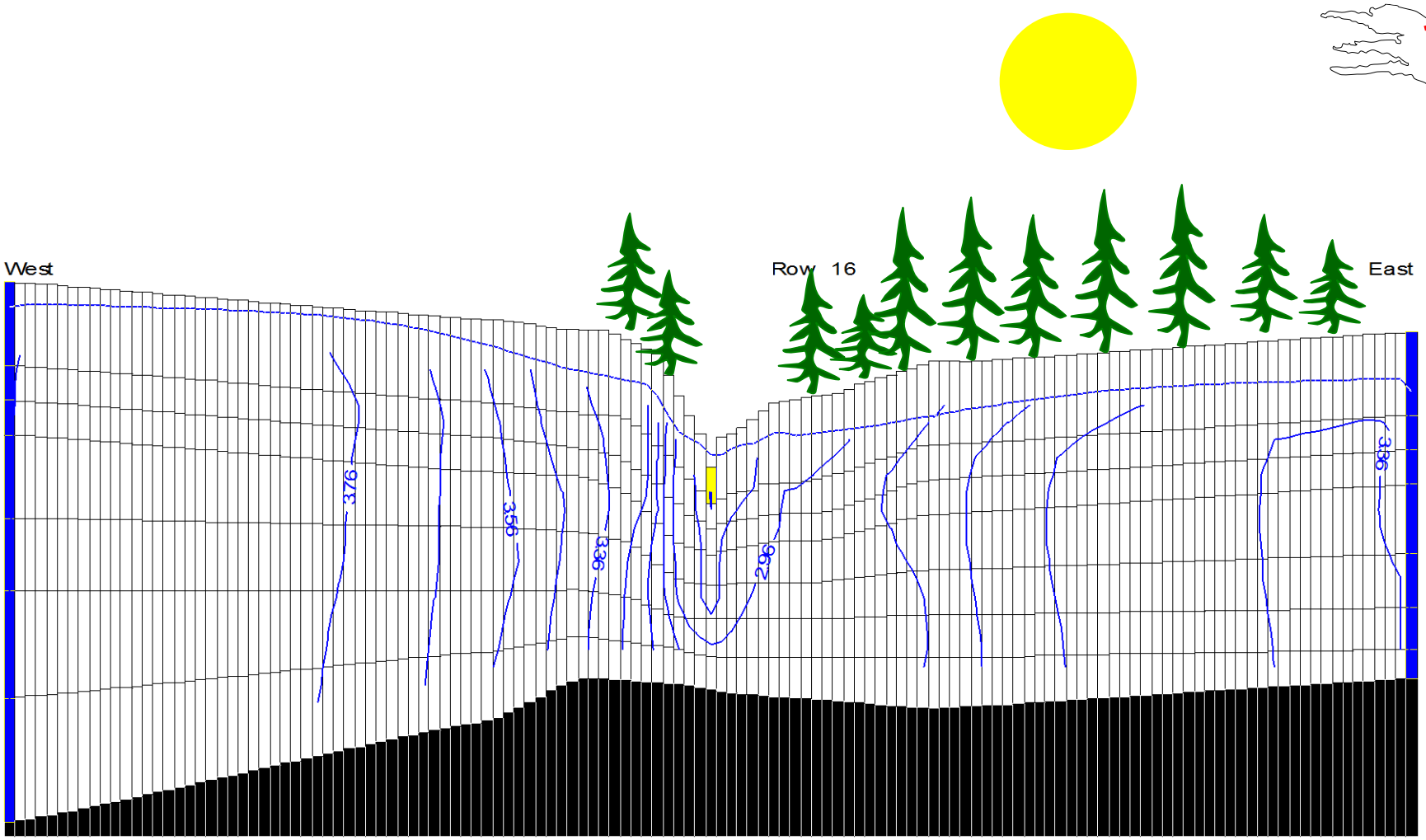

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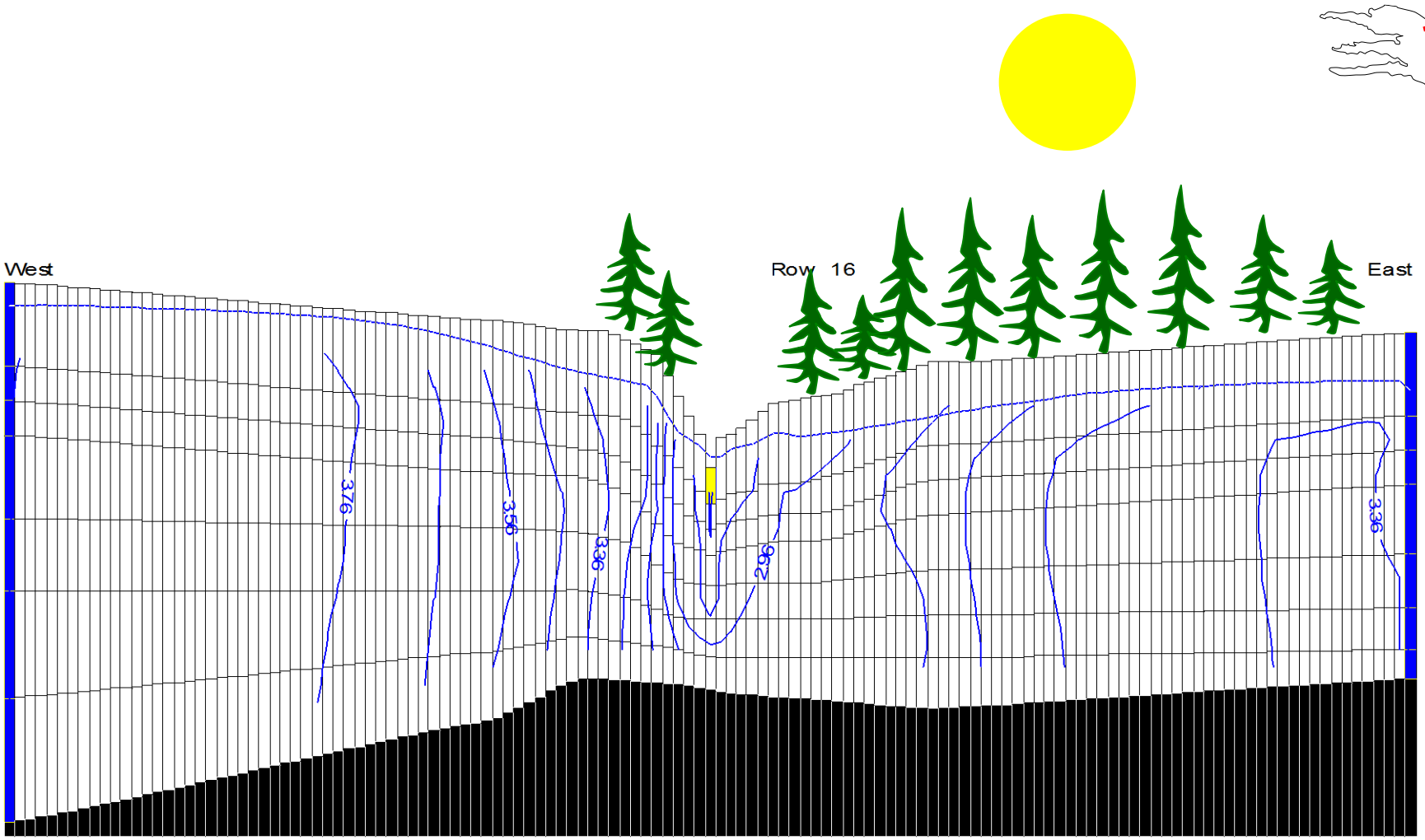

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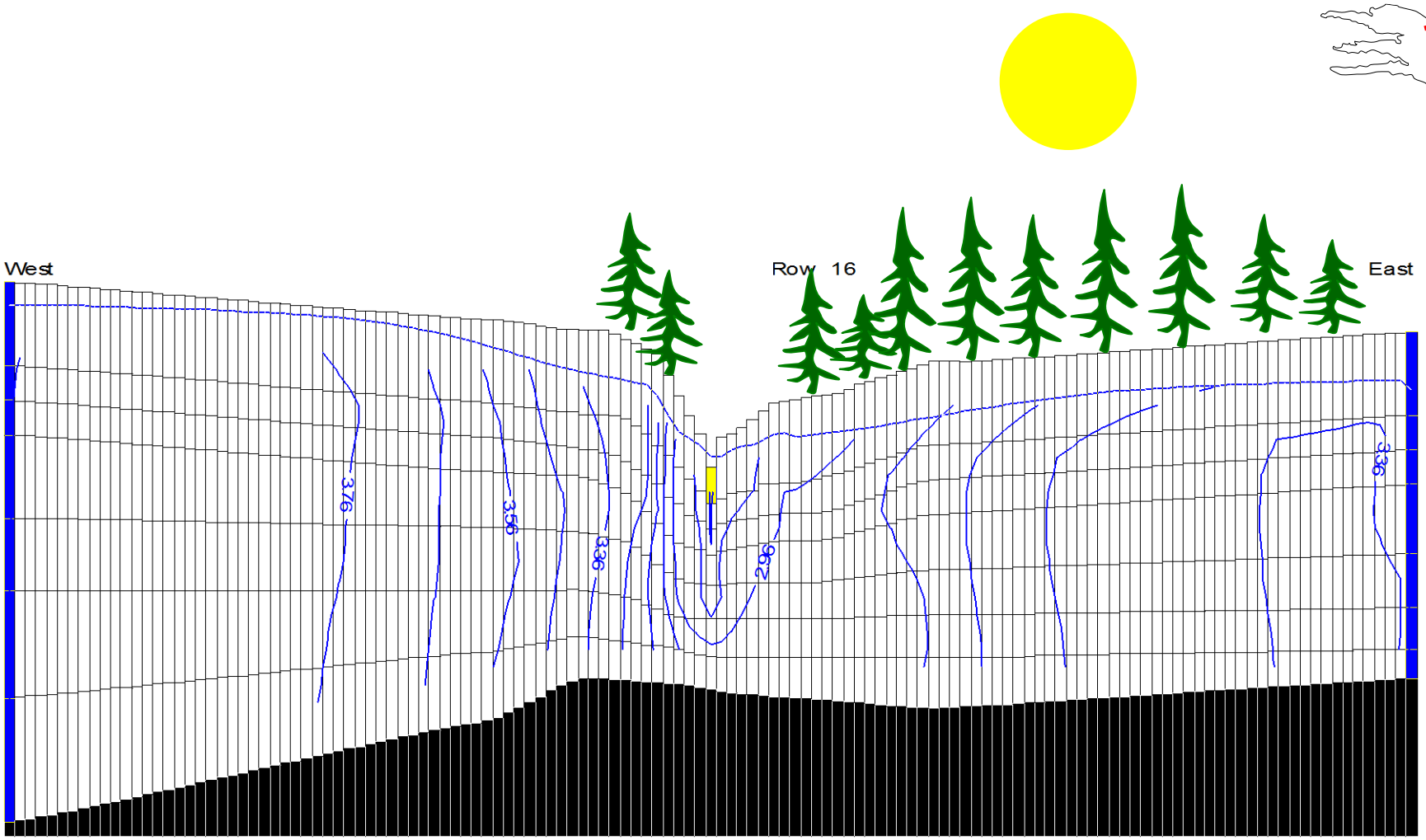

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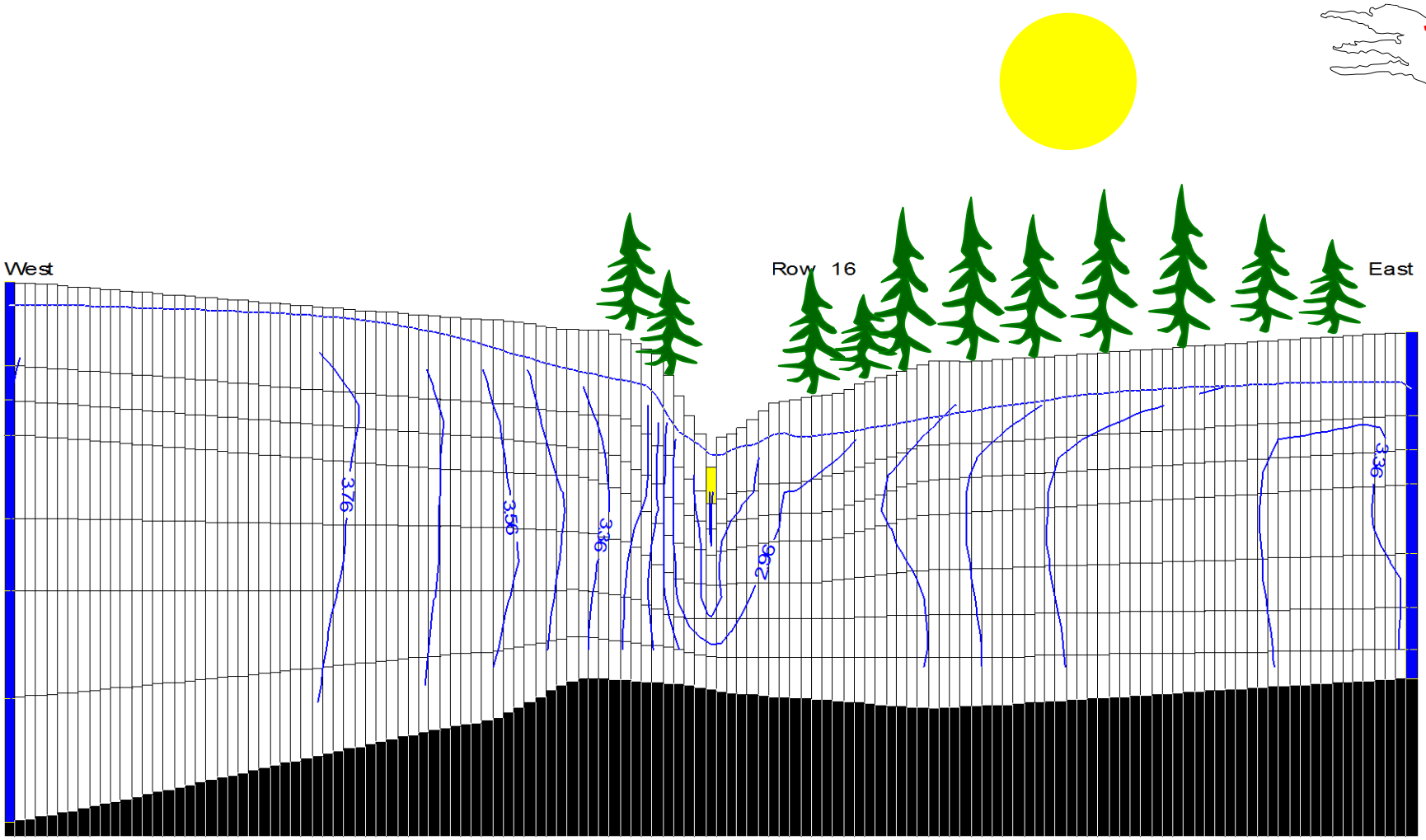

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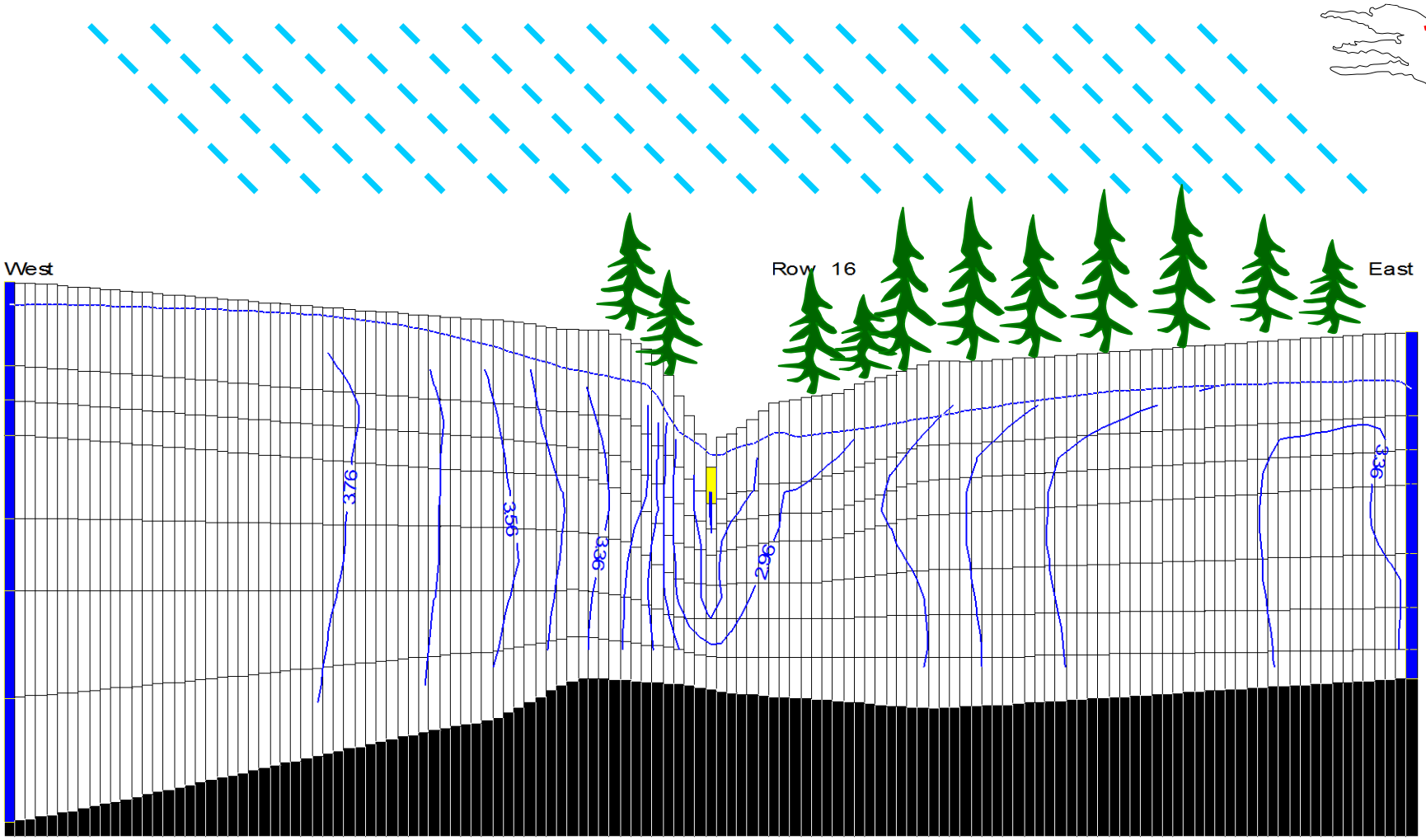

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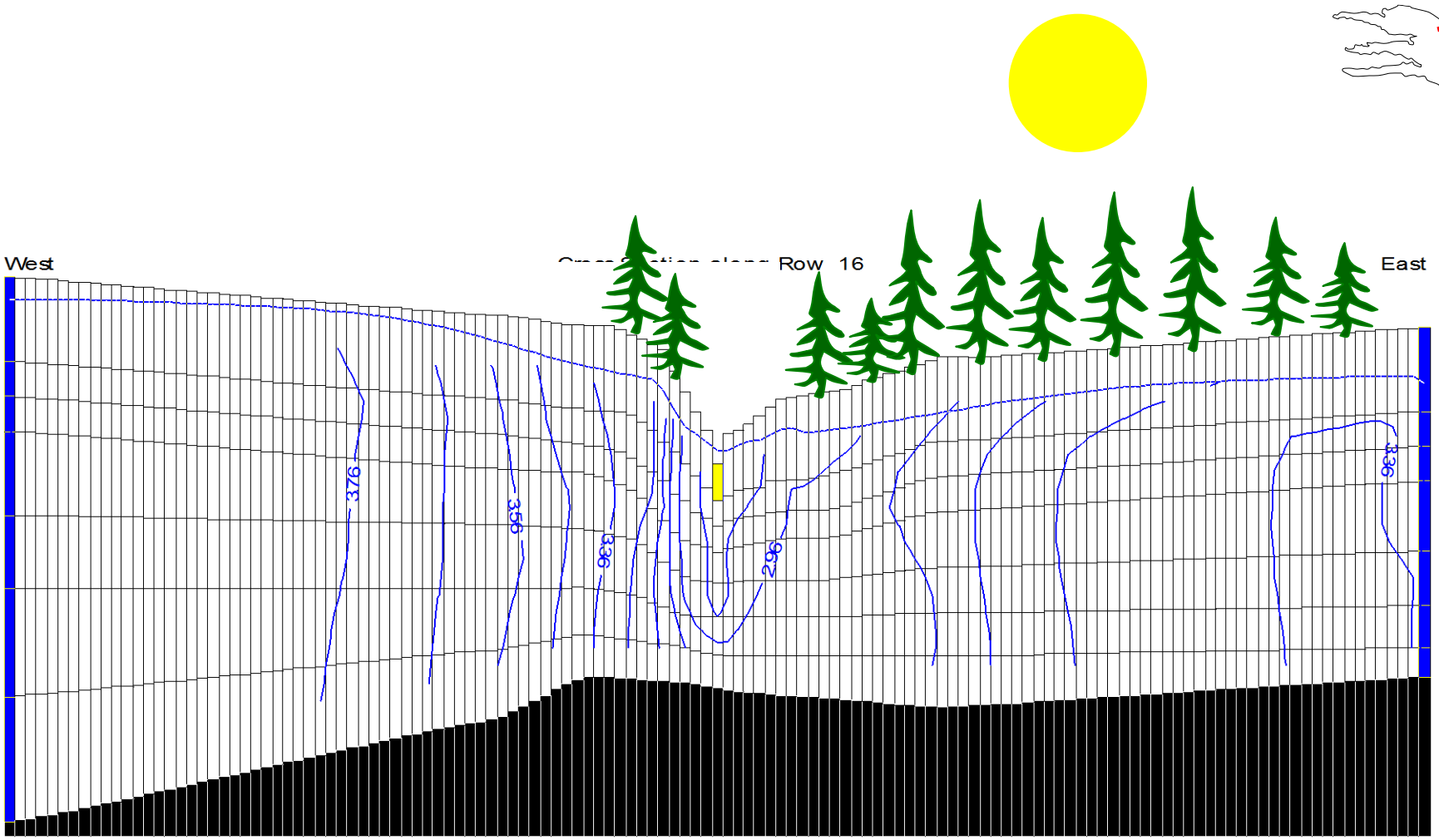

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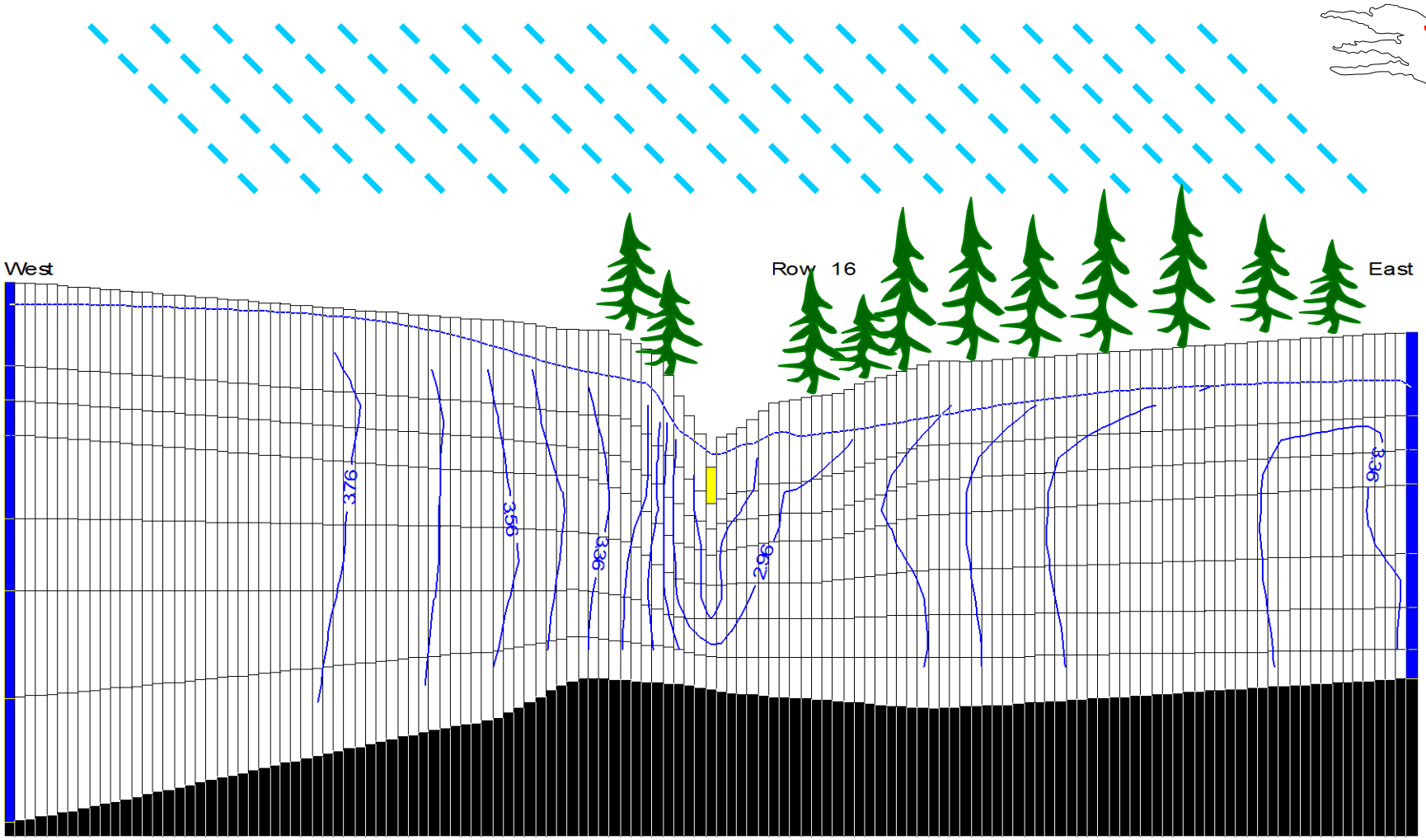

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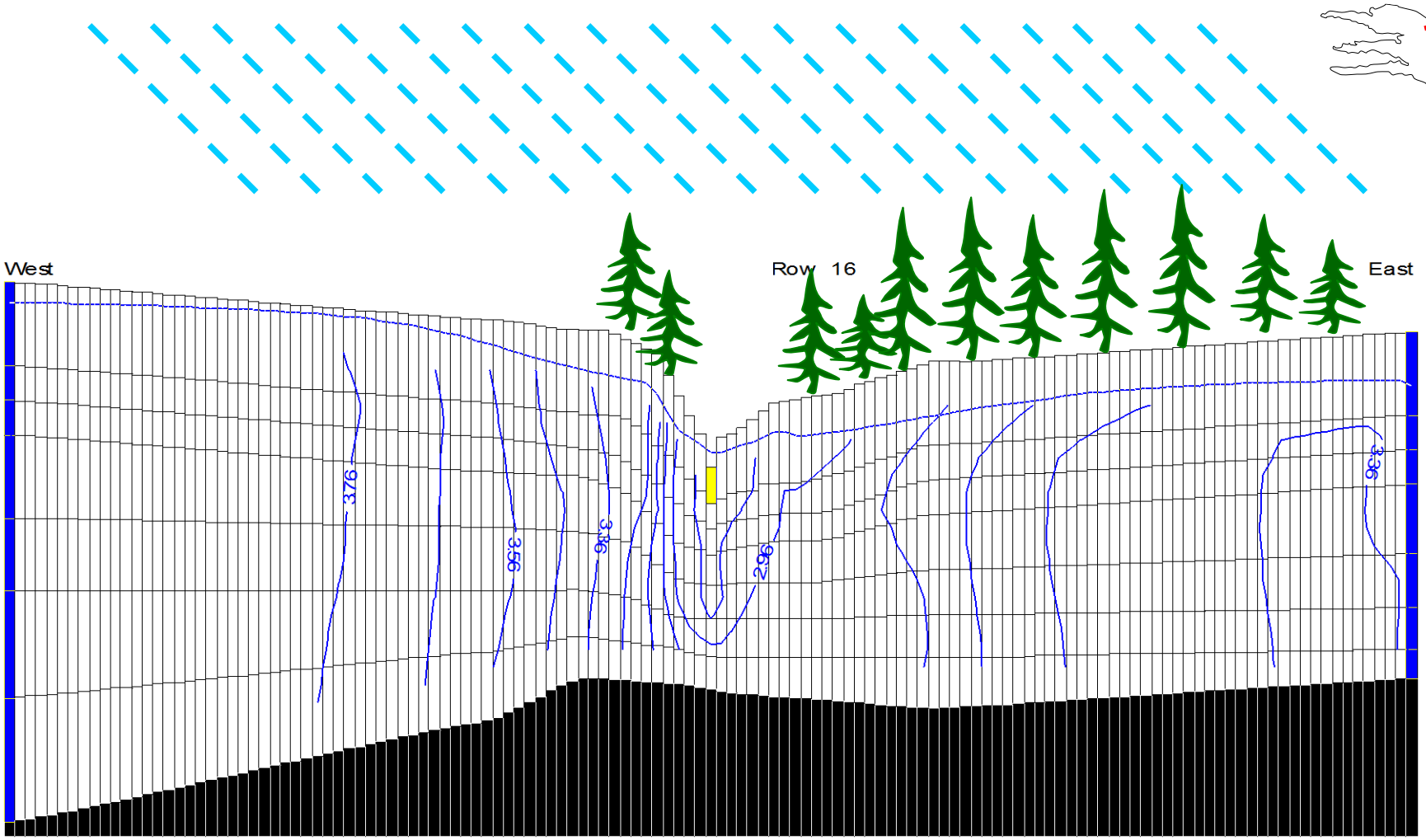

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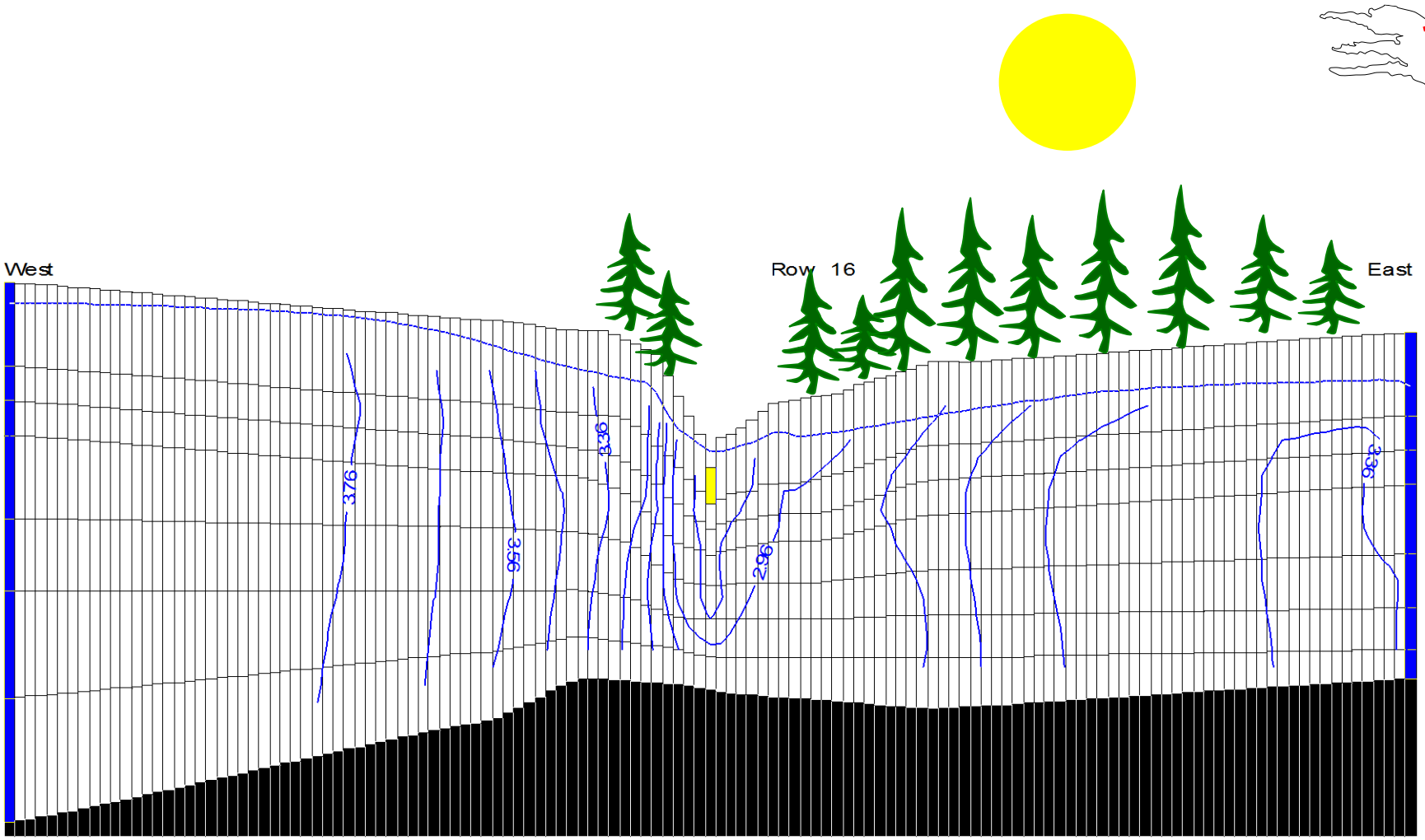

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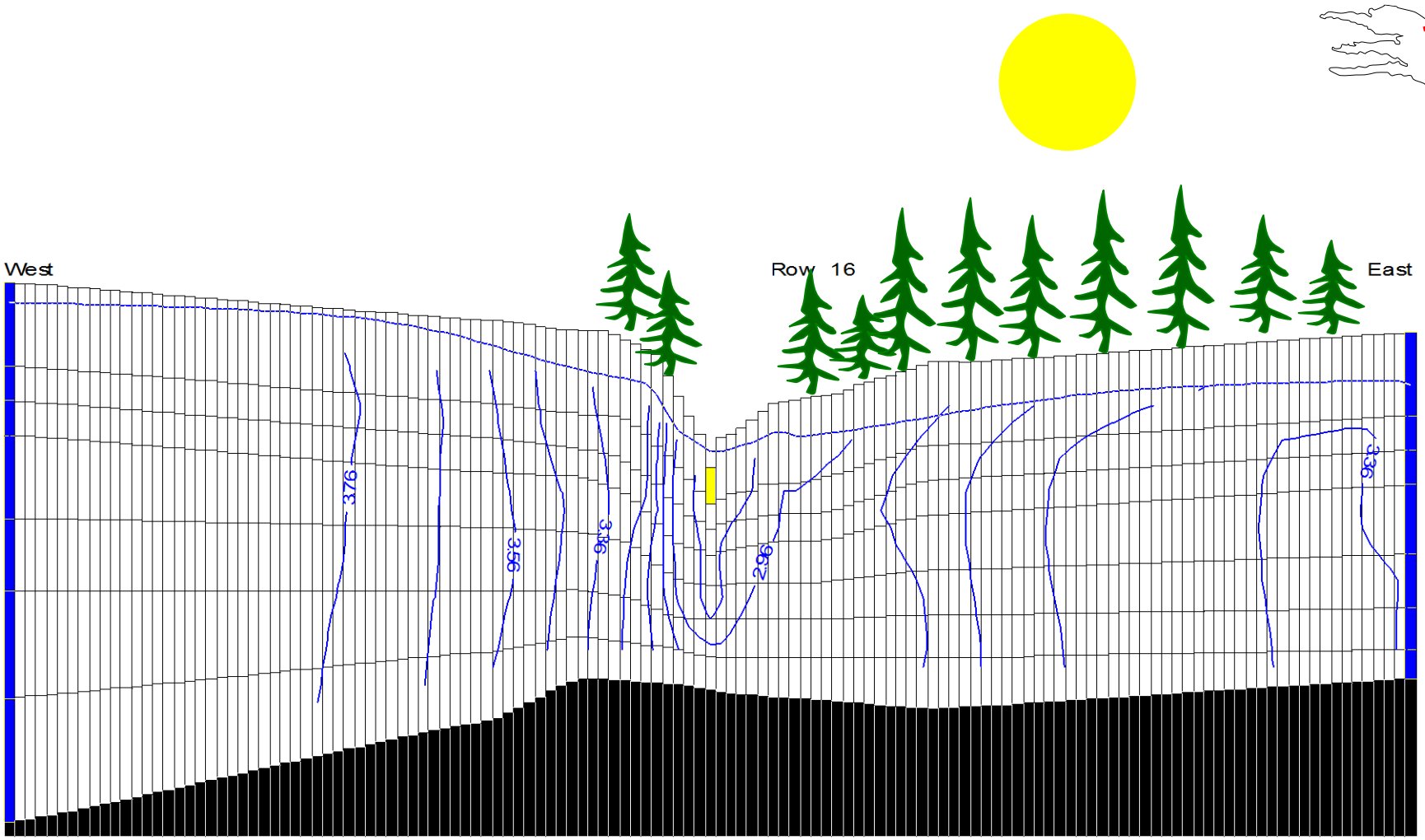

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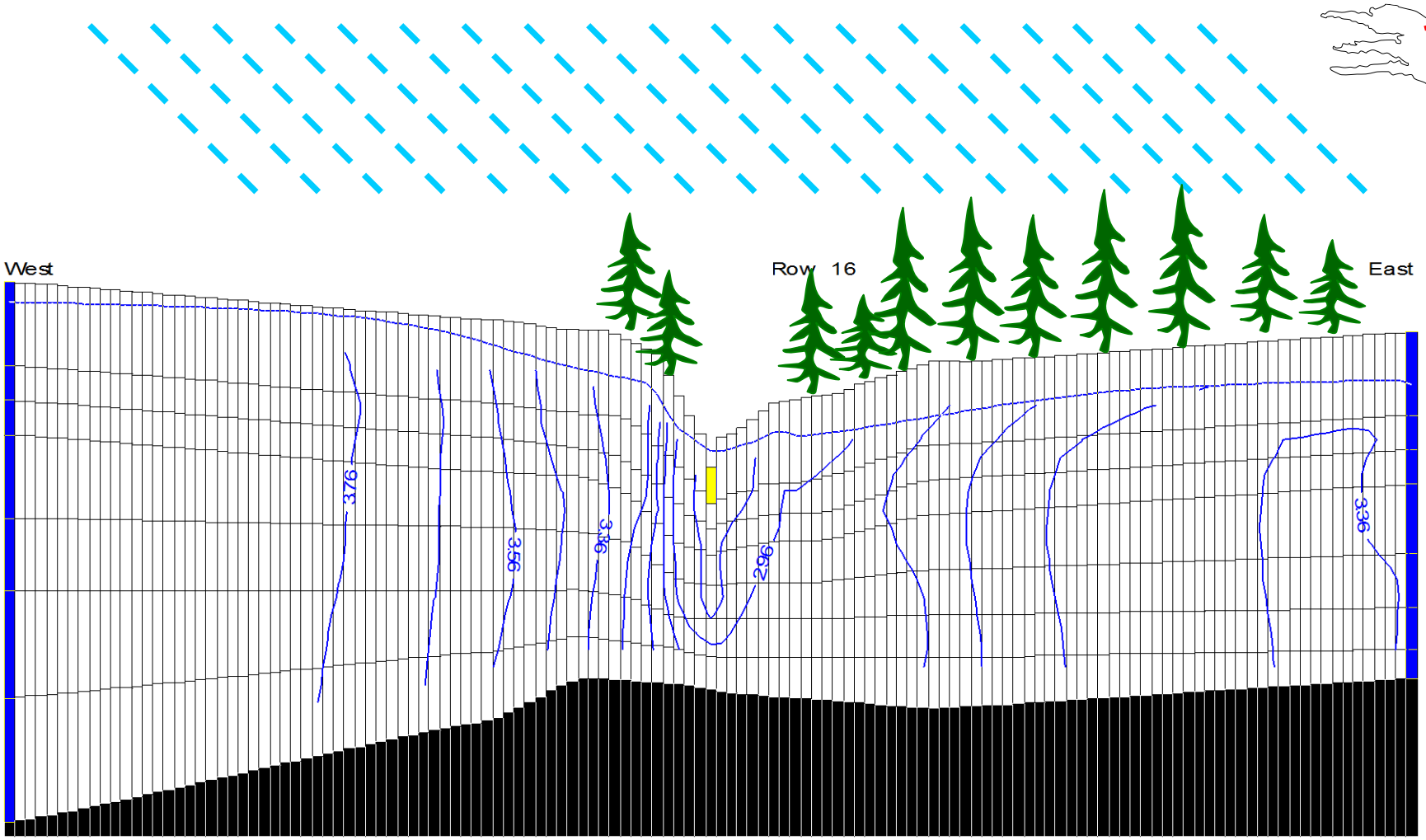

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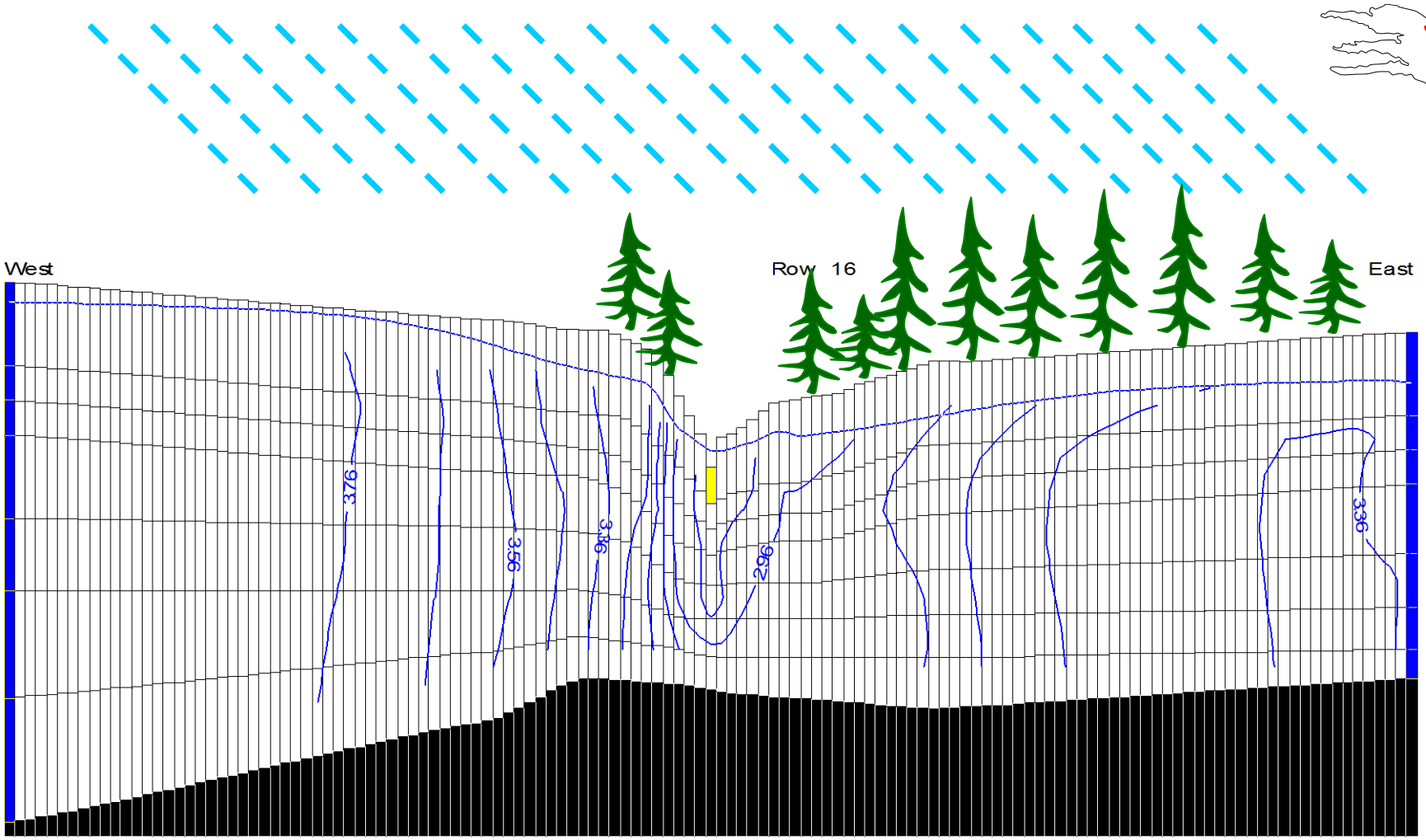

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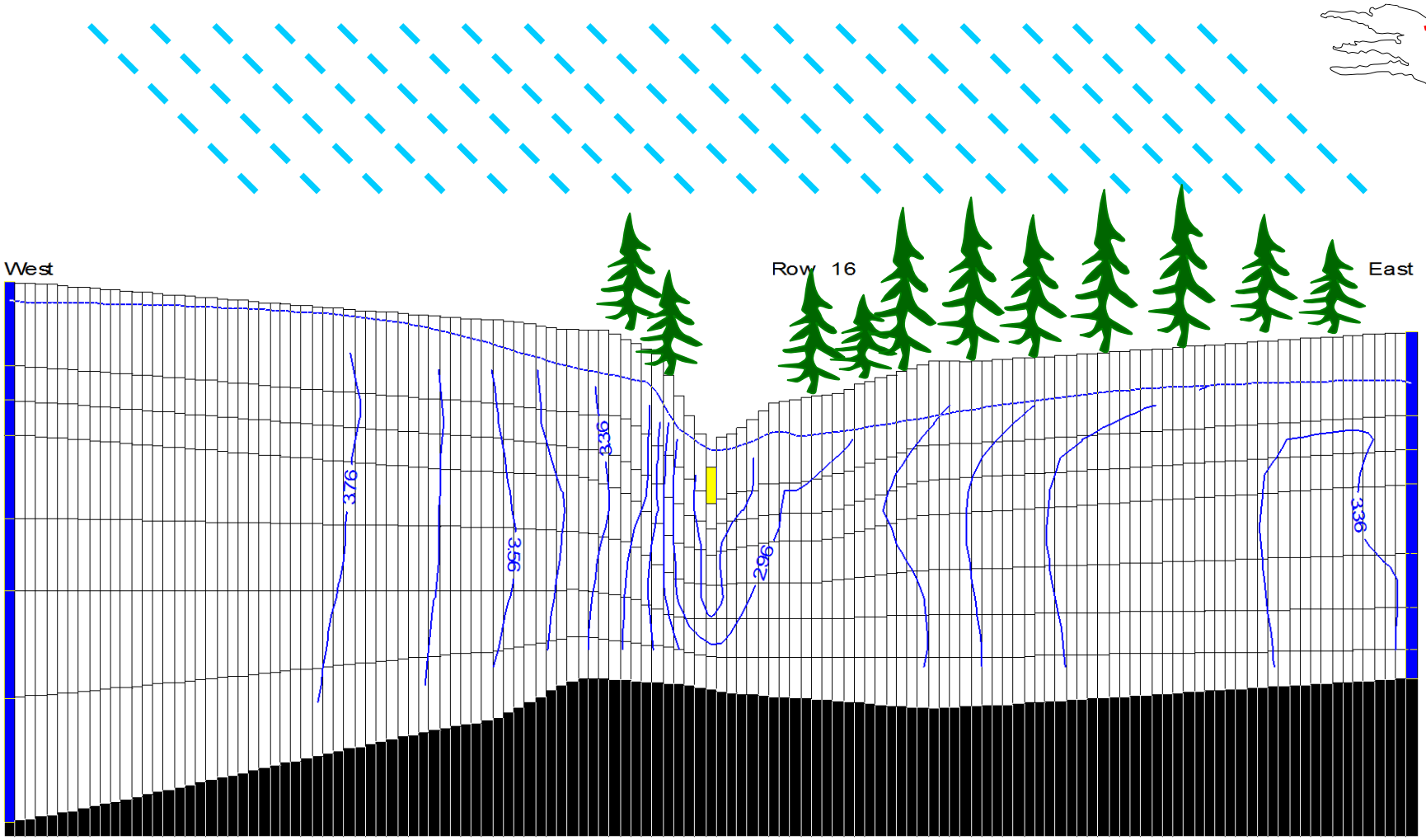

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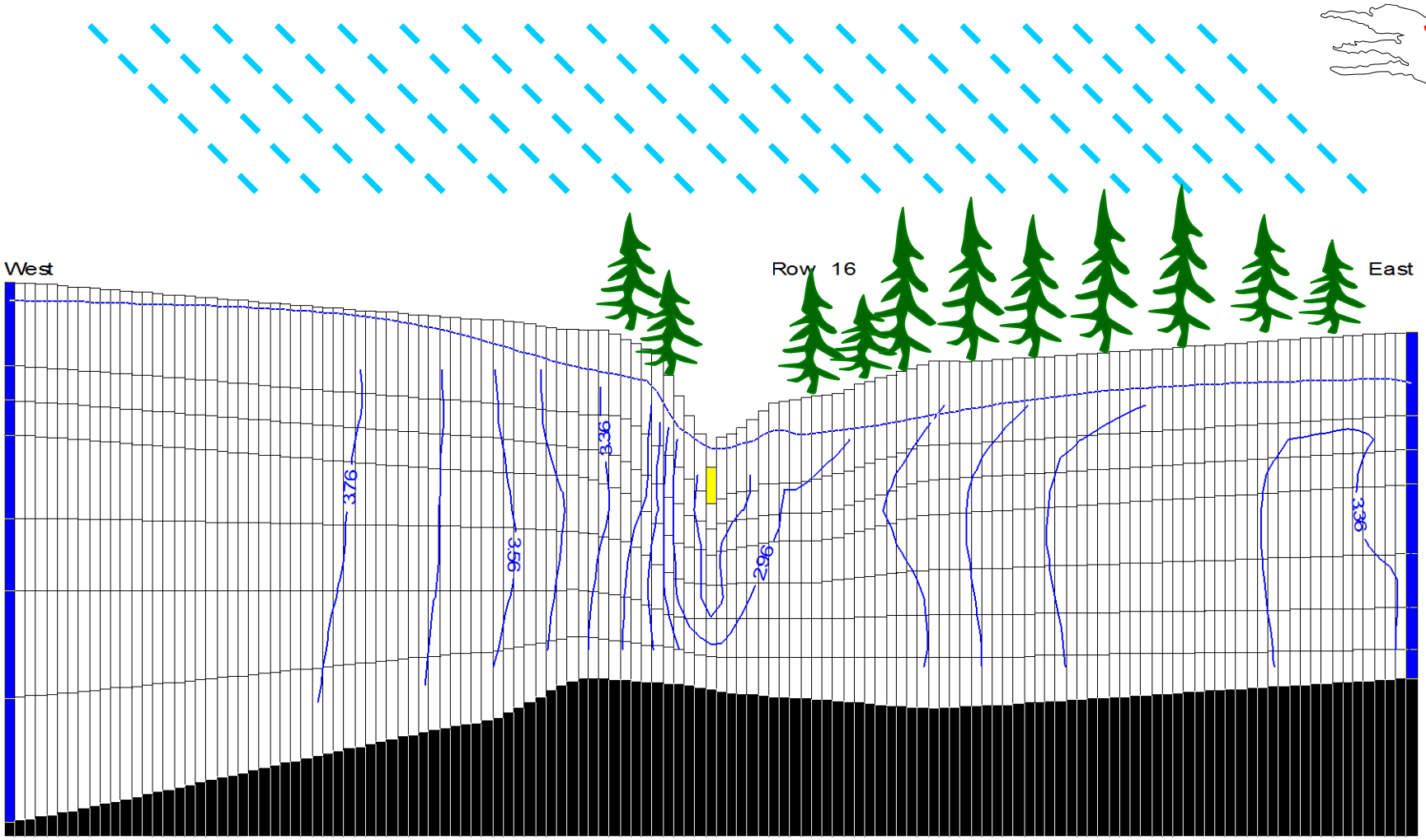

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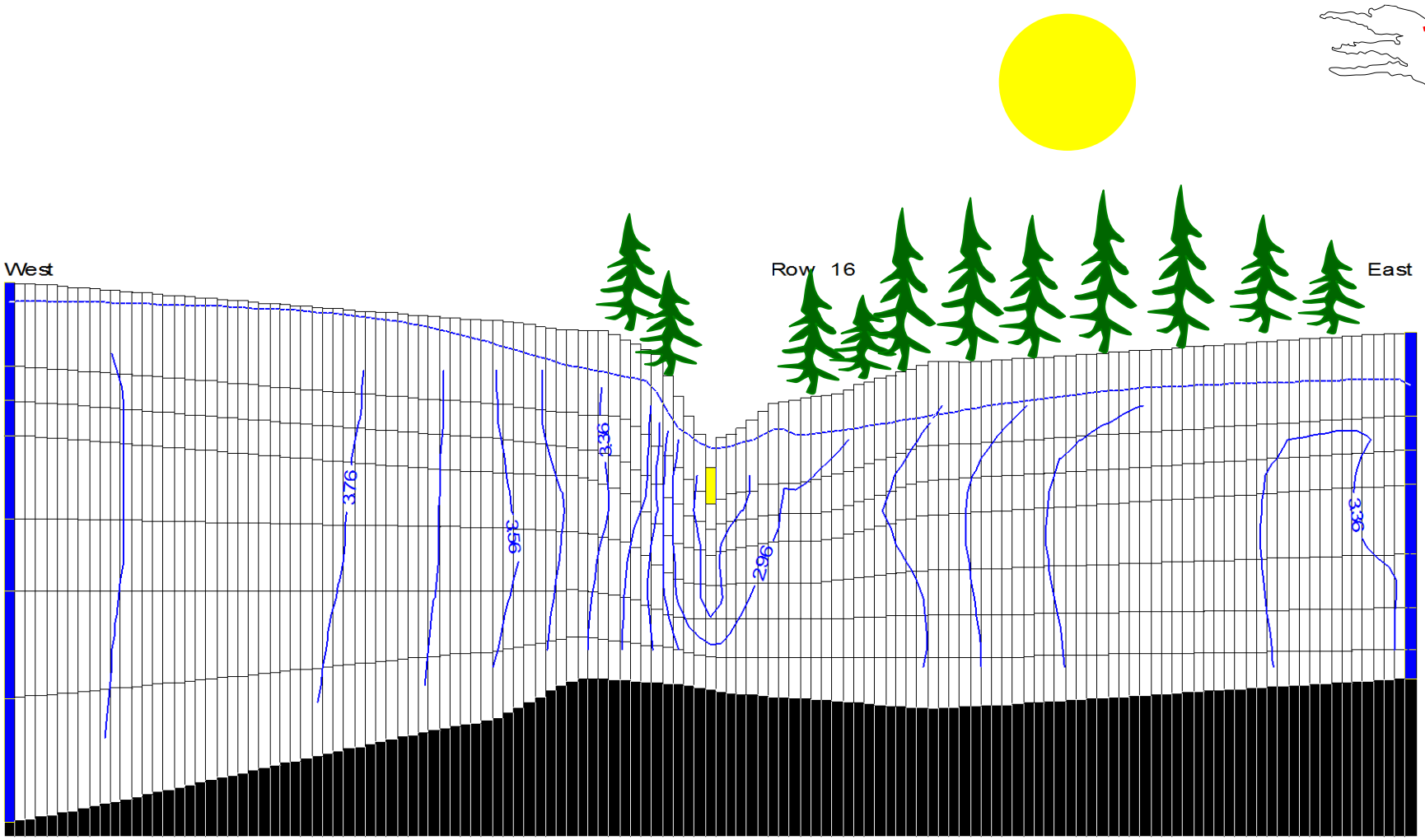

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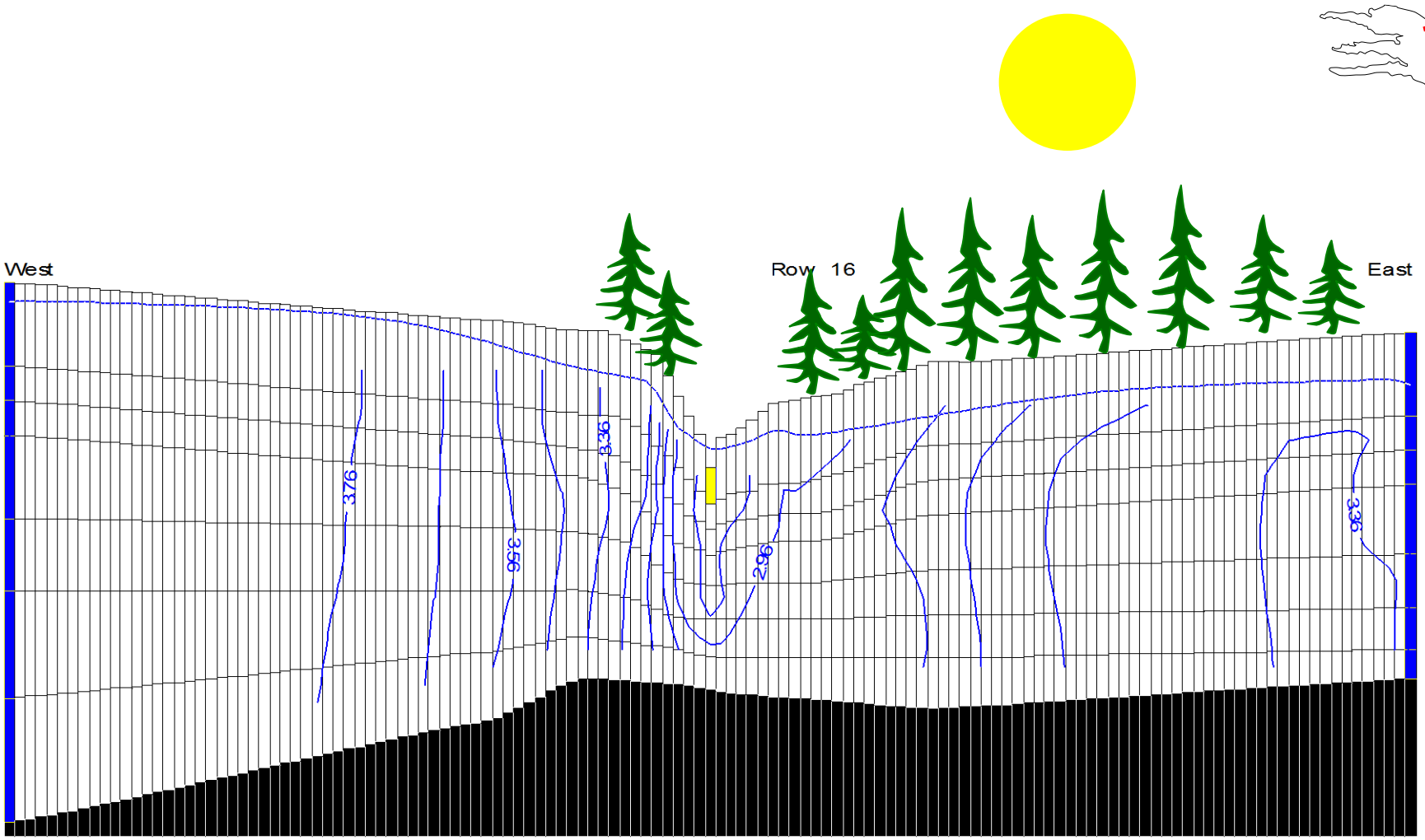

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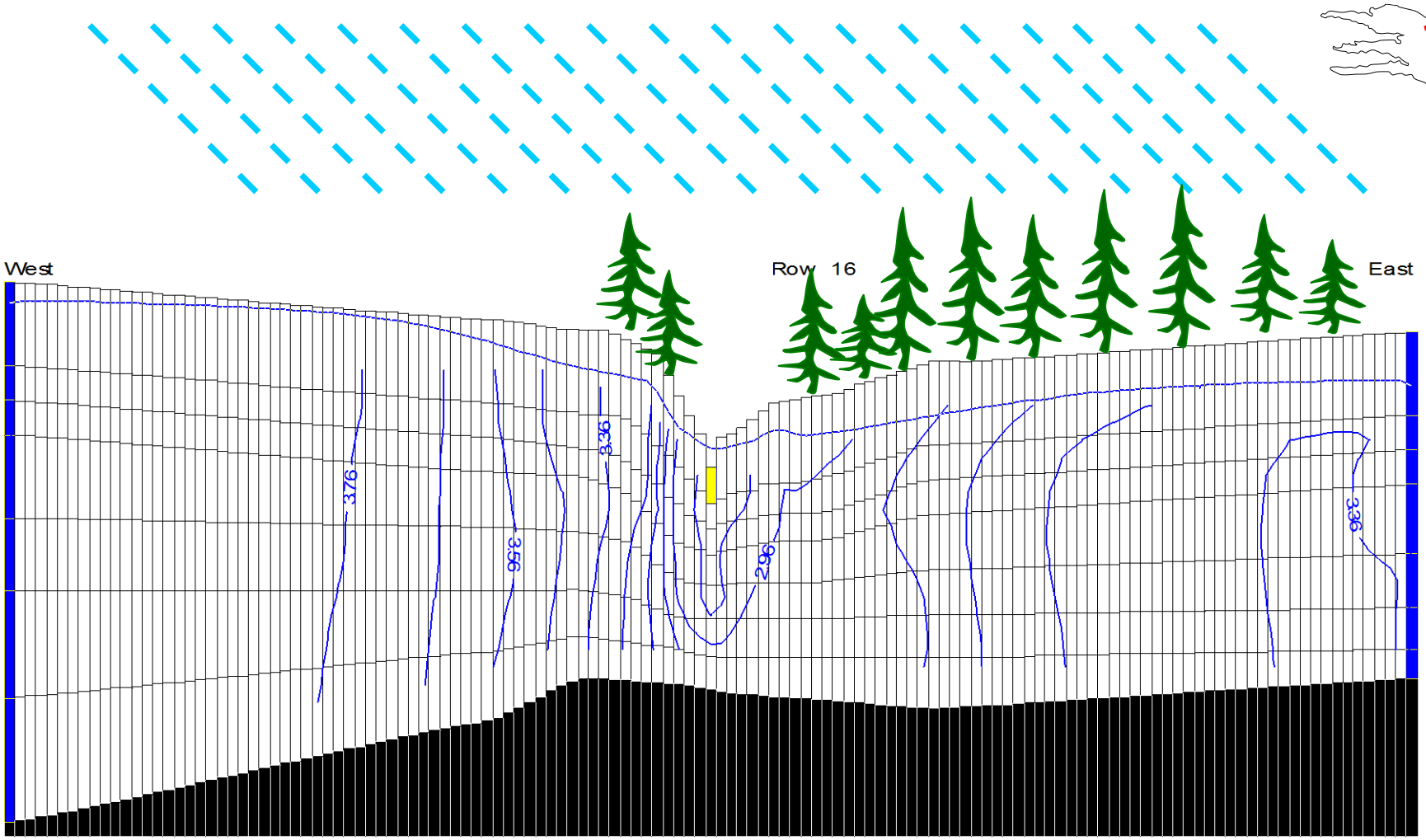

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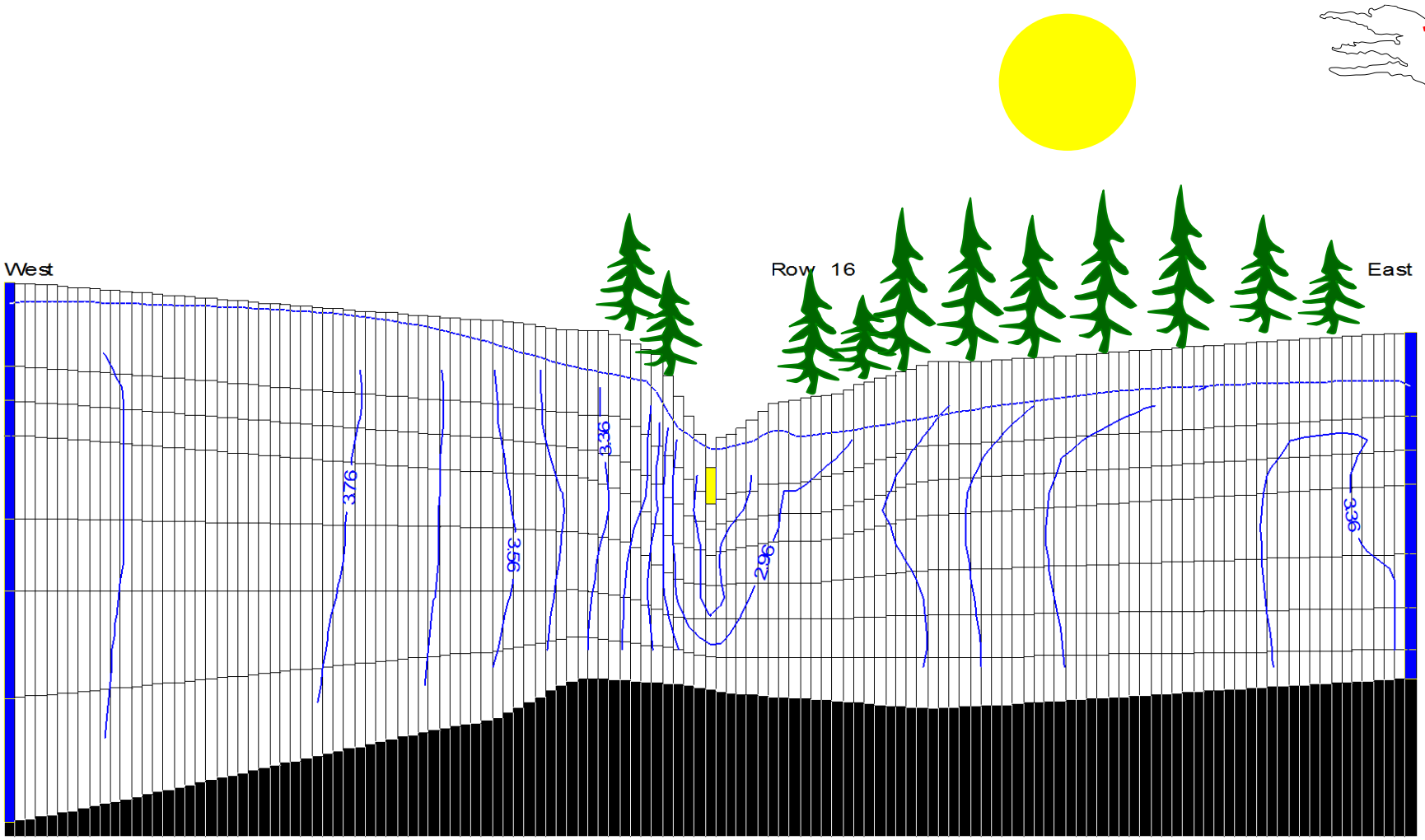

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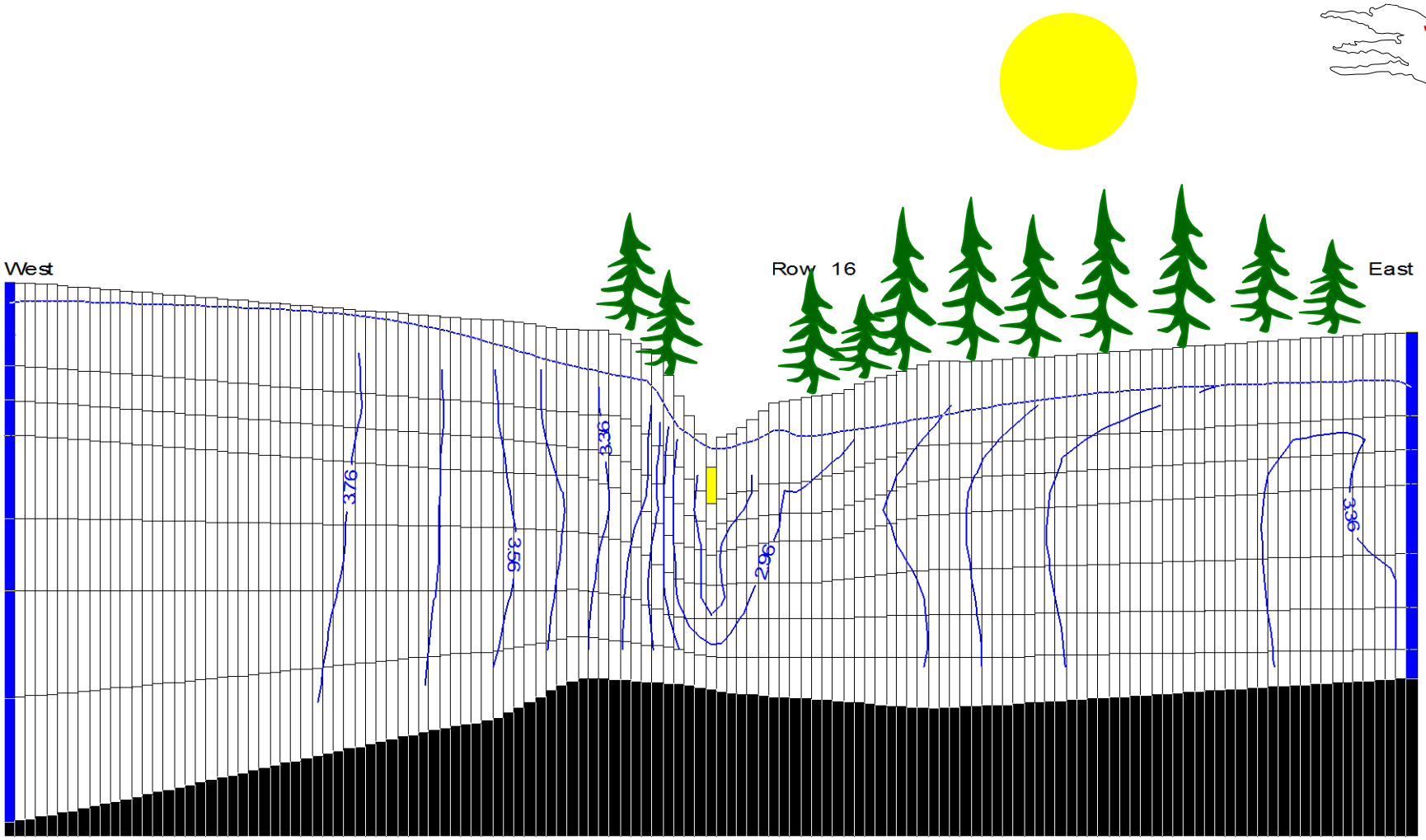

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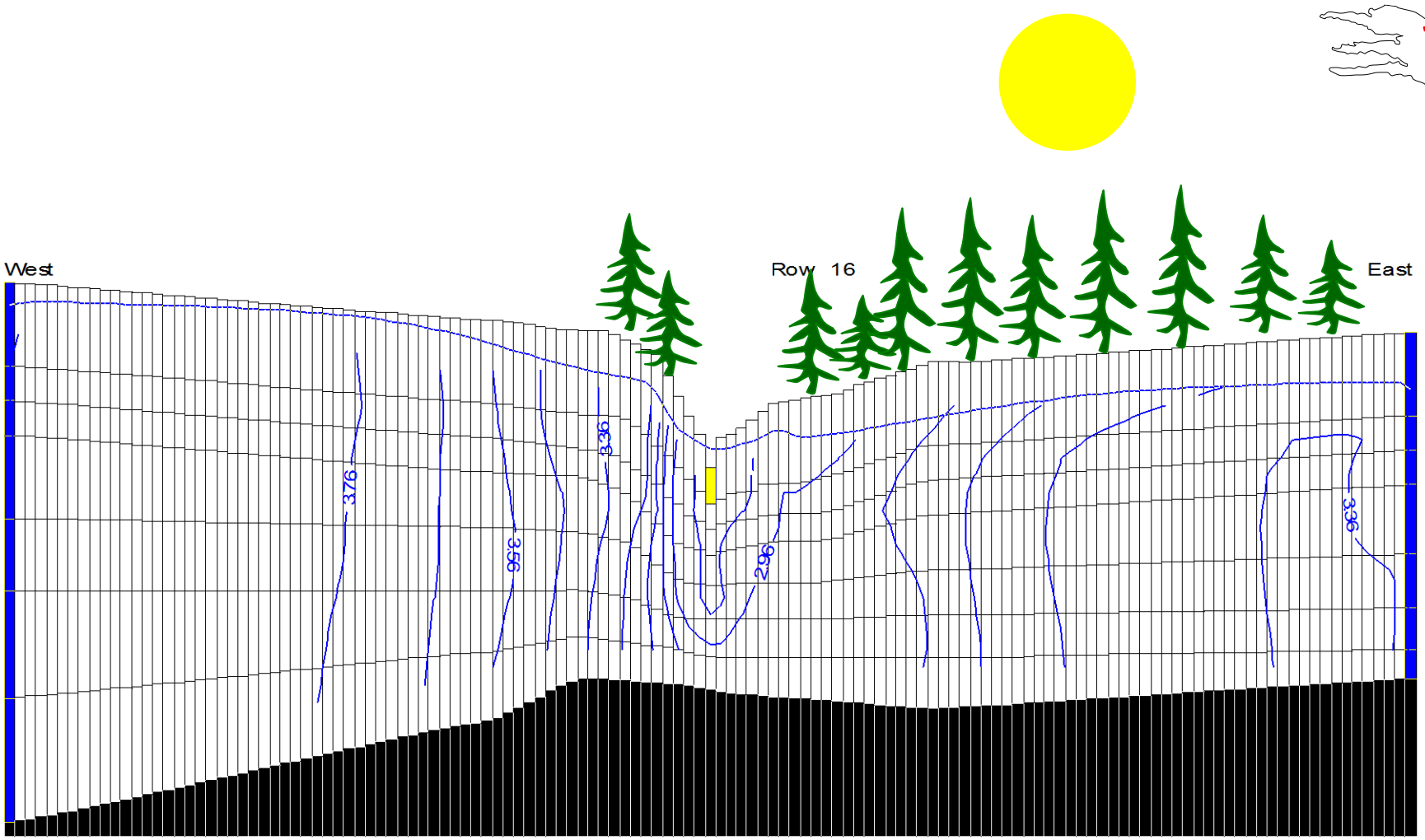

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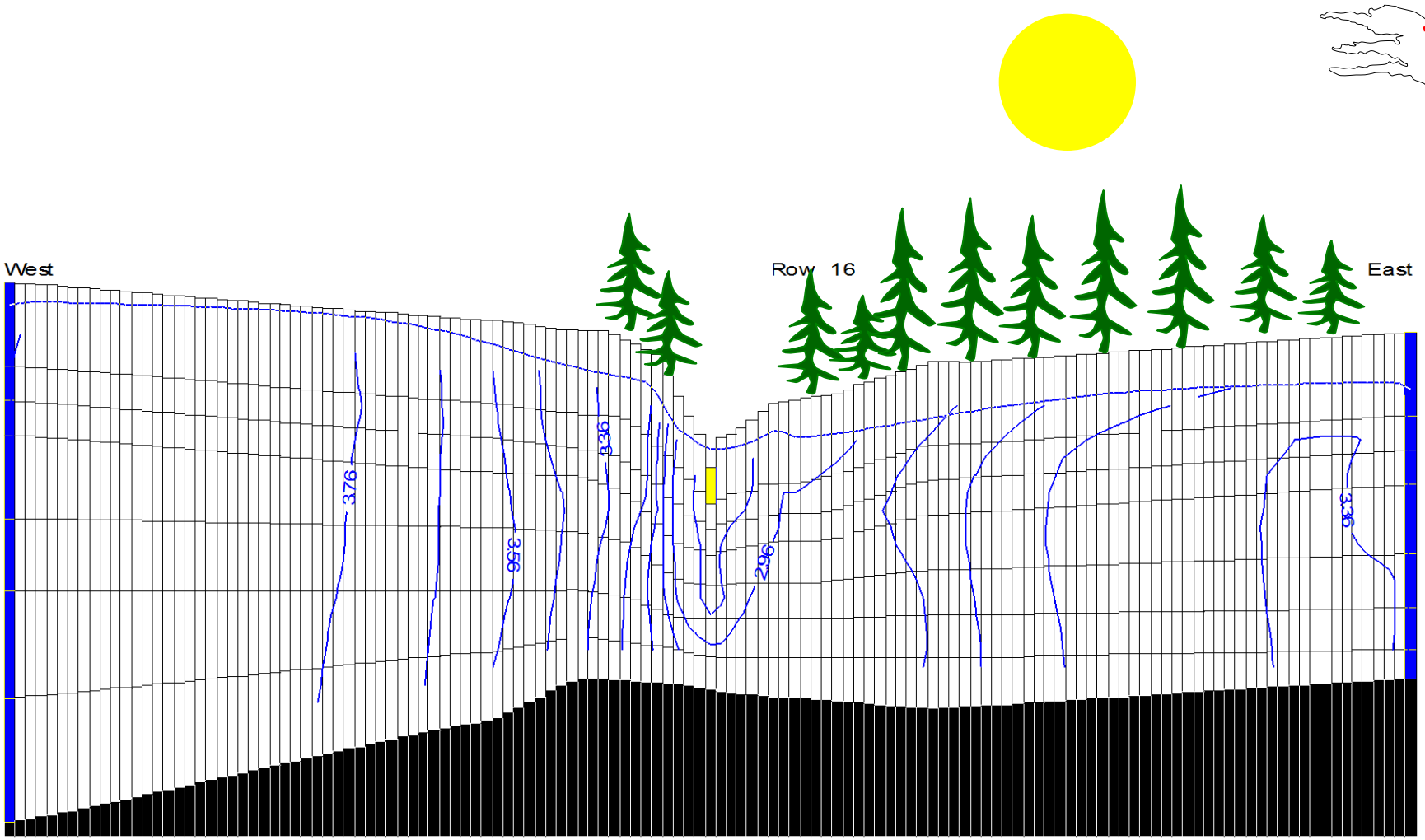

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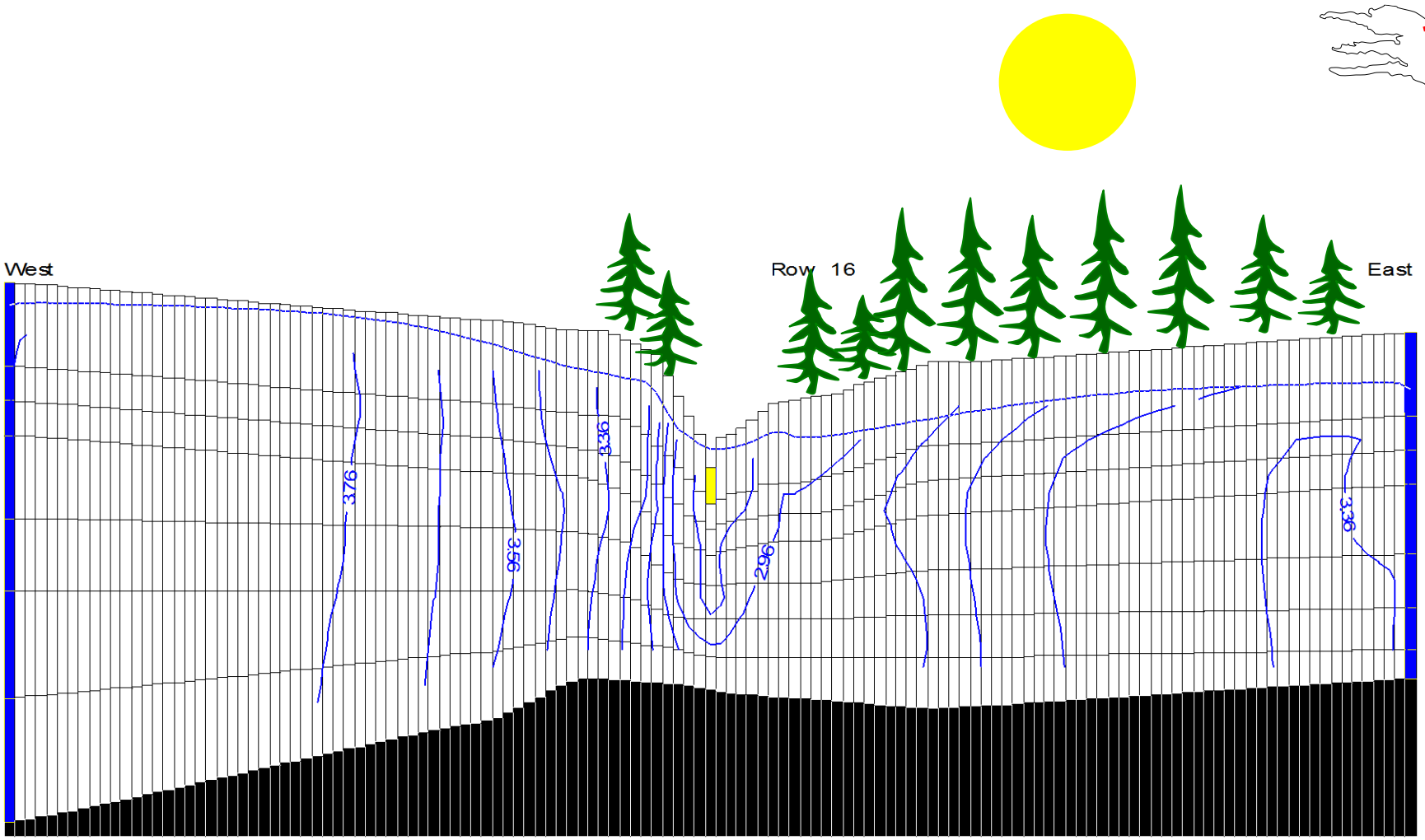

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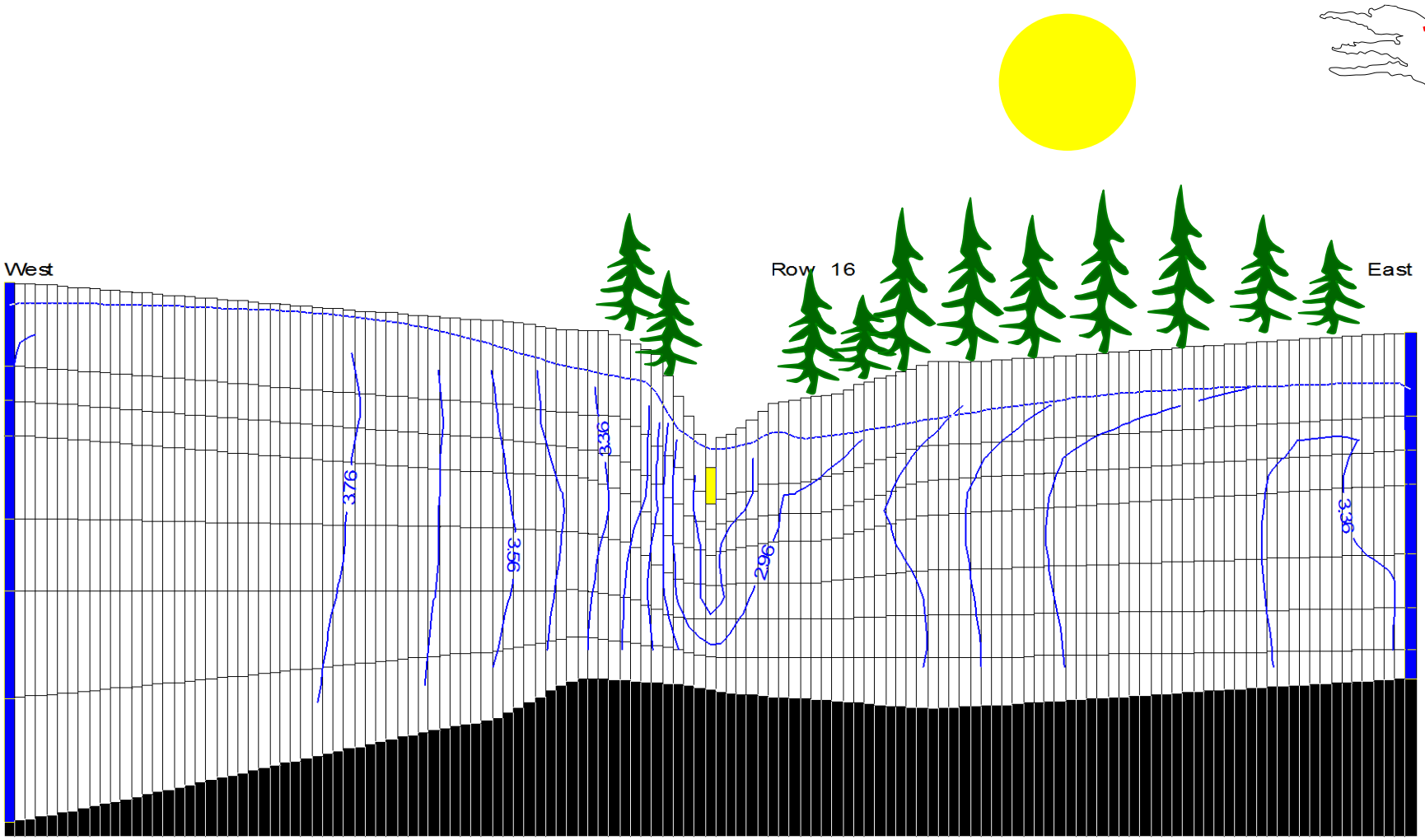

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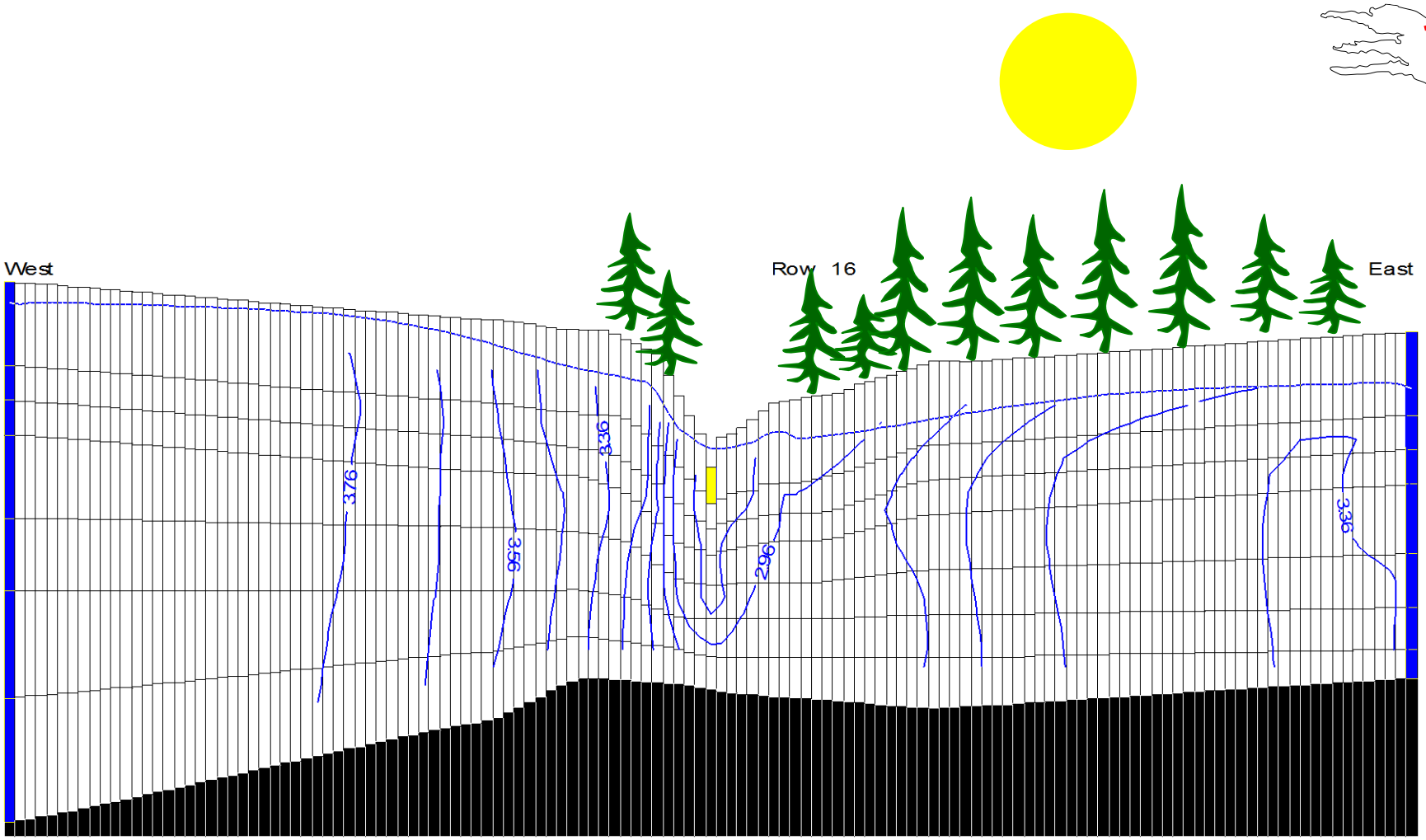

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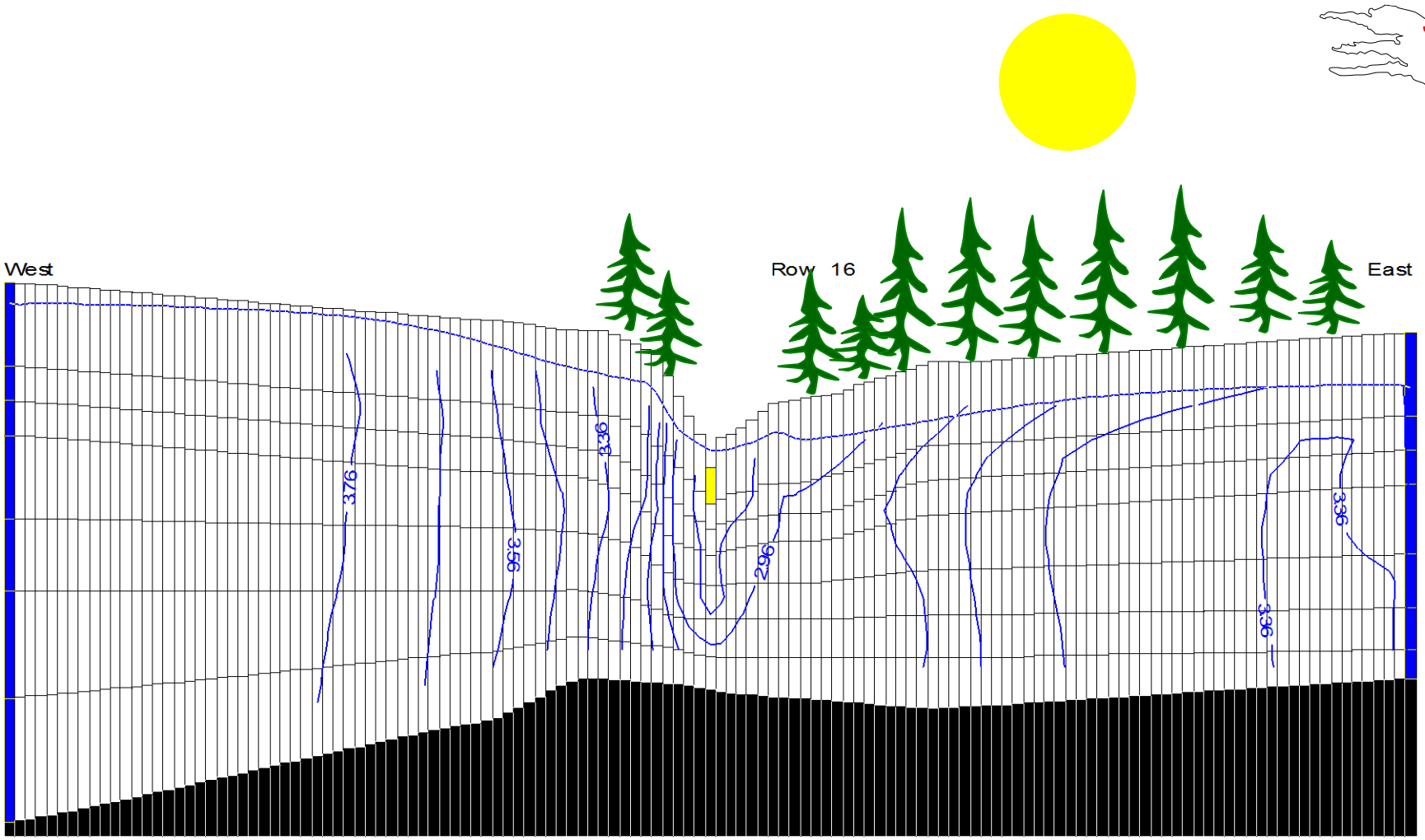

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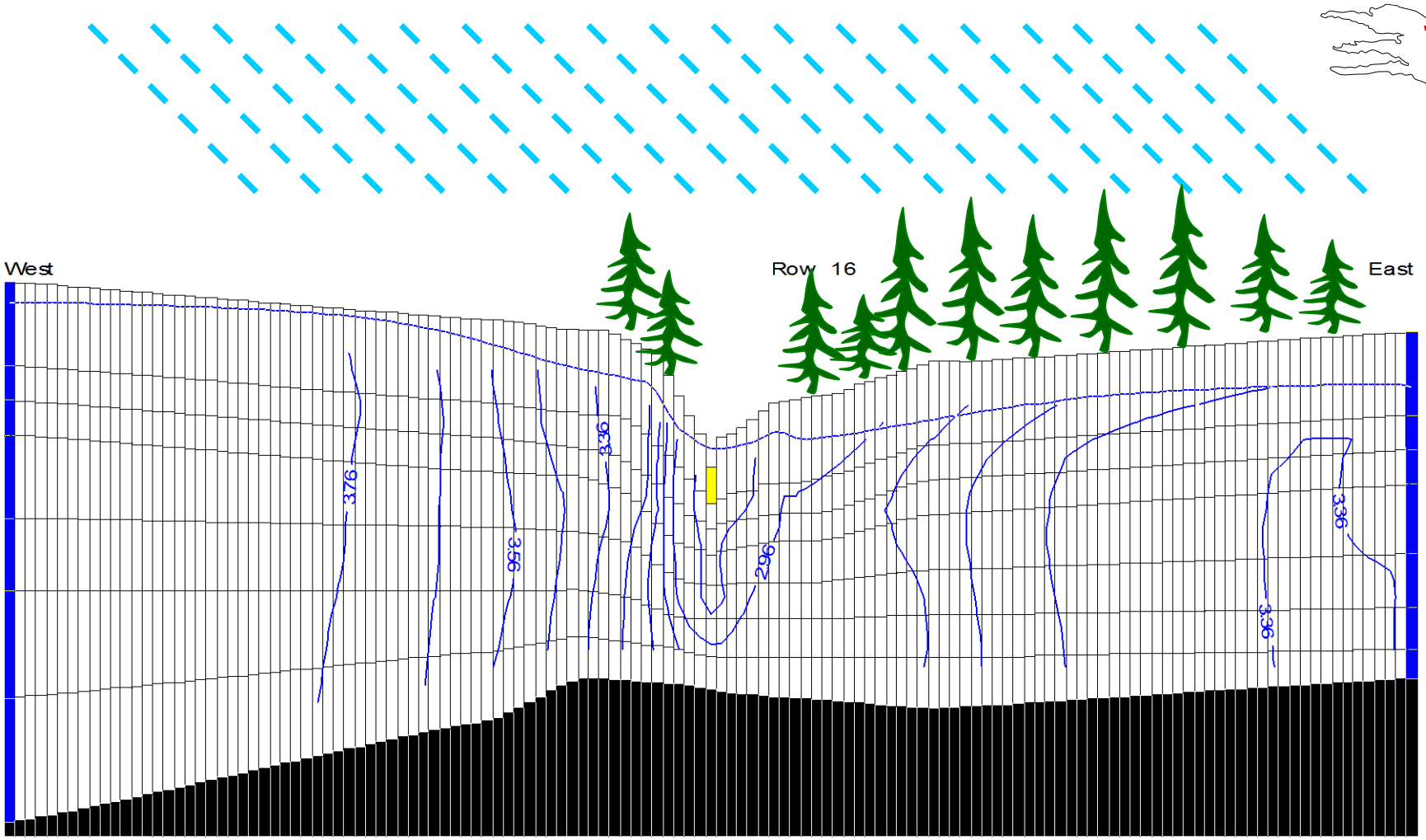

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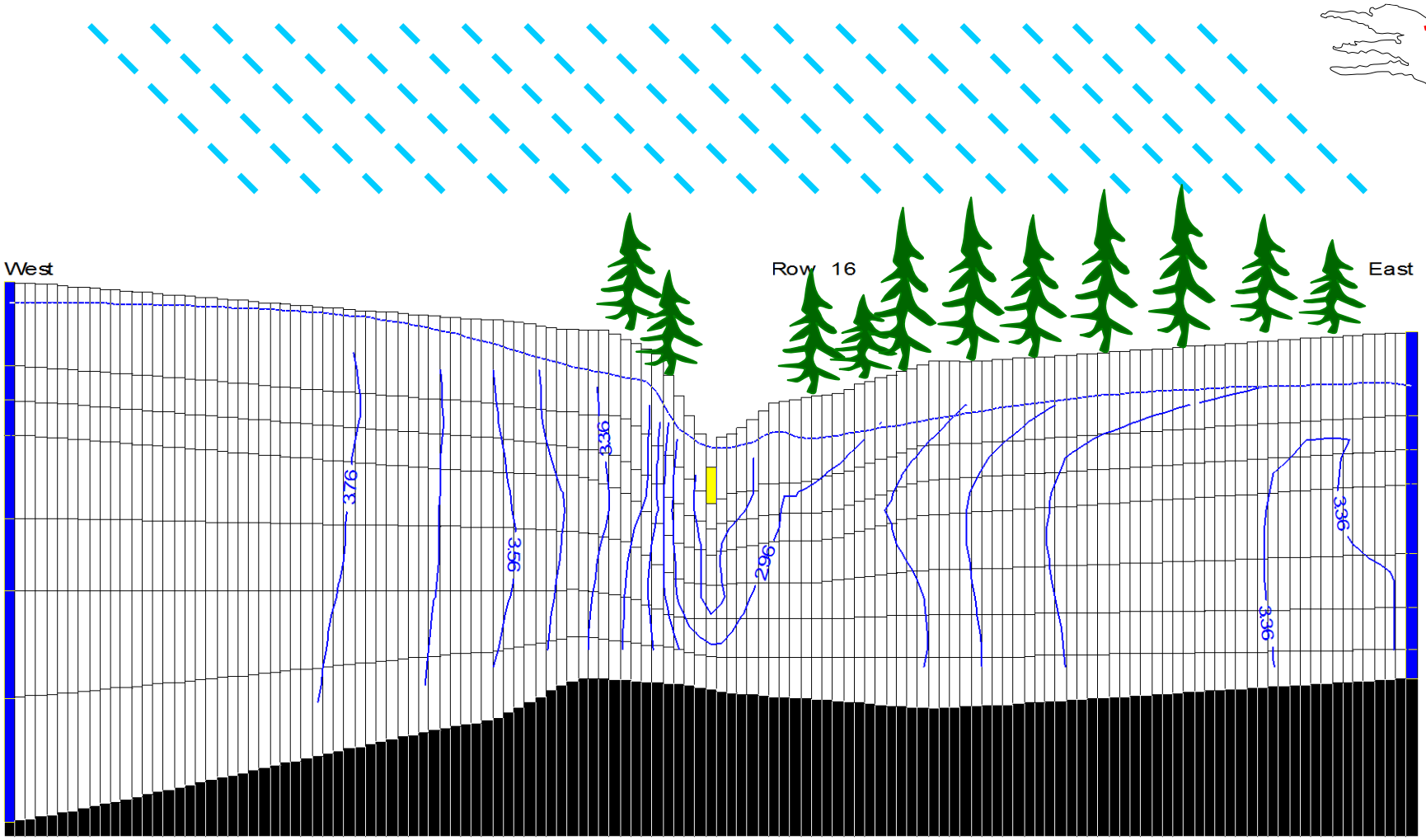
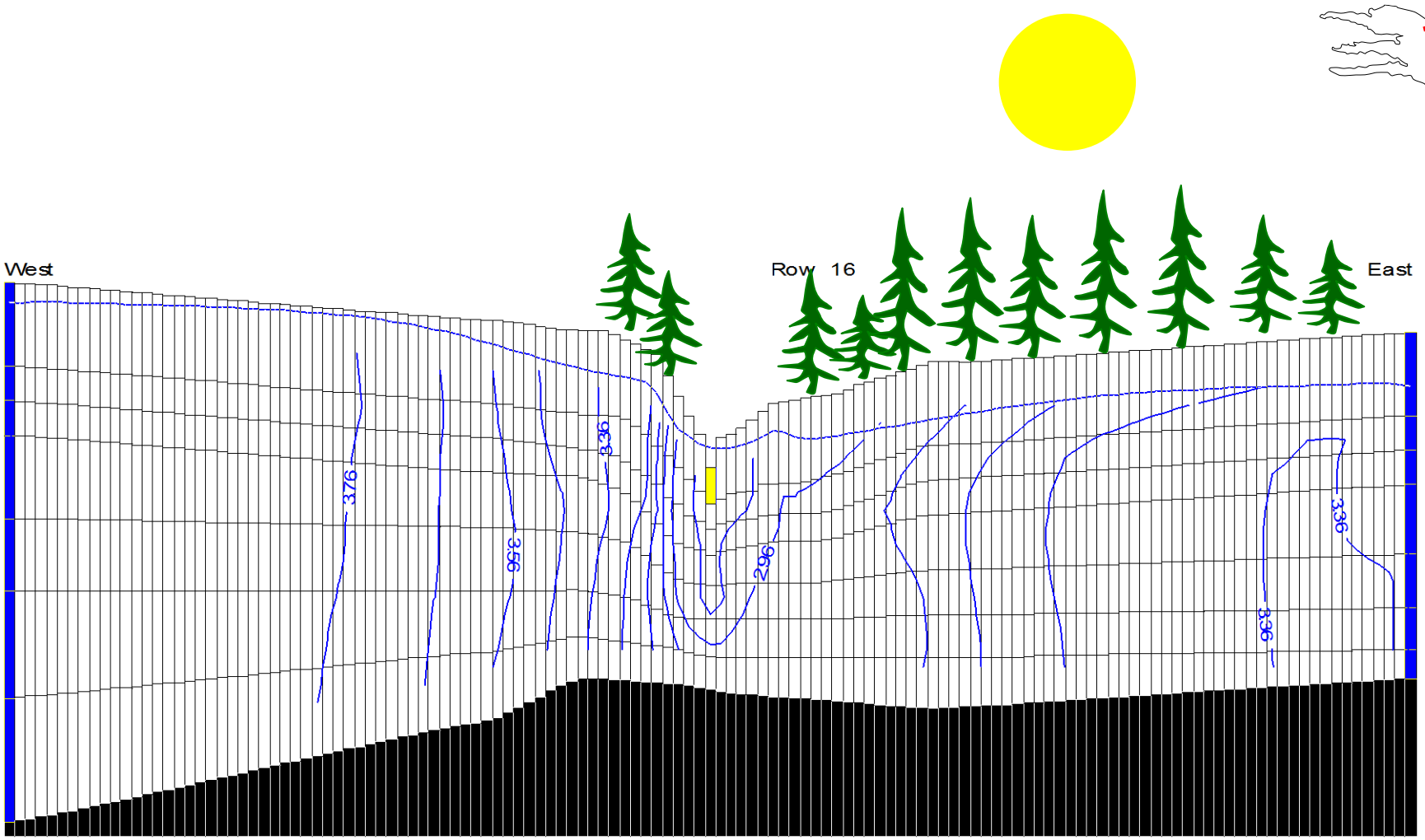


26-Sep-08



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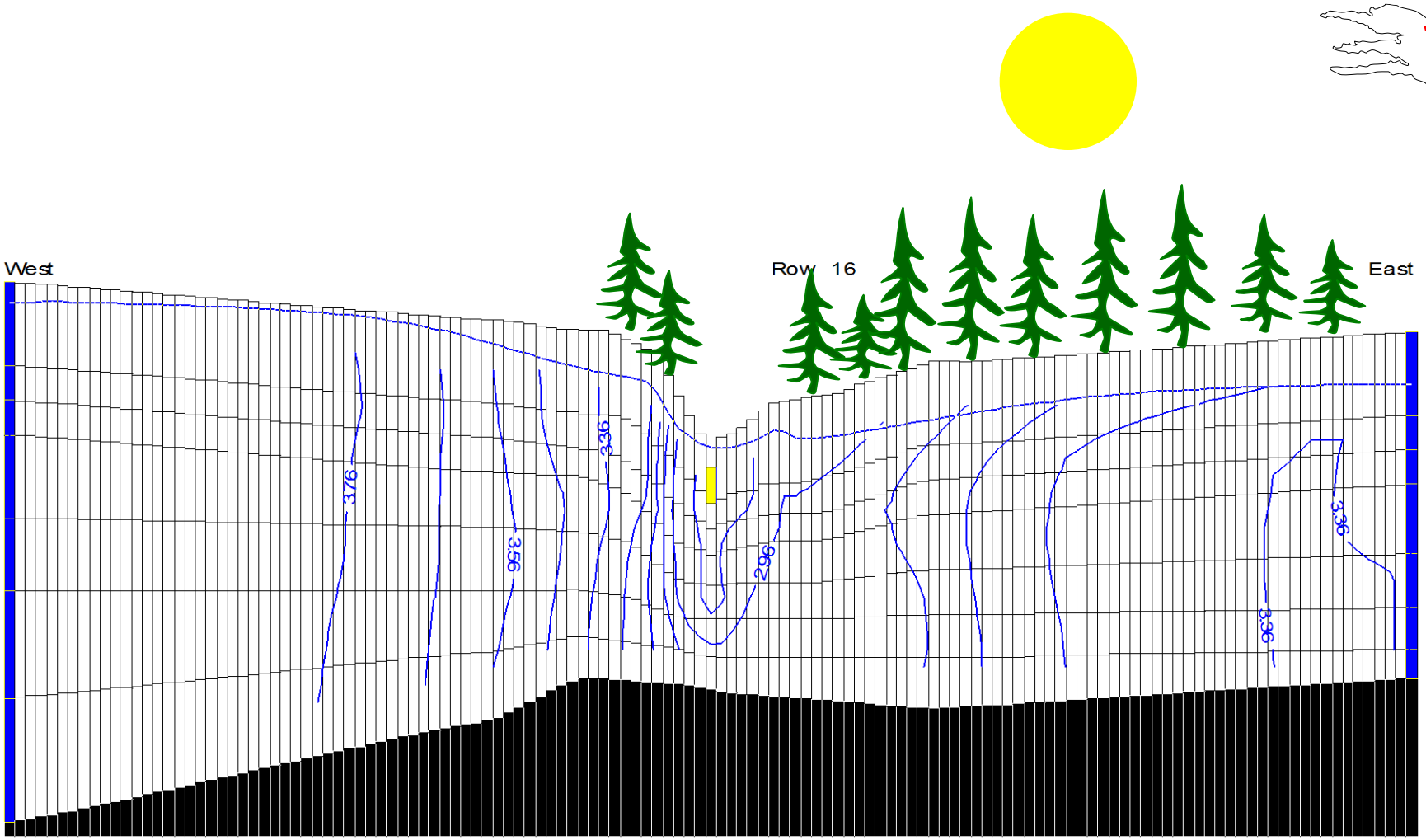
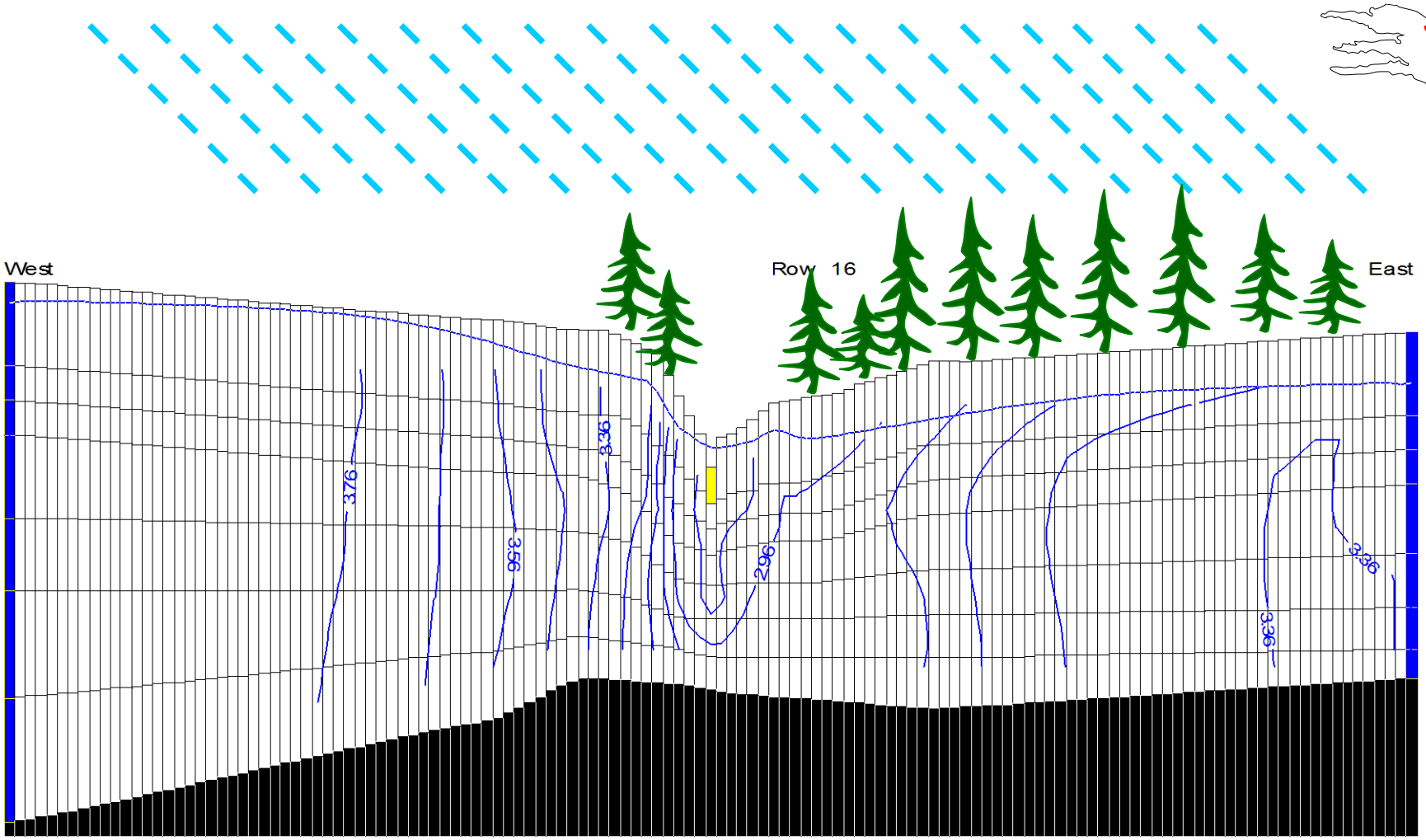
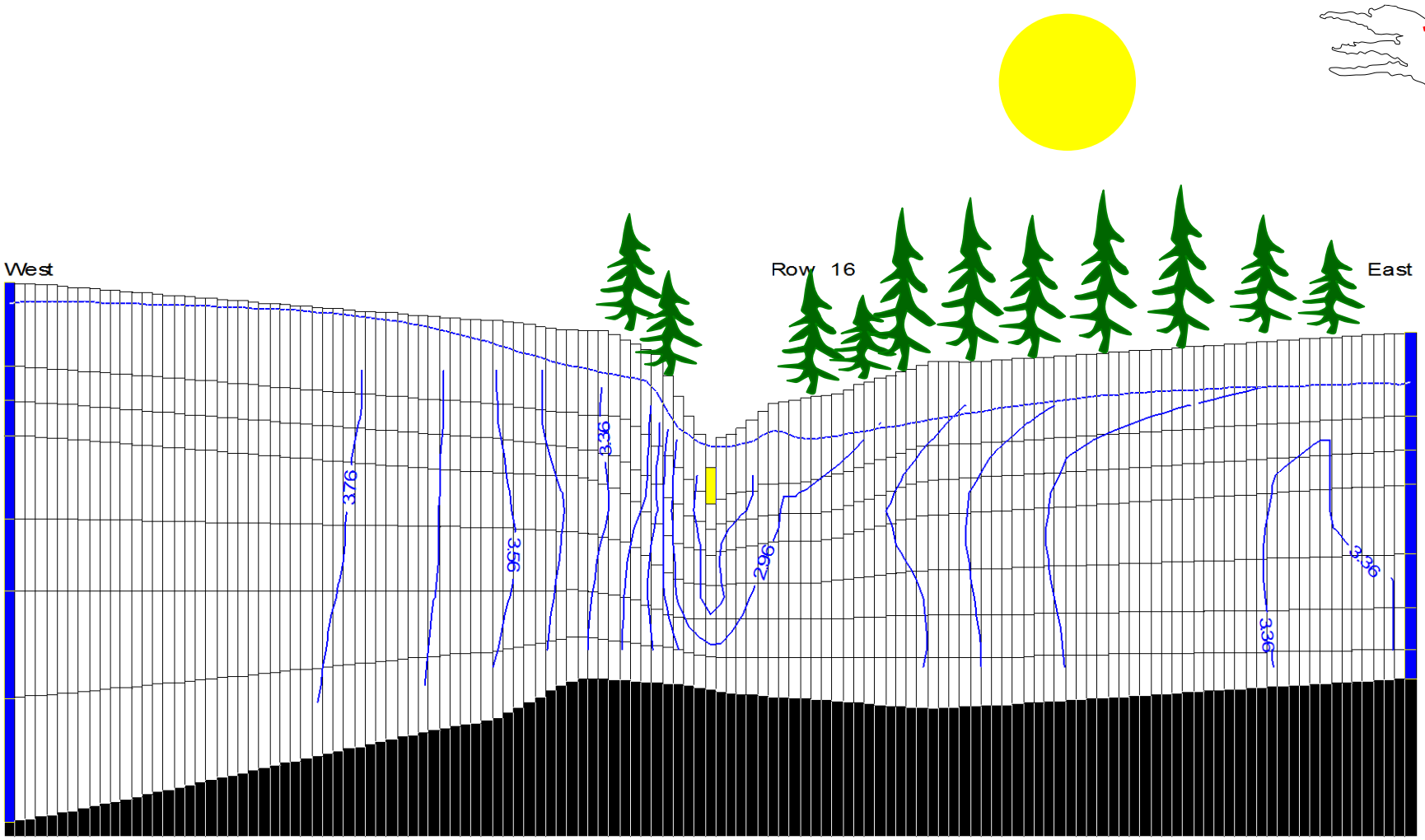


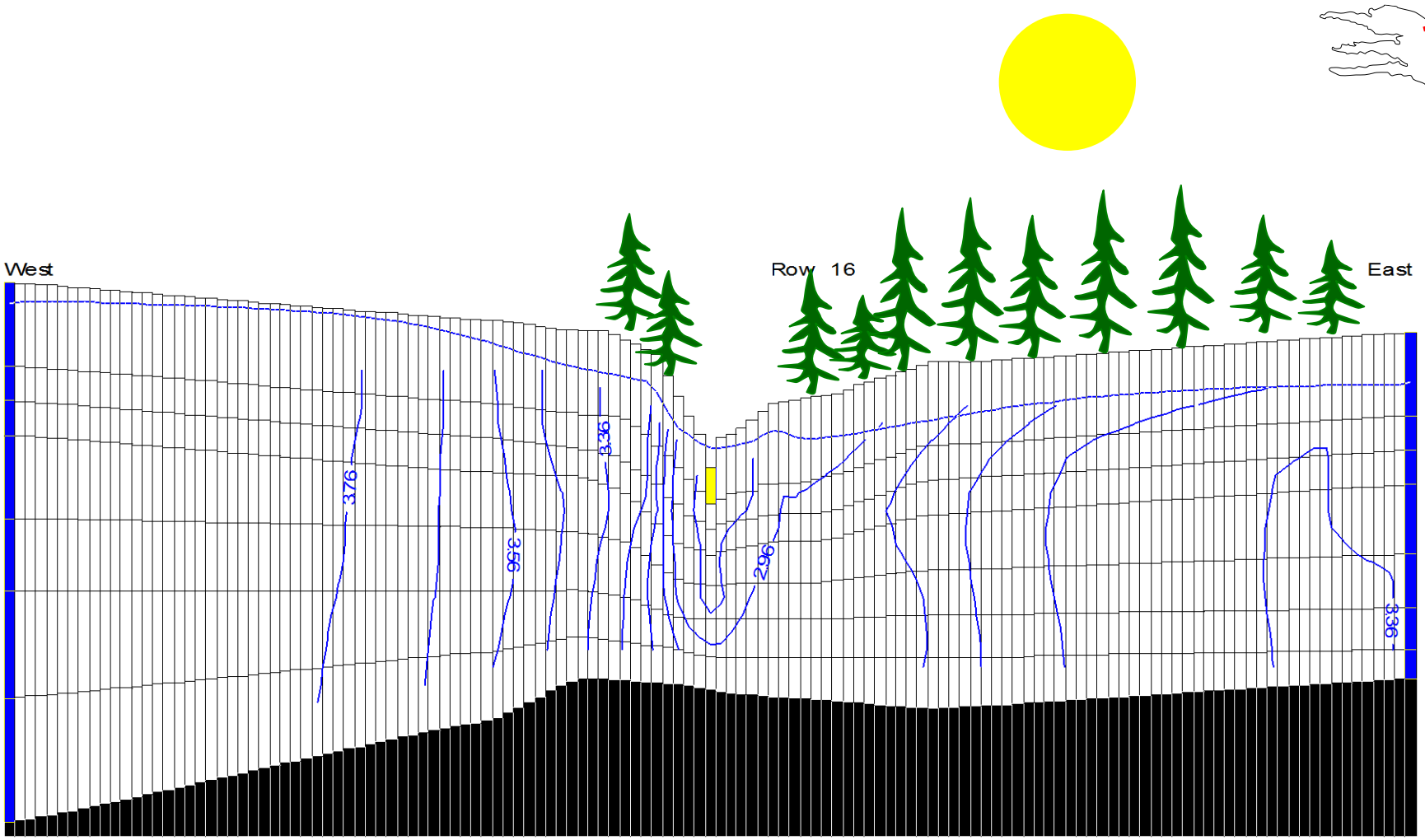
28-Sep-08



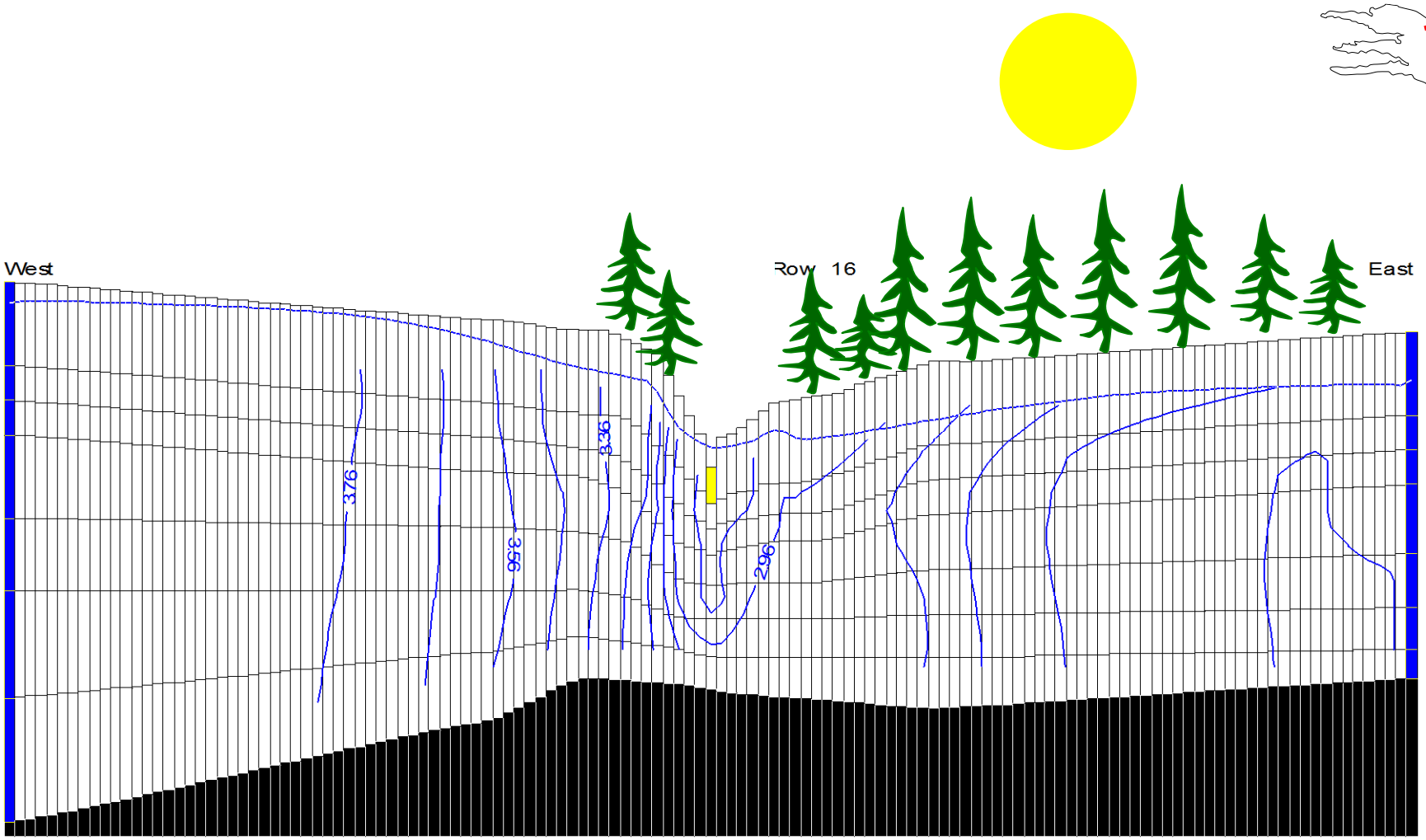
29-Sep-08



30-Sep-08

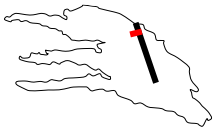


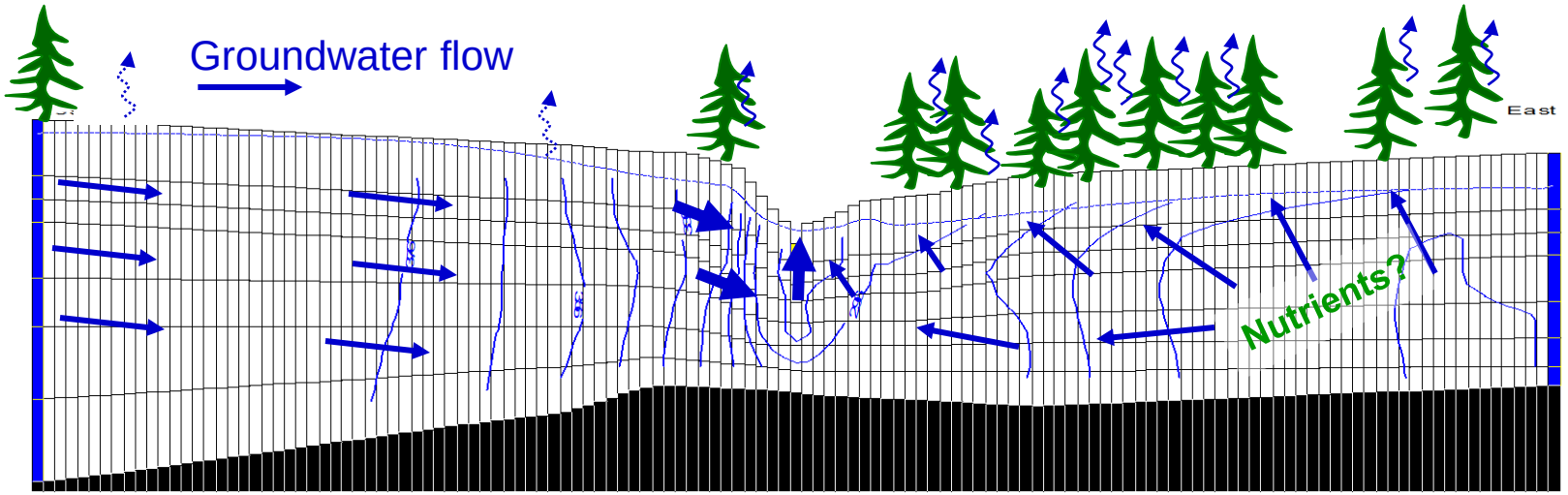
01-Oct-08

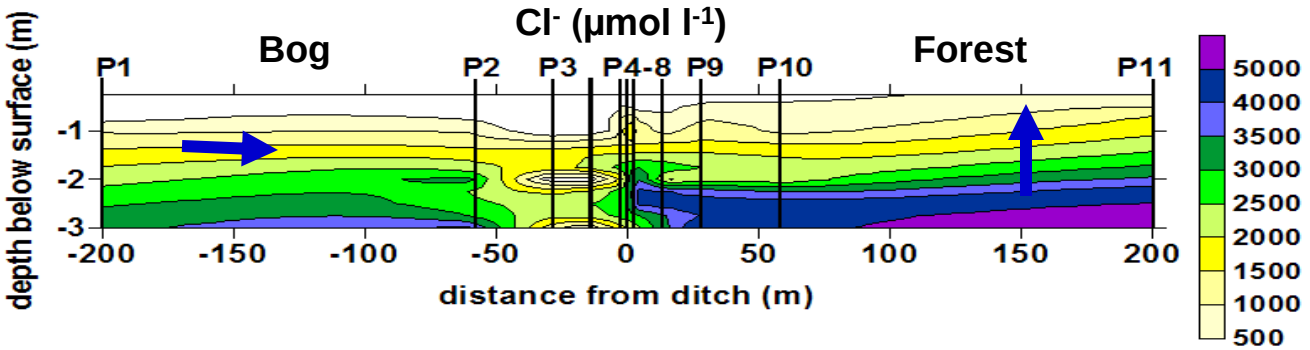


02-Oct-08

Reasons: positive feedback because of trees!



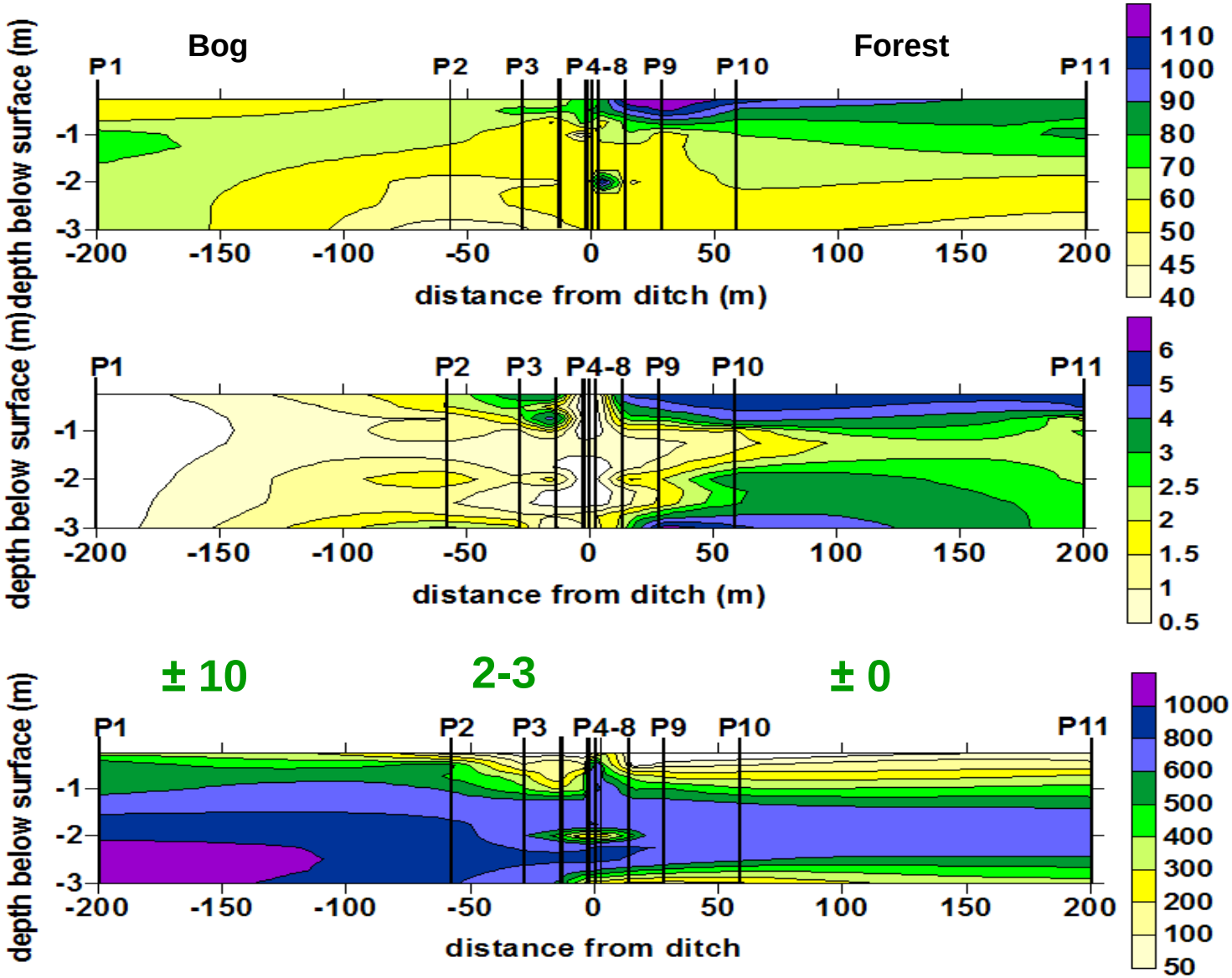




Groundwater movement is upward under the newly established forest because of higher transpiration, bringing nutrients with it; under Bog it is mostly downwards because of precipitation > transpiration

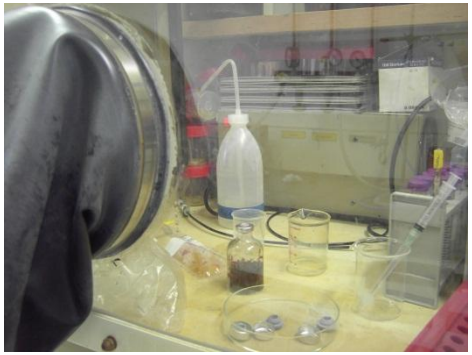
Kopp and Blodau et al. (2011) Hydrologic Processes, in review

Biogeochemical consequences



Talbot, J. (2009)

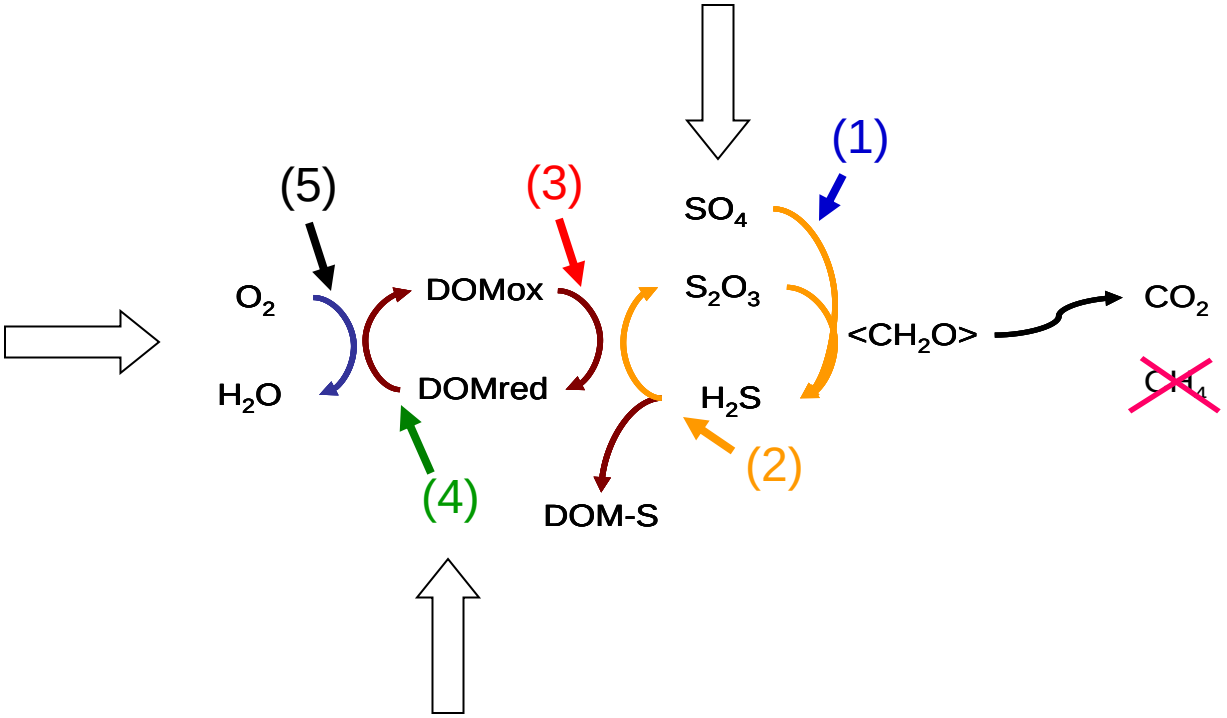
Why so little methane under forest?



Anaerobic incubation study

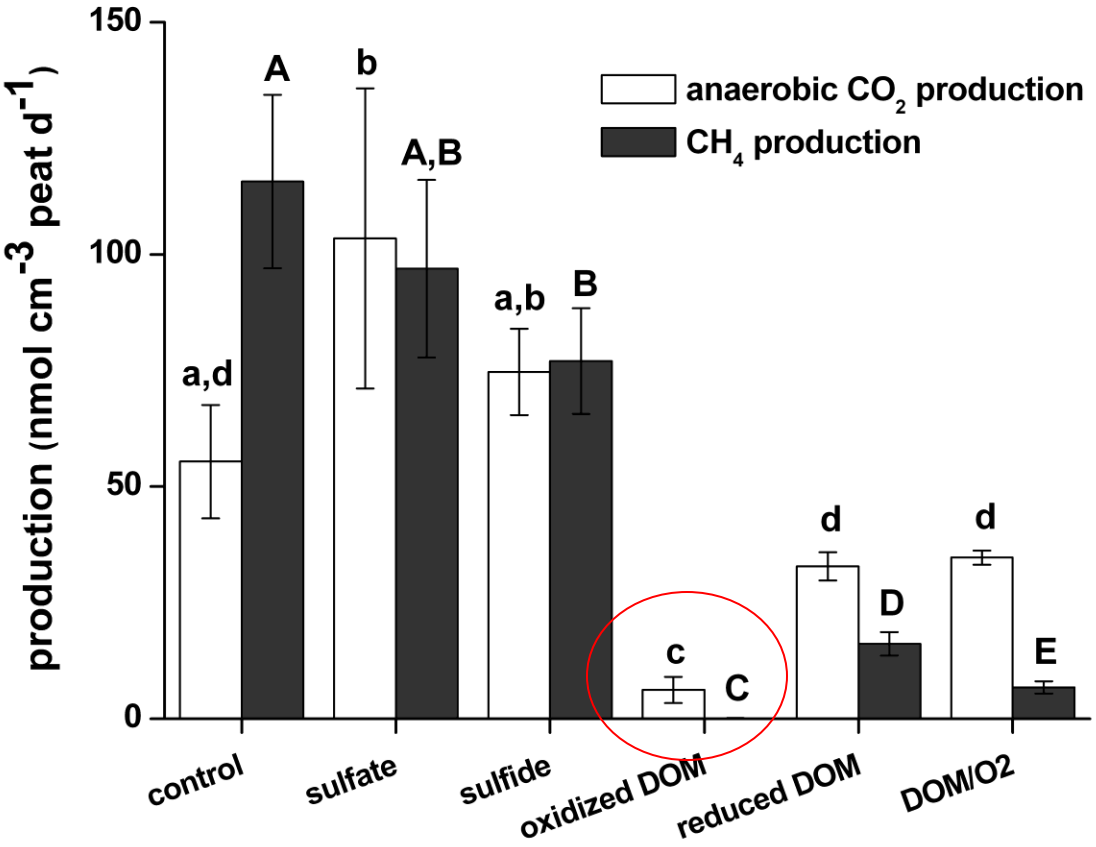
Sulfate / Sulfide

Methanogenic bog peat



DOM extract from non-methanogenic forest peat

Respiration and methanogenesis

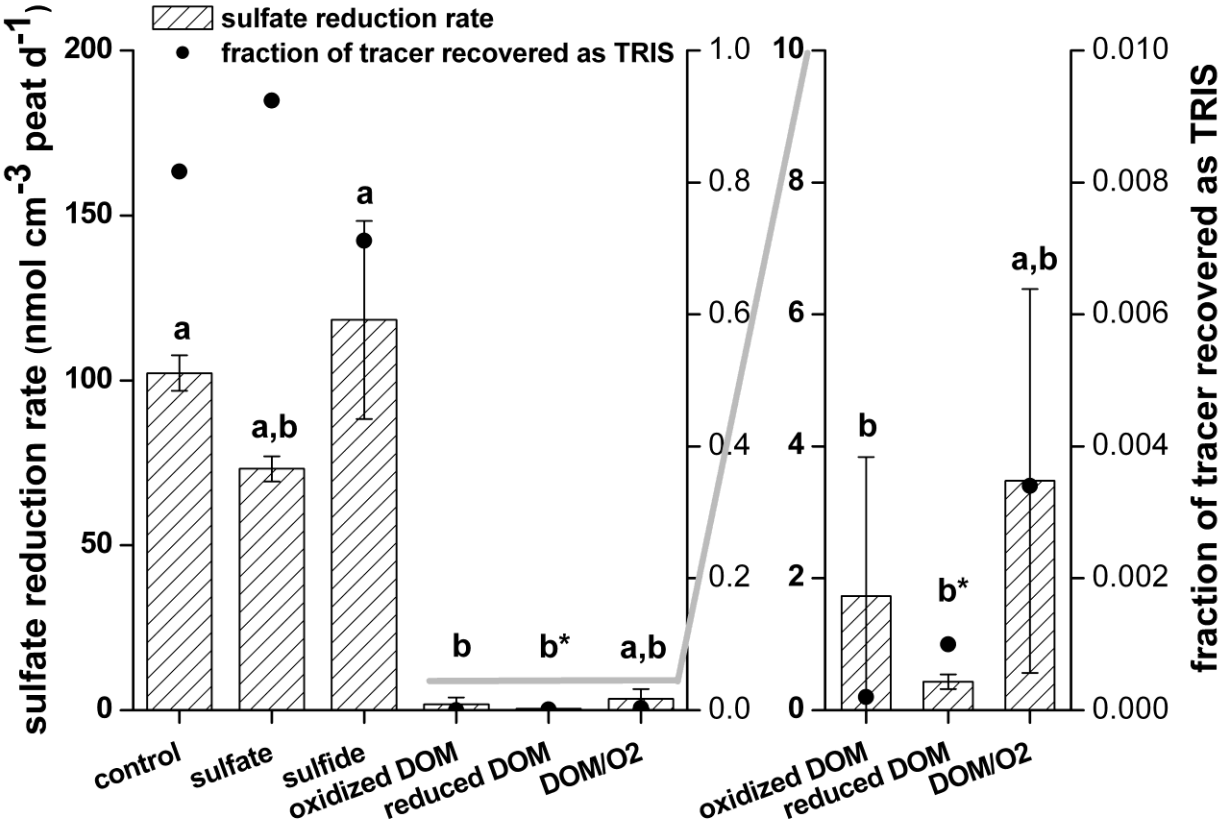


- ANOVA
- Sulfate and sulfide have expected effects on respiration and methanogenesis
- Forest-DOM extract shuts down methanogenesis and diminishes respiration in bog peat

Minderlein, S. and Blodau, C. (2010) Soil Biology Biochem.

ANOVA

Bacterial sulfate reduction

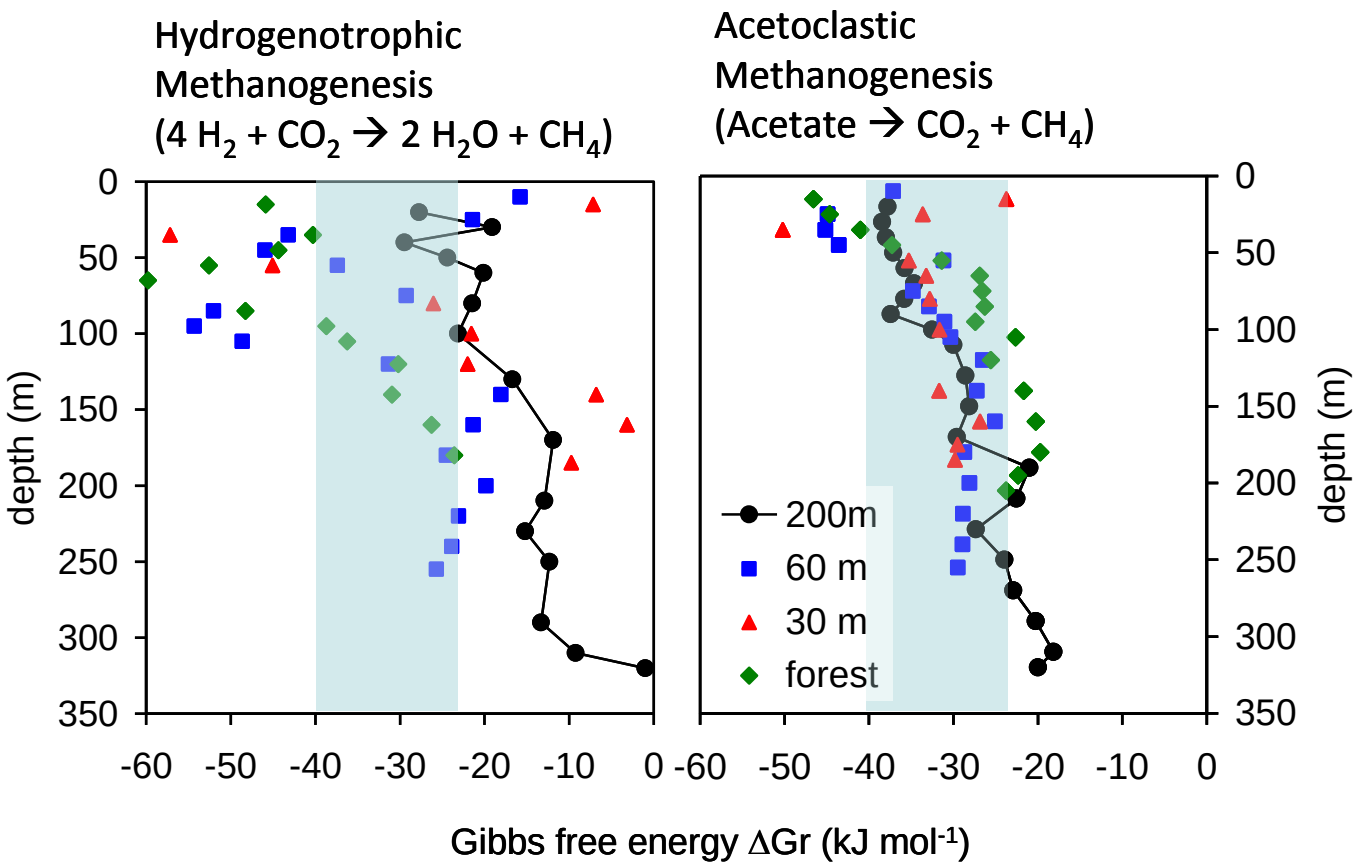


- Forest-DOM extract shuts down bacterial sulfate reduction in bog peat

Kruskal-Wallis test

Minderlein, S. and Blodau, C. (2010) Soil Biology Biochem.

Insight from the thermodynamics of in situ *methane production*



- Free energy is not well utilized by hydro-genotrophic methanogens in strongly humified surface peats

⇒ argues for toxic effects on methanogenesis

⇒ does not argue for suppression by other electron acceptors

Blodau, C, Siems, M. (2010) Biogeochemistry.

Conclusions

Drainage

Enhanced decomposition

Watershed large?

Small water table change

Self-stabilization by ‚plugging'

Bog, methane production

Watershed small?

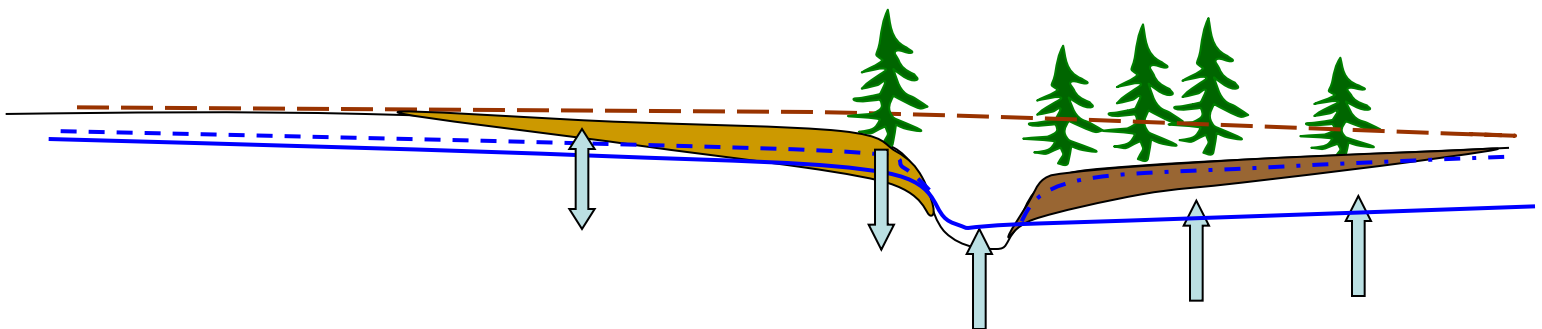
Large water table change → Invasion of trees

reversal of flow patterns, upwelling flow

Oxidation-reduction cycles

Accumulation of humic OM & DOM (toxic??)

very little methane production



UNIVERSITY of GUELPH

Limnological Research Station
Department of Hydrology
University of Bayreuth

Thank you for your attention!

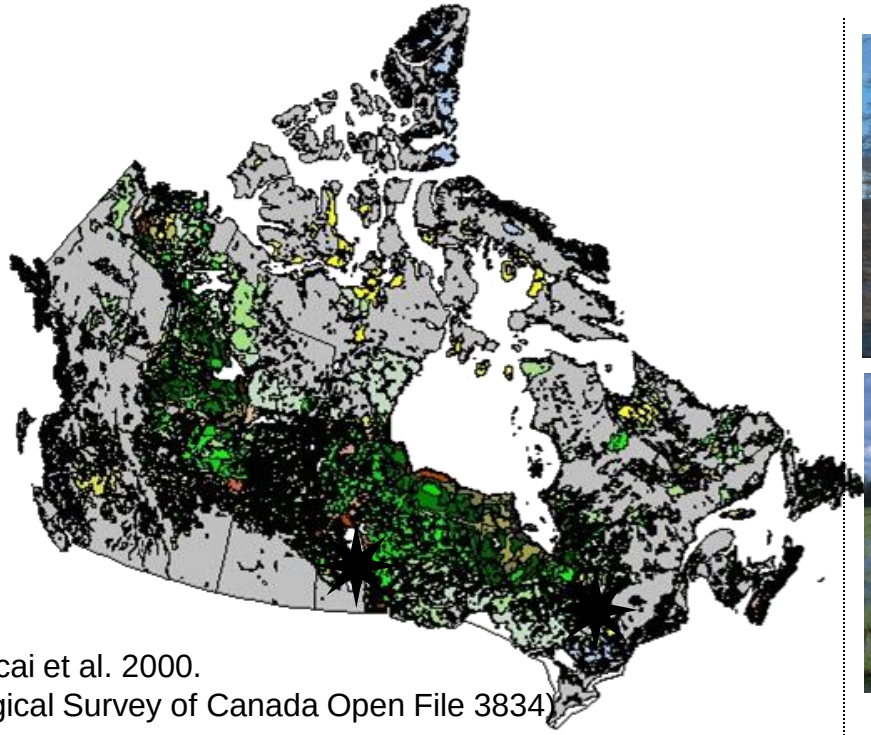
DFG, BMBF, NSERC, Fluxnet Canada

Julie Talbot, Tim Moore, Mike Dalva, Silke Hammer, Jutta Eckert, Martina Heider, Heidi Zier

Outline

- The impact of drainage at the Mer Bleue bog as an analogue for climate change
  - Peat decomposition and hydraulic properties
  - Groundwater flow patterns
  - Below ground biogeochemistry and methane
- Conclusion: Ecohydrological structures as a regulator for methane production

A few words about northern peatlands



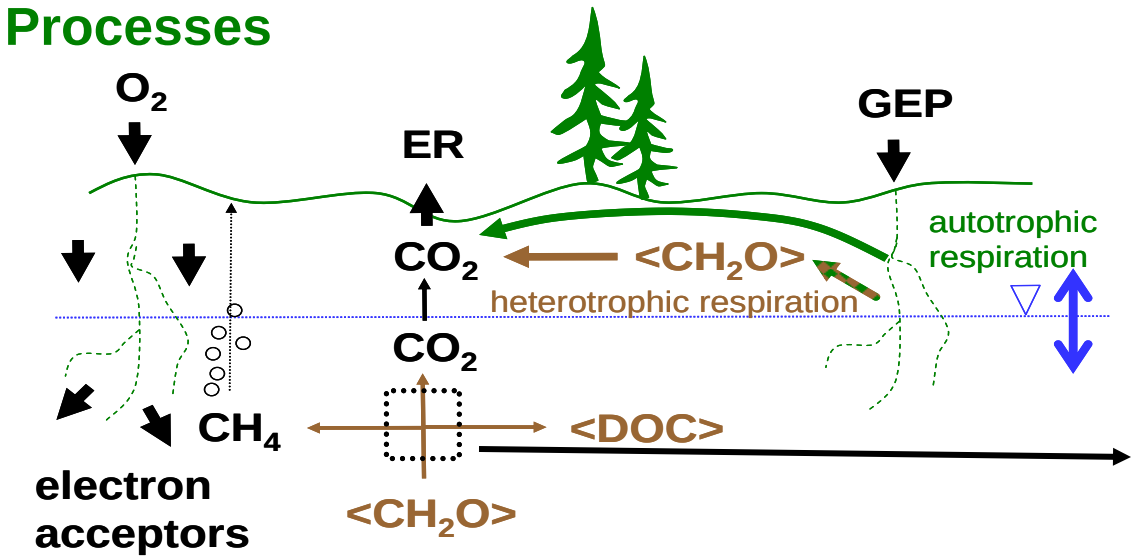
(Tarnocai et al. 2000.
Geological Survey of Canada Open File 3834)

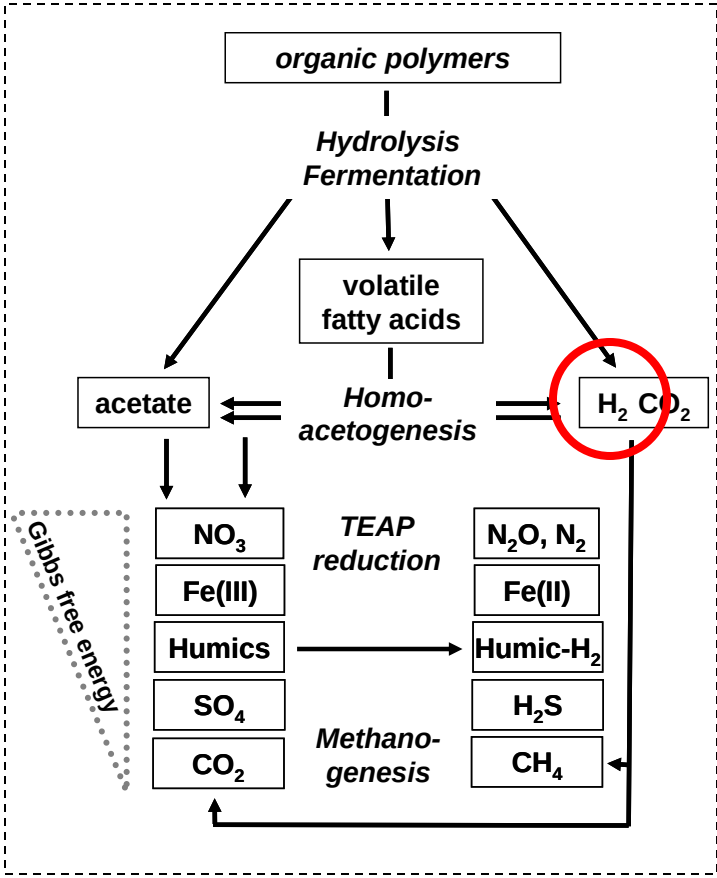
DOMINANT PEATLAND CLASSES					EXTENT OF COVERAGE
BOG	FEN	BOG/FEN	SWAMP	MARSH	
					0% - <1%
					1% - 5%
					>5% - 20%
					>20% - 35%
					>35% - 55%
					>55% - 75%
					>75% - 100%

- large area ~ 4 x 10^6 km^{-2}
- critical role in global C cycle
- sensitivity of structure and functioning to hydrology

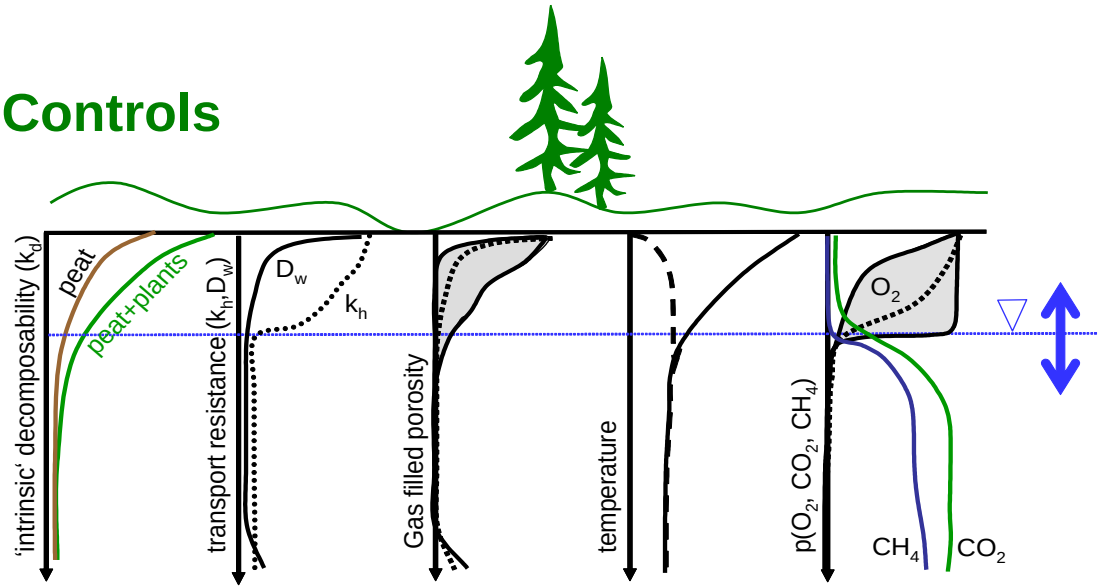
Ecosystem structure and biogeochemistry

Processes



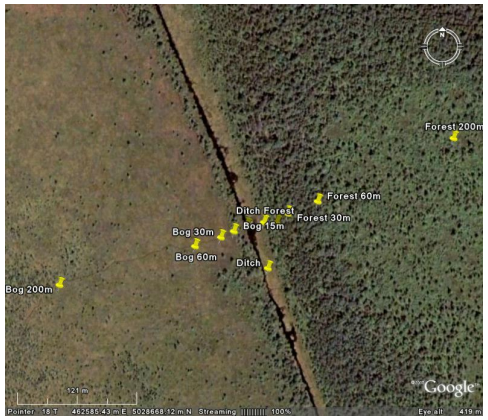


Controls



$$\Delta G_r = \Delta G_r^0 \cdot R \cdot T \cdot \ln \frac{p(CH_4)}{p(H_2)^4 \cdot p(CO_2)}$$

Ecohydrology



⇒ Drainage had a very different impact on ecohydrology (related to watershed area)

Stabilization versus regime shift!

⇒ What are the thresholds (hydrologic forcing, watershed area,nutrient availability) that determine which way bogs will respond to drying?

Why so little methane under forest?

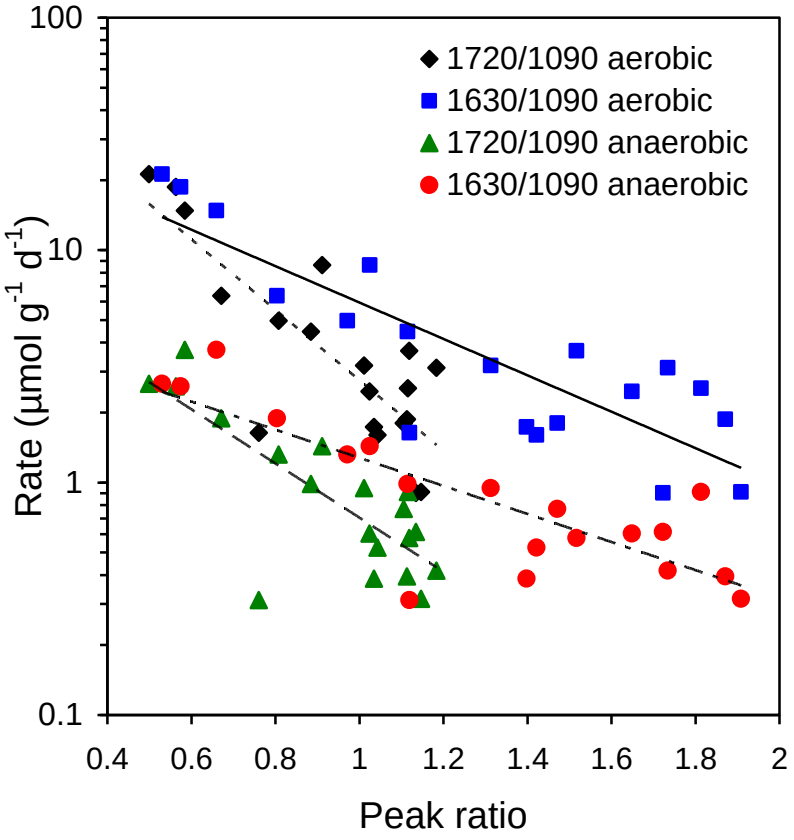
- Forest peat humic substances can inhibit methane production in bog peat
- Inhibition seems to be of toxic rather than thermodynamic nature

- Potential constraint evolves from feedbacks between biogeochemistry and ecohydrology

Conclusions

- Long-term ecosystem change alters relationships between environmental variables and biogeochemical processes and elemental fluxes
- Need to investigate factors, thresholds, and time scales involved in ecosystem and ecohydrological structures and processes
- Need to understand biogeochemical constraints on elemental transformations

Peat humification versus in vitro *respiration*



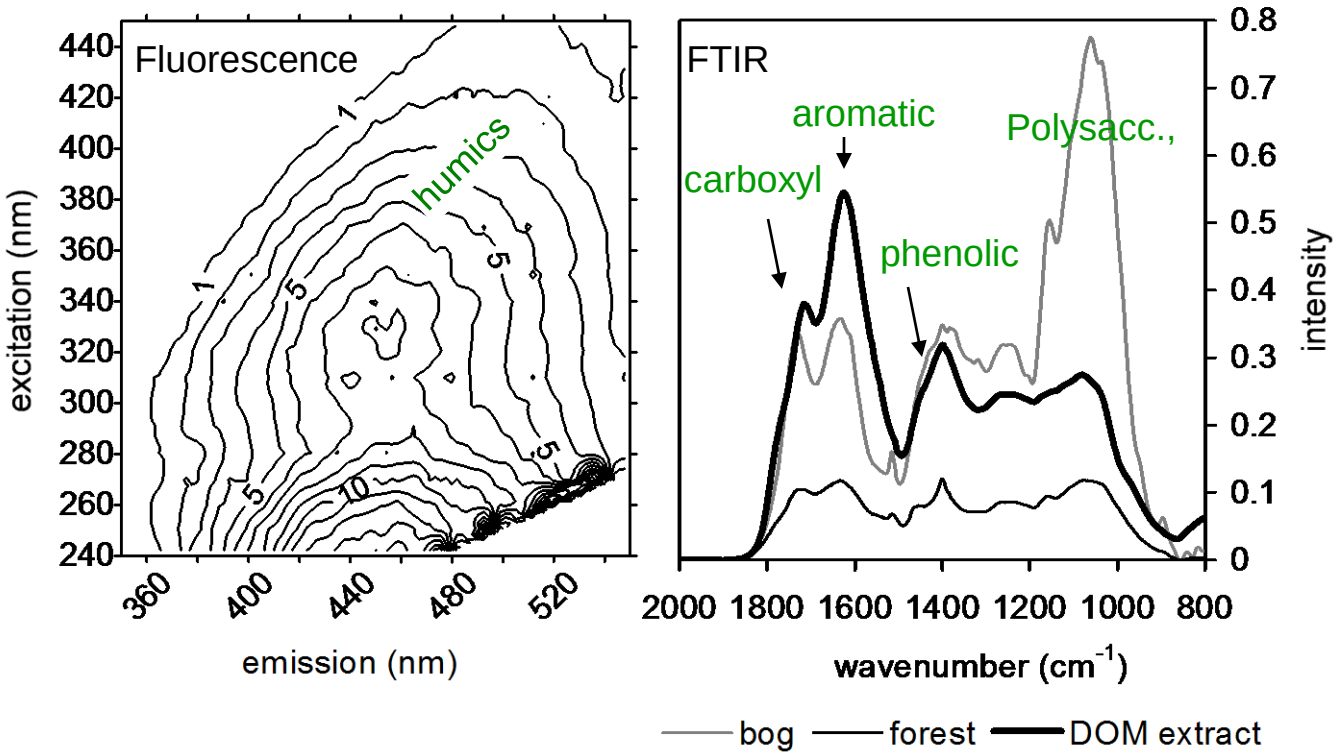
- Denser peat rich in carboxlyic, aromatic, and phenolic moieties is less decomposable
- These peats occur near the ditch and particularly under forest
- ⇒ impact on hydrology?

Blodau, C, Siems, M. (2010) Biogeochemistry , submitted.

Incubation study: forest peat extract

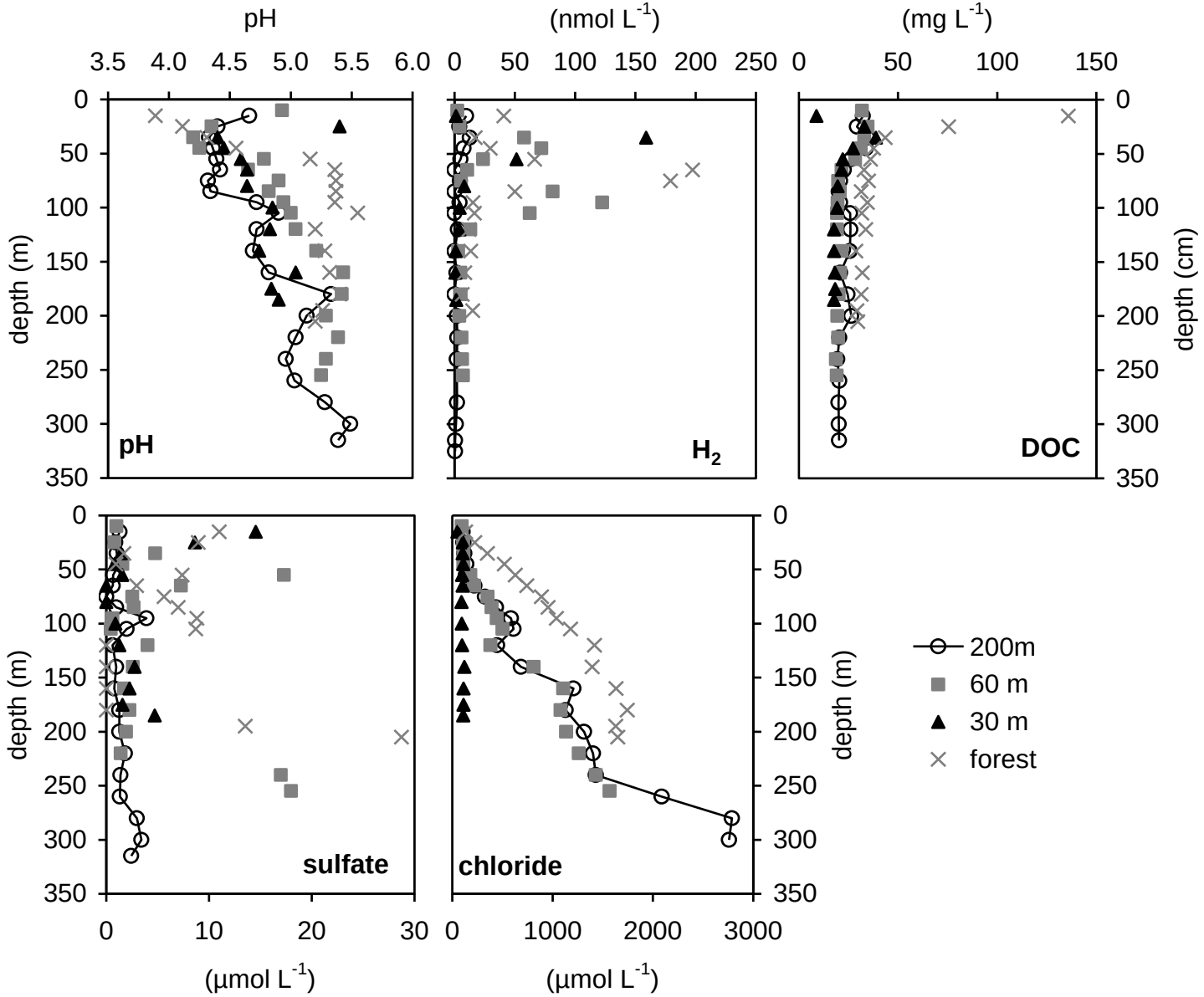
- Fluorescence spectroscopy
- FTIR spectroscopy
- trace metal analysis

-> chemistry ‘normal‘ but typical for deeper peat

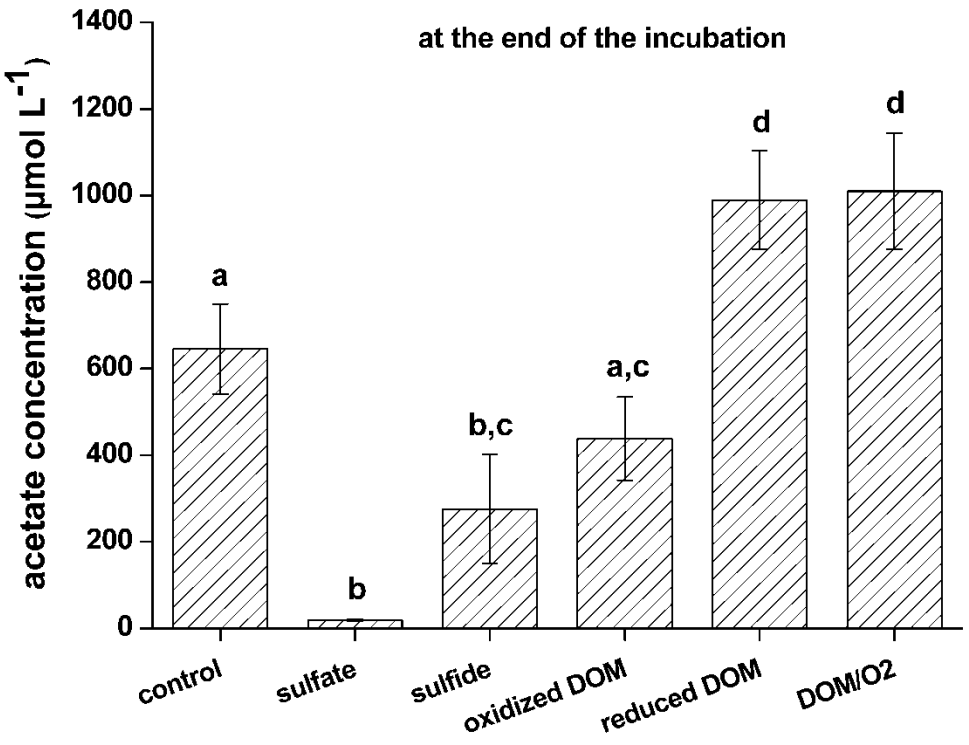


Minderlein, S. and Blodau, C. (2010) Soil Biology Biochem., in revision

Solute chemistry



Acetate concentrations



- Additional acetate is consumed when sulfate and sulfide are added
- Acetogenesis does not seem to be negatively affected by DOM extract addition

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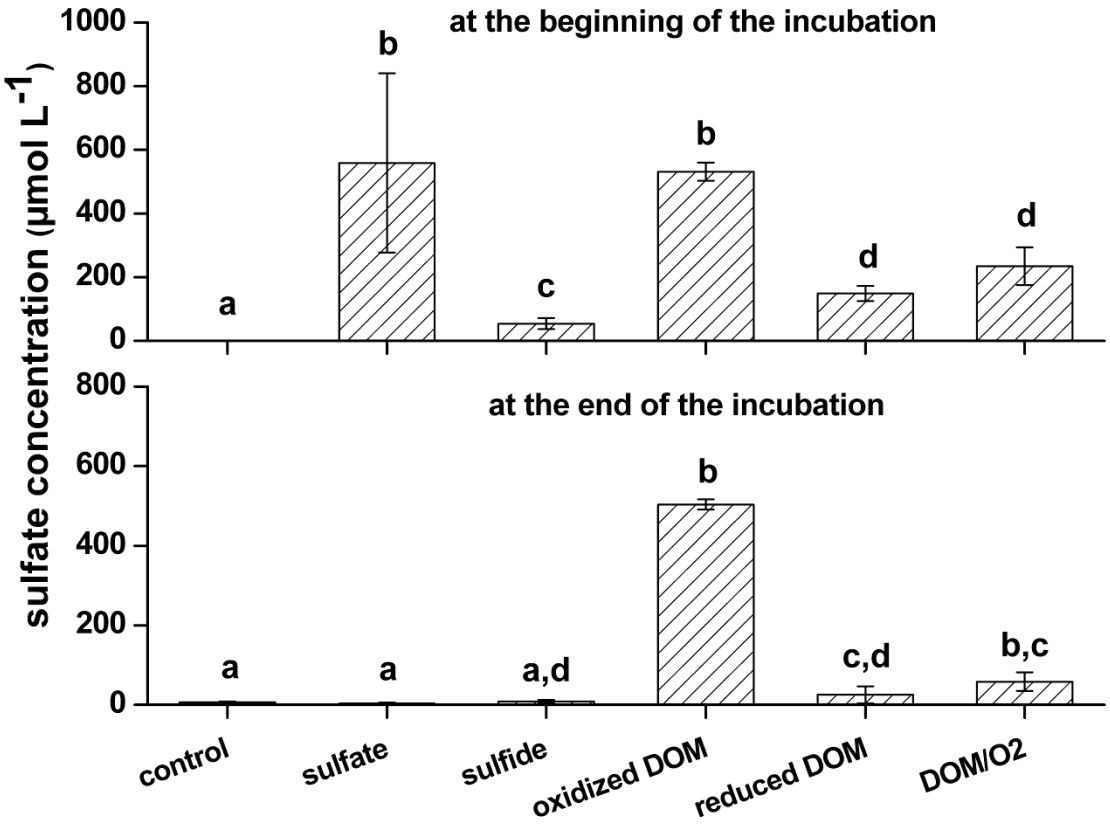

Minderlein, S. and Blodau, C. (2010) Soil Biology Biochem., in revision