DISPERSION MODELLERS (SOMETIMES) DO IT IN TUNNELS

Steve Fraser
The Airshed Ltd steve@theairshed.com

INTRODUCTION

An odour impact assessment was conducted for a new process as part of an Environmental Impact Assessment (EIA). The proposed site, within a disused quarry near sea level ~10m AOD, was chosen after a protracted site selection process involving the local planning authority, Environmental Health Officials and the local community. This raised a number of related issues including: the credibility of process design assumptions; the reputation of the operator; the environmental quality standards necessary to protect local amenity; and the complexity of the terrain undermining confidence in dispersion estimates, thereby increasing model, uncertainty.

The nearest sensitive receptors to the proposed site are two dwellings, both relatively close to the site boundary, 70m from the proposed stack. The next closest dwellings, to the north, are more than 100m distant, on a narrow coastal strip, with steep ground rising behind. To the south, the next closest dwellings are 300m from the site on the steep hillside overlooking the sea. Two process options were considered as part of the EIA (RPS 2004). The process operations are to be contained within a simple cuboid shaped building with all emissions from a stack at near ambient temperature, with mechanical extraction. Initially the design proposed was a 10m high process building with stack. Increased process capacity requirements, as the design process evolved, identified the need for a slightly higher building and external ancillary structures.

MATHEMATICAL MODELLING

The dispersion of odour from the process was initially predicted using ADMS 3.1 (CERC) and hourly sequential meteorological data. The terrain map used for the models was based on OS Landform Profile data outwith the quarry. A detailed physical survey was conducted within the quarry to provide a high resolution 1m spot height grid. The terrain algorithm for ADMS has been validated for slopes < 30^o - the quarry includes near vertical walls with the main wall sloping above 45^o - outwith the conditions for which the ADMS model has been validated. Two field tests were conducted to assess whether the model predictions were reliable. The smoke tests within the quarry confirmed that terrain caused significant re-circulating flow which was not predicted by the dispersion model. The results from ADMS 3.1 were therefore considered to be unreliable in this situation in the absence of further validation. The model version available at the time of assessment could not consider the simultaneous effects of terrain and buildings. Steady state CFD simulations using ANSYS CFX were conducted for two stack heights prior to detailed wind tunnel tests in order to gain an understanding of the local dispersion characteristics and to help refine the physical model tests. (BMT) Simulations were carried out for 30^o wind sectors for wind speeds of 2m/s and 5m/s. The highest predicted concentration for Design Option 1 (stack terminating 13m above roof ridge of 20m AOD) was 0.00207% of the emission concentration. The results from a later version of ADMS 3.3 are also reported.

WIND TUNNEL MEASUREMENTS

The results from the CFD modelling were used to inform conditions for wind tunnel tests. A physical model was constructed at scale 1:200 for the building, stack, quarry terrain and surrounding hillside. Air flow was visualised and tracer gas measurements used to estimate dilution and dispersion from the stack to the nearest two receptors (R1 & R2). Measurements were conducted for a range of wind speeds and directions for two stack heights to obtain site specific dilution factors. This stage was repeated to take account of the design changes resulting from the introduction of secondary treatment at the works. Two wind tunnel sessions were conducted to provide estimates of odour dilution:

- In the case of the initial design measurements were conducted for two stack heights, 3m and 13m above roof ridge level. (Design Option 1)
- The revised design included ancillary external structures, a higher treatment building and a different stack location.. The dispersion measurements were repeated for a stack release 13m above roof ridge level with increased stack diameter, flow rate and efflux velocity. (Design Option 2)

The flow visualisations and measurements conducted for Design Option 1 indicated that, under most conditions, the stack emissions would be drawn into the back of the quarry away from the nearest receptors. The worst case odour would occur when the wind was from 330^o at 1m/s. The highest measured concentration for Design Option 1 (stack terminating 13m above roof ridge of 20m AOD) was 0.00207% of the emission concentration.

The measurements for Design Option 2 indicated that the worst case odour would be likely to occur where the wind is from 210^o at 4m/s and the residual concentration at the nearest receptor was 0.004% of the emission strength.

COMPARISON OF MODEL PREDICTIONS

The predicted concentrations in Table 1 below are based an odour emission rate of 28,500 OU_E/s from a stack terminating 13m above roof ridge level with an efflux velocity of 15m/s with worst case wind direction. The wind tunnel measurements are in reasonable agreement with the results predicted by ADMS 3.3 and CFD. The ADMS 3.3 predictions are consistently greater than all three sets of wind tunnel measurements.

Table 1
Worst Case Odour comparing ADMS 3.3, CFD and wind tunnel measurements

Design Assessed	ADMS 3.3 Prediction $OU_{E/m}{}^3$ 98%^{ile} 1 hour	Wind Tunnel Measurement $OU_{E/m}{}^3$ 1 hour	CFD Prediction $OU_{E/m}{}^3$ 1 hour
Design Option 1 (3m stack)	5.6	5.0	2.1
Design Option 1 (13m stack)	3.5	1.4	-
Design Option 2 (13m stack)	3.5	1.1	-

The comparison between the worst case wind directions is less convincing. The results for Design Option 1 wind tunnel measurements indicated that the worst-case wind direction for the nearest house was 330^o, whereas the dispersion model ADMS 3.3 predicted the highest odour concentrations when the worst case wind direction would be 270^o. ADMS failed to predict the re-circulating flow observed in the quarry during the smoke tests.

The results from wind tunnel measurements for Design Option 2 indicated that the worst-case wind direction for the nearest house is from 210^o. ADMS 3.3 predicted the highest odour concentrations when the wind direction is from 240^o. While the CFD worst case predictions agree reasonably well with the other models considered, the worst case CFD wind directions are completely different from the other two models.

Table 2
Worst Case Wind Direction comparing ADMS 3.3, CFD and wind tunnel measurements

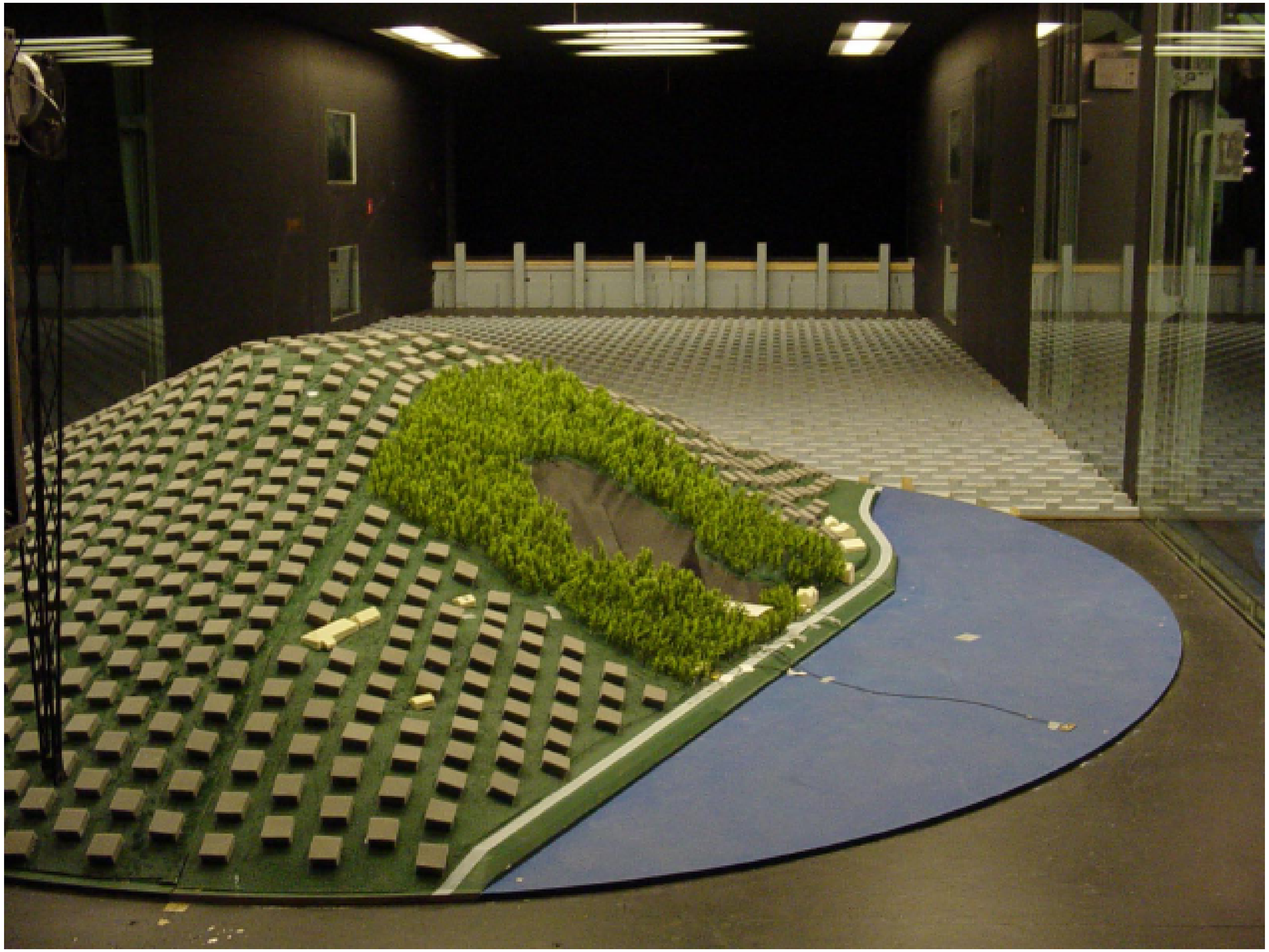
Design Assessed	ADMS 3.3	Wind Tunnel	CFD
Design Option 1 3m stack	210	270	180
Design Option 1 13m stack	240	330	-
Design Option 2 13m stack	240	210	-

CONCLUSIONS

The ground level concentrations at the nearest receptors provided by the wind tunnel tracer gas measurements and ADMS 3.3 predictions are similar and this good agreement has been repeated for three separate physical models. This provides limited validation for the terrain algorithm in ADMS 3.3, for slopes $>30^o$, at least in terms of overall dilution estimates. ADMS 3.3 does not appear to reliably predict the re-circulating flows within the quarry observed during the preliminary smoke tests conducted within the quarry. The CFD predictions are of a similar magnitude to the dispersion estimates provided by both other models, but on this limited comparison do not provide reliable estimates of worst case wind direction.

RPS Consultants 2004.
CERC 1999 *ADMS-3*, *The Multiple Source Air Dispersion Model,'* CERC, Cambridge, 1999.
BMT Fluid Mechanics Limited 2004 and 2005.

Overall view of the 1:200 scale model located in the wind tunnel



Scale Model in Wind Tunnel (Design Option 1)

Close up view of the quarry

Wind Tunnel Testing by BMT Fluid Mechanics

Figure 2

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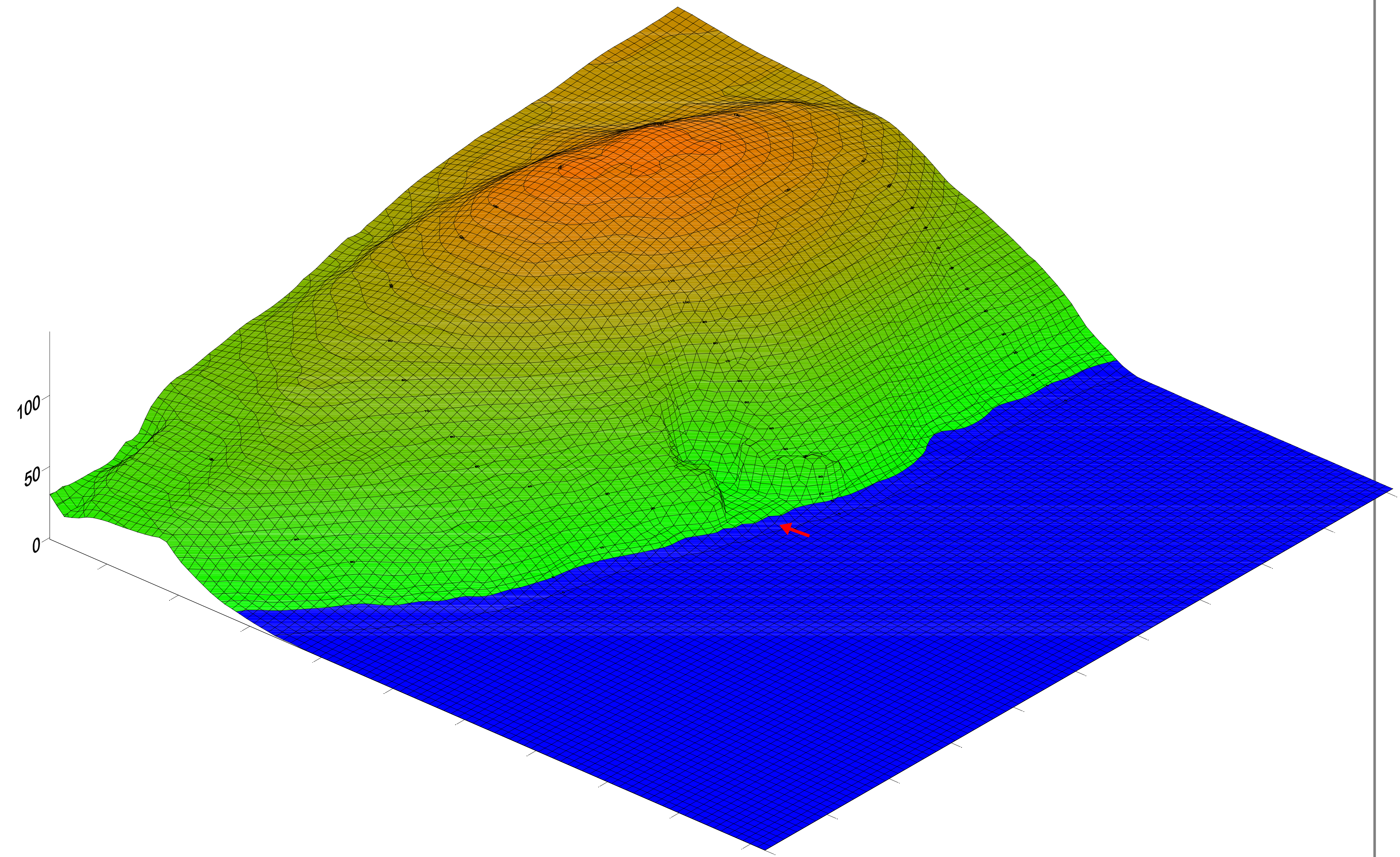

Landform Profile and Site Survey

Site Location

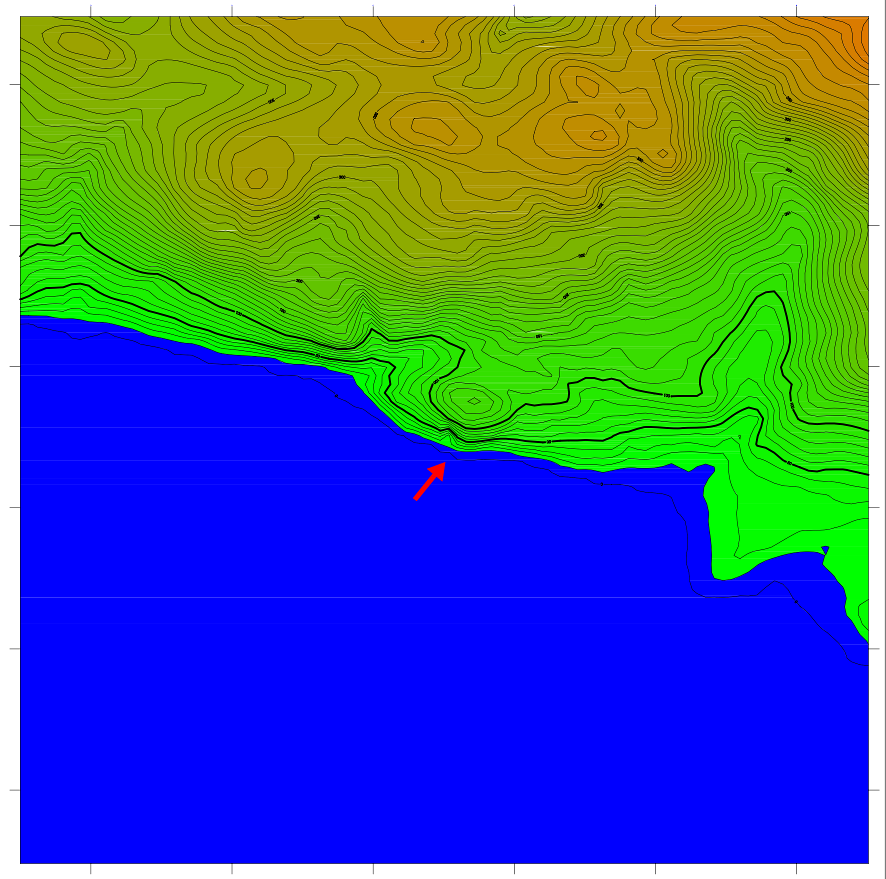

Figure 1

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