Modelling Future Aggregate Opportunities:

A National Model to Understanding Our Resources and Plan for the Future

Matthew Hill – GNS Science

Quarry NZ Conference

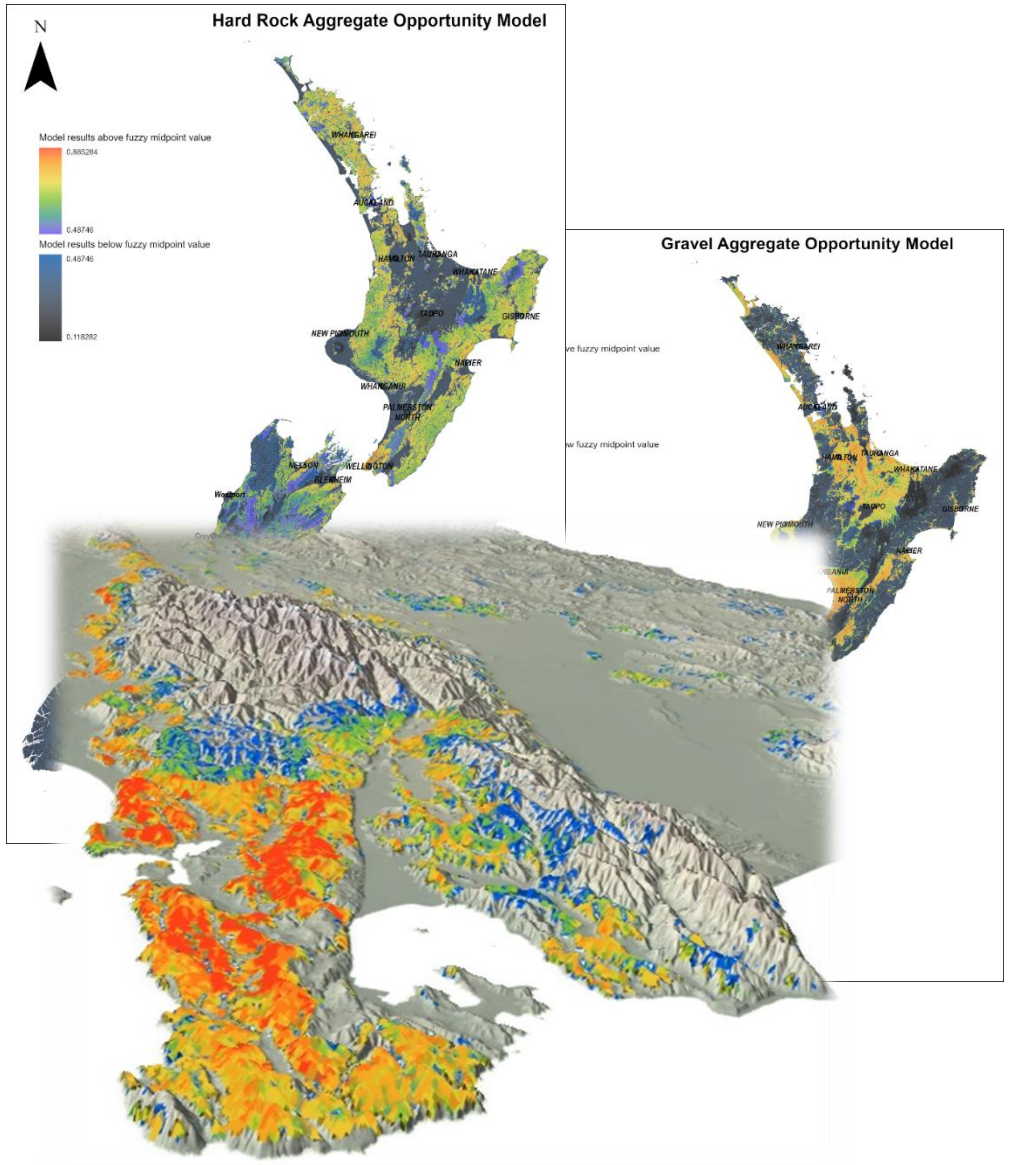
16 July 2021

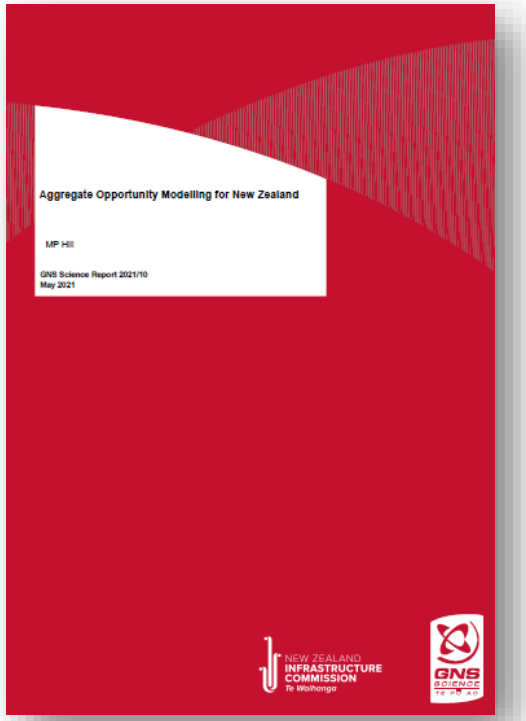
Todays Presentation:

1. **About the New Zealand Aggregate Opportunity Model**
   a) New Zealand aggregate background
   b) Predictive model components
      - Source material
      - Land use
      - Demand analysis
      - Supporting infrastructure
      - Cultural sensitivity
   c) Model results
2. **Regional Aggregate Opportunity**
   - An example from the Hawke's Bay
3. **Creating New Rock Property Maps**

The New Zealand Aggregate Opportunity Model

- Started by GNS Science in 2018 and refined over several years with input from industry experts.
- Designed to provide a national-scale model of where aggregate opportunities exist so they can be investigated before allocated to other land use.
- The most recent version of the modelling was published this year in collaboration with the NZ Infrastructure Commission.
- The project locates areas where aggregate opportunity exists and where follow-up studies would provide more insight into the resource potential.





Hill MP. 2021. Aggregate Opportunity Modelling for New Zealand. 106 p. + maps and GIS. GNS Science Report 2021/10.

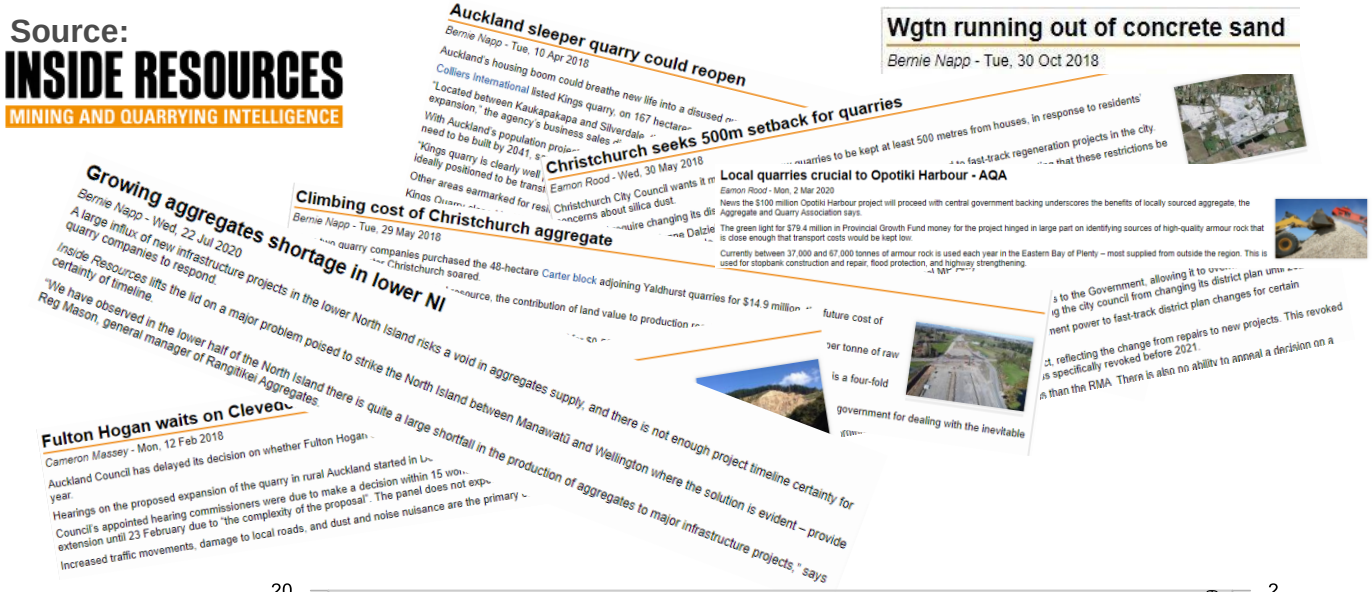
Report

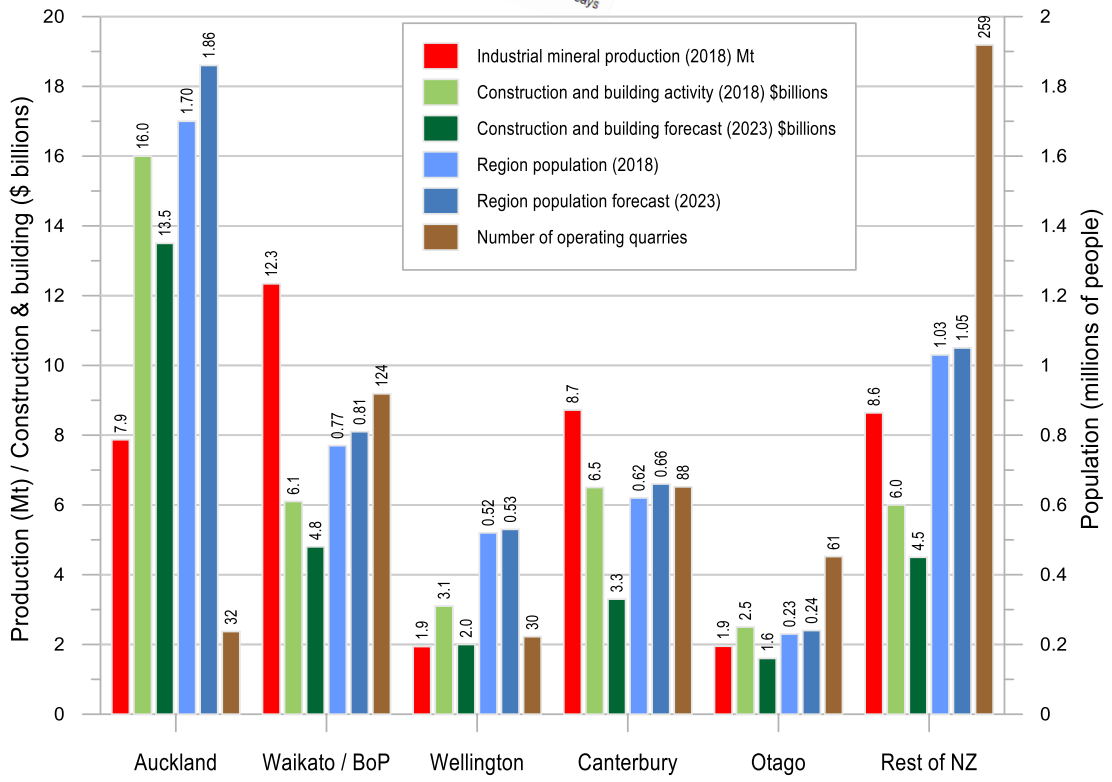
Maps & data

New Zealand Aggregates

- New Zealand's economy is demanding large quantities of industrial minerals and aggregate for building, roads and agriculture.
- Domestic production of aggregate is approximately 41 Mt per year with ~75% of that consumed in the North Island.
- Efficient utilisation of our aggregate resources is critical to reducing costs and transport emissions.
- Long-distance transport is generally uneconomic, so sources of aggregate are required near the end users.
- Managing the future demand requirements and planning for aggregate supply is essential.

Source:
INSIDE RESOURCES
MINING AND QUARRYING INTELLIGENCE



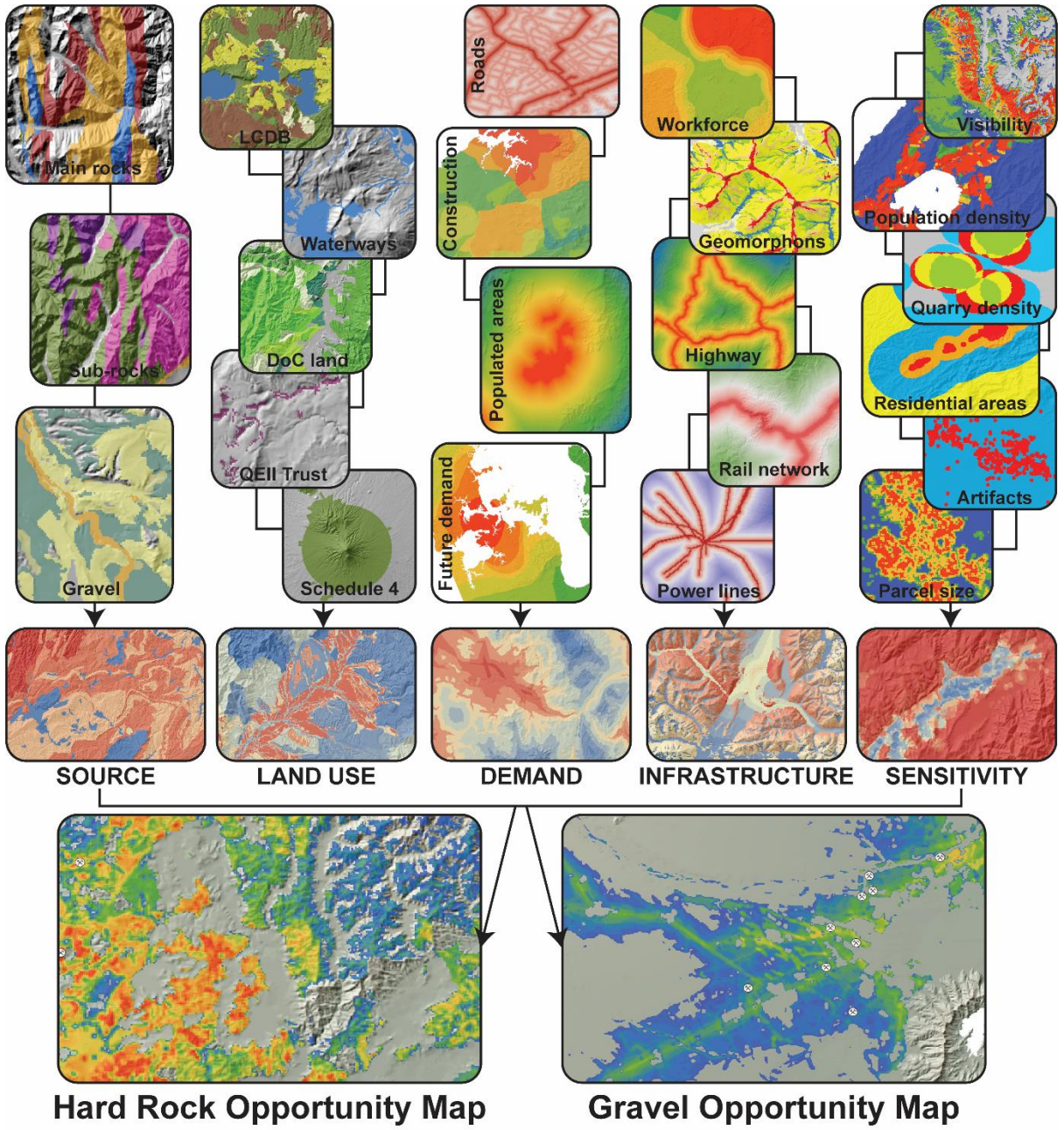


Aggregate Potential Modelling

- A focus on the rock properties that define ideal material for aggregate supply.
- E.g. rock type, volume / extent, and mechanical rock properties (e.g. density, strength, weathering resistance, alteration, etc.).

Aggregate Opportunity Modelling

- A focus on external effects to the extraction process.
- Basic locations of rock from national-scale mapping and other spatial data from DoC, Stats NZ, Landcare, etc.
- E.g. environmental restrictions, demand for material, infrastructure, and society.



LEVEL 1:
Mappable criteria layers

These are maps of source data that are classified and weighted.

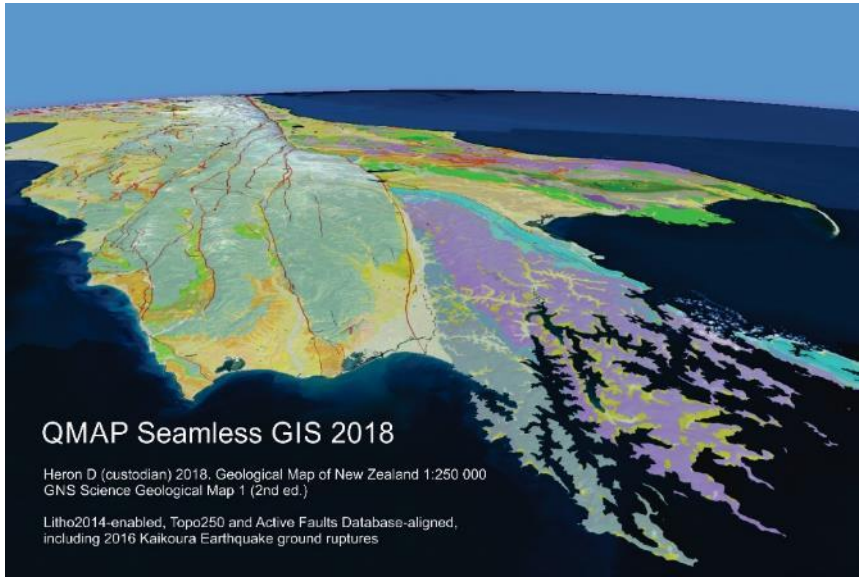
LEVEL 2:
Predictive model components

The five components of aggregate opportunity in this model.

LEVEL 3:
Final models for aggregate

Data Sources

- National Geological Map (QMAP)
- DOC
- Ministry for the Environment
- Landcare Research
- Geophysical surveys
- LINZ, NZTA, NZP&M
- Satellite data
- Statistics NZ



Stats NZ

Ministry for the Environment
Manatū Mō Te Taiao

Manaaki Whenua
Landcare Research

Department of Conservation
Te Papa Atawhai

LRIS portal

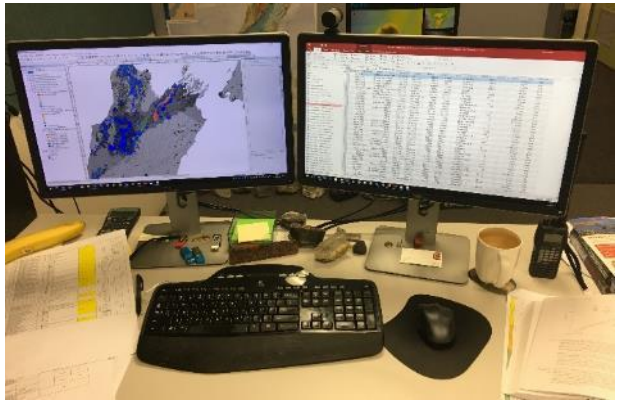
NEW ZEALAND
PETROLEUM & MINERALS

Land Information New Zealand
Toitū te whenua
LINZ DATA SERVICE

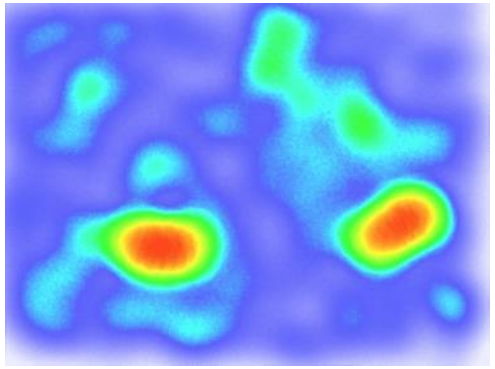
The Modelling Process

Scientists and industry experts

Spatial analysis



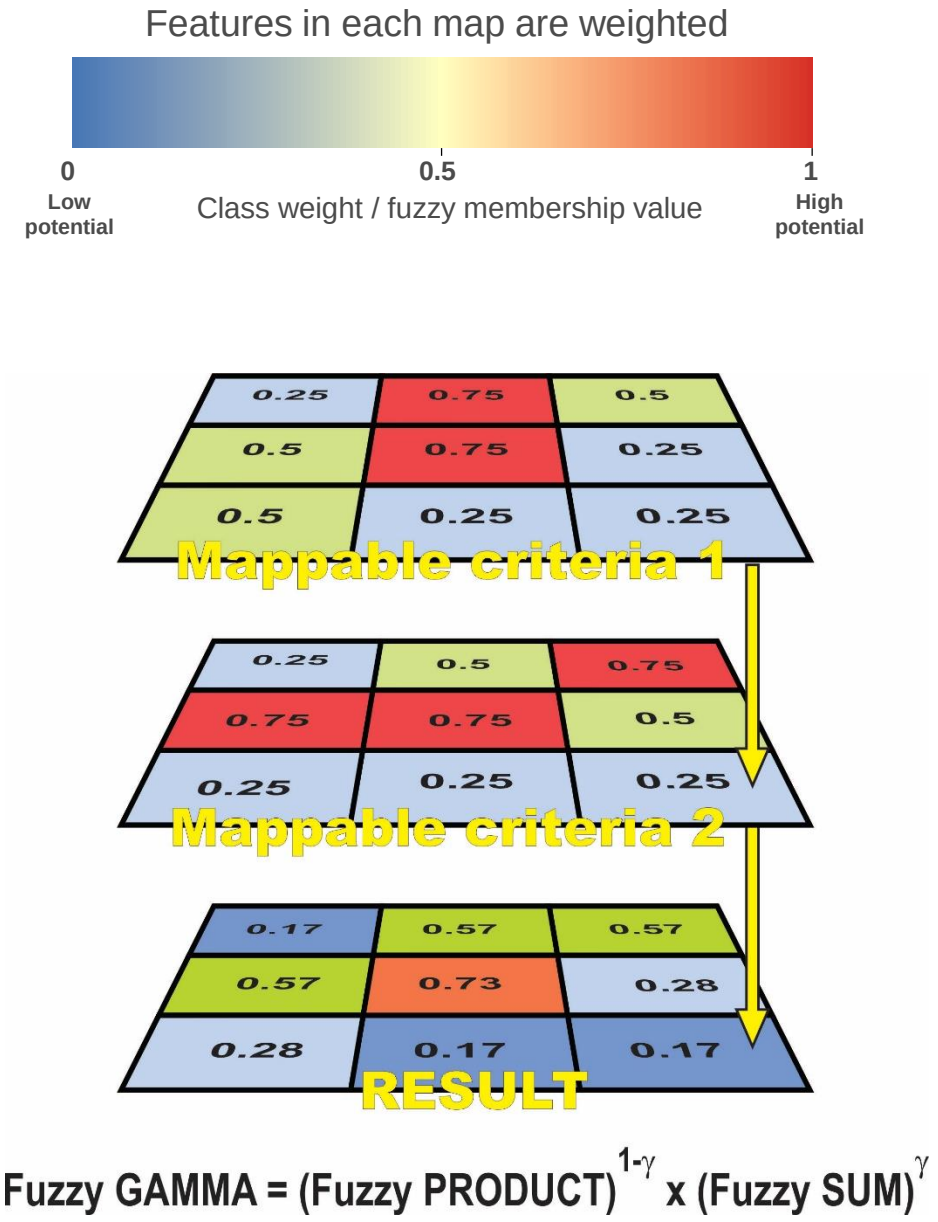
Aggregate model



Mapping reviews

Combining the Predictive Maps

- Knowledge-driven rather than data-driven method.
- Data is assigned a fuzzy membership value which is an expert assigned weight of how important the data is (positive or negative) to the predictive map.
- We have used fuzzy operators to combine the predictive maps.
- This modelling uses very simple mathematics so is therefore easily understood.
- We have tested some machine learning and spatial statistics methods, but these techniques produced poor results.
  - ➢ Instead, we have used the training data to assist in classification and weighting of map areas.



Aggregate Rock Sources

- Due to differences in the exploration and operation of hard rock and gravel aggregate, two models have been created for this project that represent these aggregate types.
- Although the two models utilised many of the same information, their classification differs for some elements such as rock type, waterway proximity, and terrain.

Greywacke quarry at Waitohu (Otaki)

Gravel quarry at Waimakariri (Canterbury)

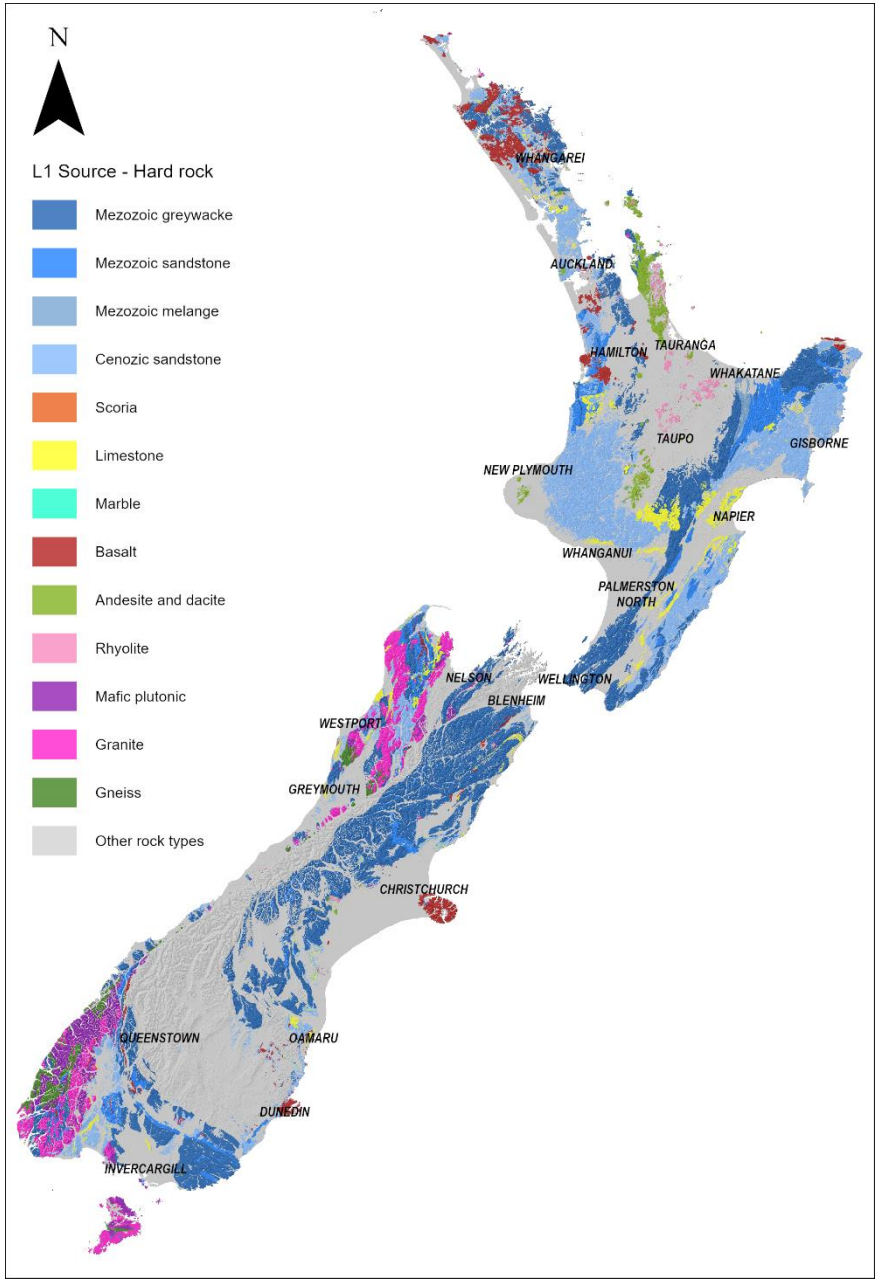
Basalt at Pukekawa Quarry (north Waikato)

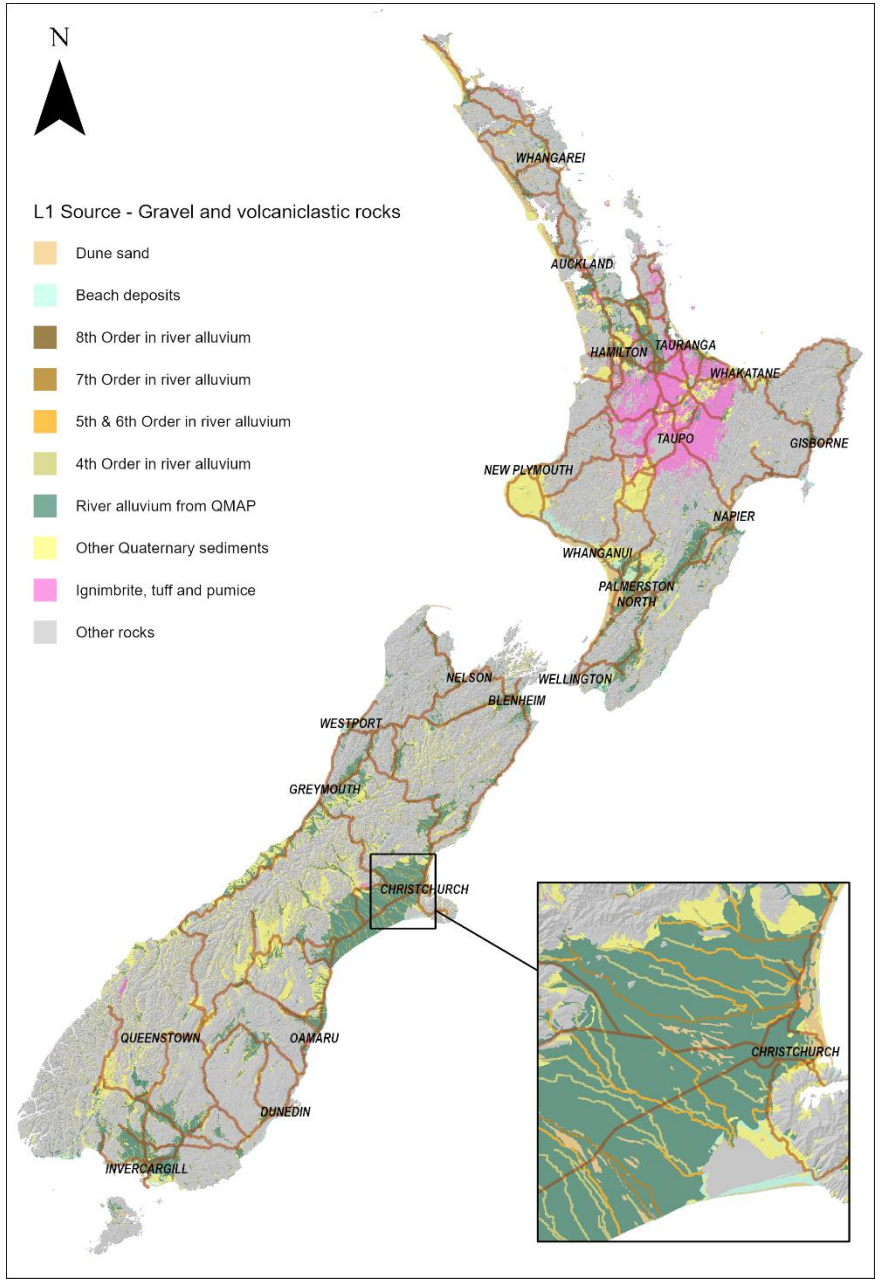
Sand quarry at Otaihanga (Kapiti Coast)

Gravel from the Rangitikei Quarry (Manawatu)

- The *in situ* source rocks are mapped from the new 2018 QMAP database (1:250,000 scale).
- Large river deposits are mapped from the Ministry of Environment river databases and river alluvium and dune sand is mapped from QMAP.
- Some rock sources are not included as they are only identified on larger-scale (more detailed) maps or are below surficial deposits.

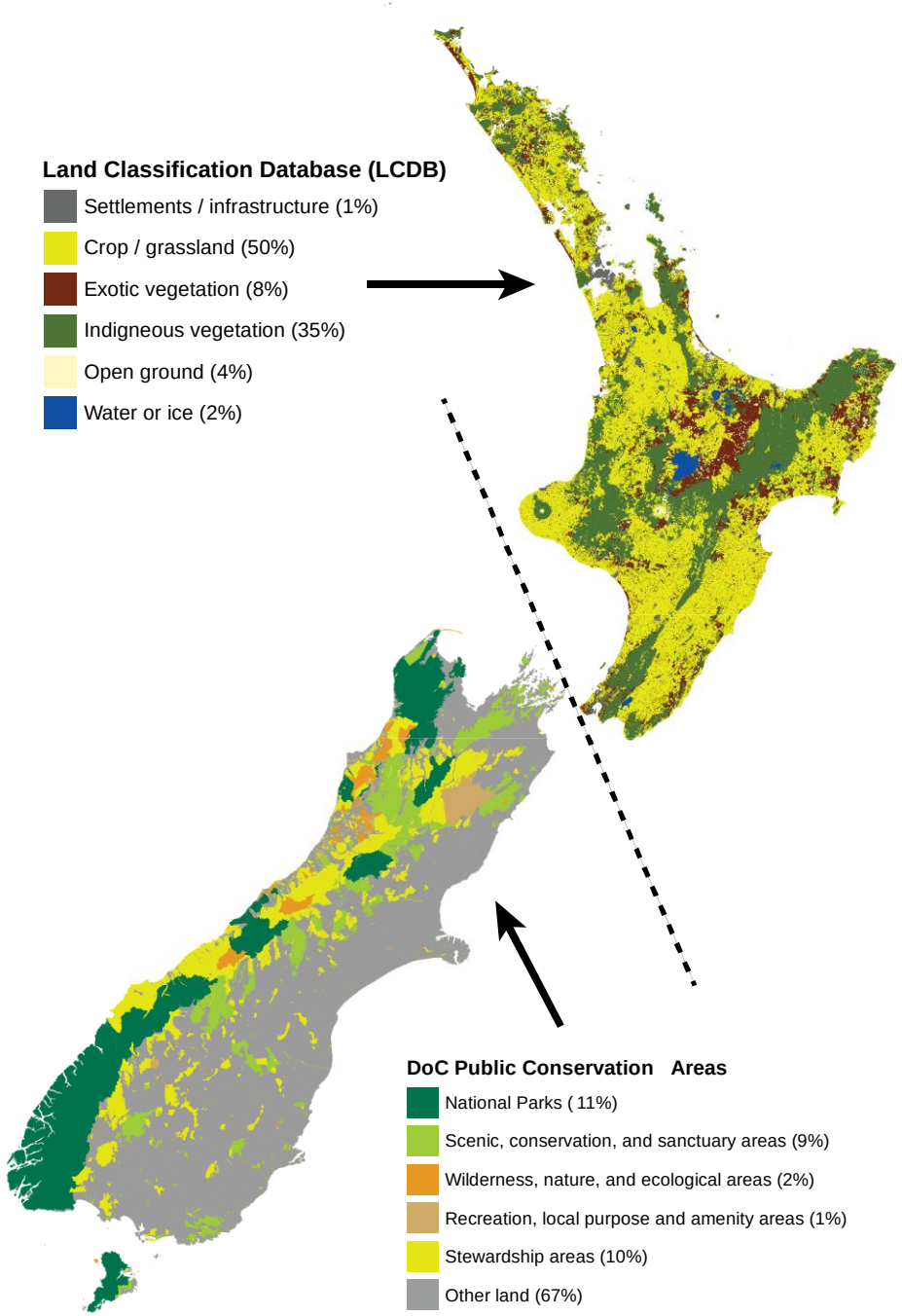
- The resulting maps show areas where there are ideal rock types for aggregate resources.
- These different hard rock and alluvial rocks are weighted in the modelling process.
- The model does not take into account any engineering qualities of the rock.
- The model also does not include lithological differentiation; e.g. argillite-rich vs. sandstone-rich zones in the greywacke.



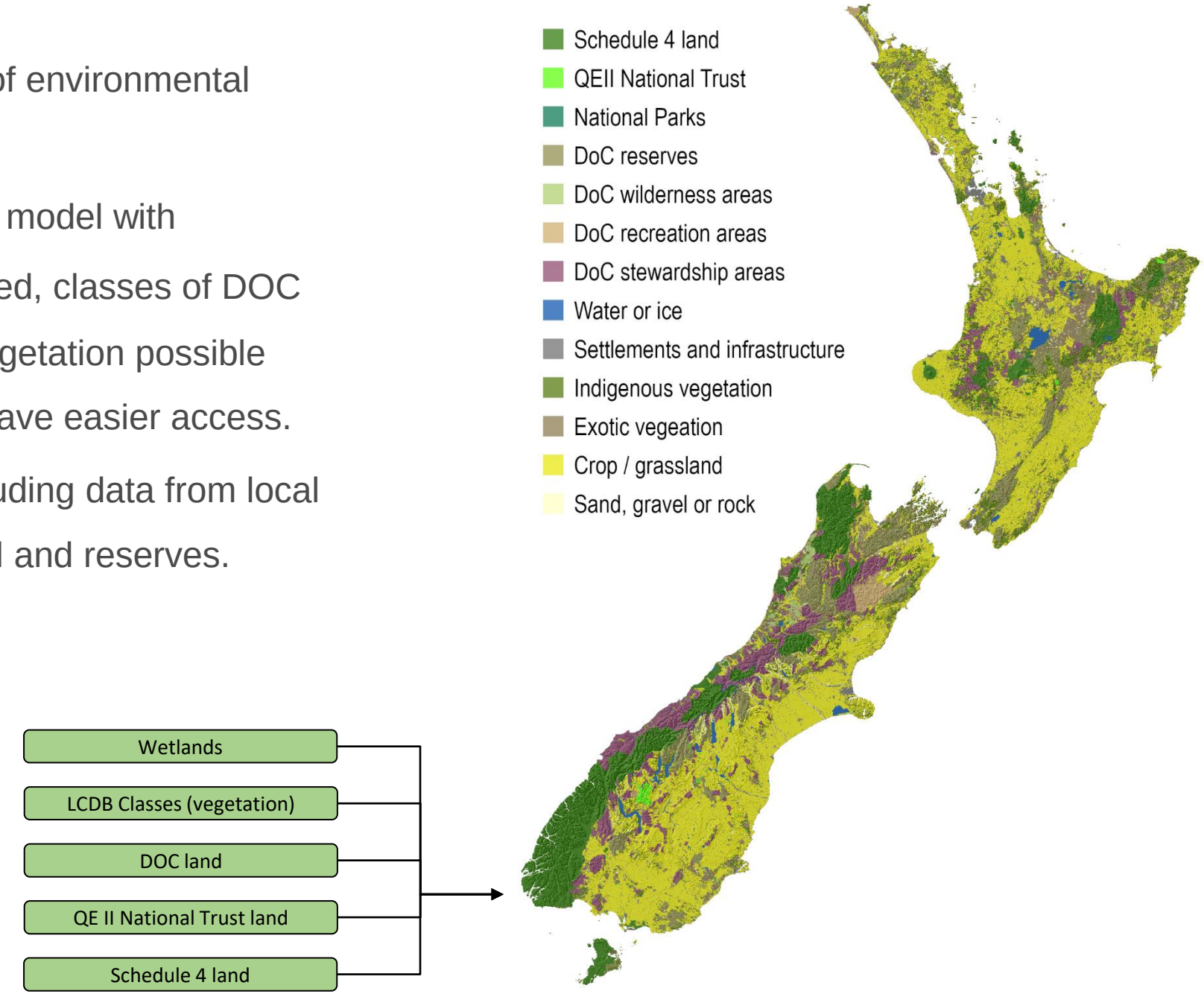


Land Use

- Our model uses maps of land use to locate areas most suitable for quarrying activities.
- In particular those land areas that are restricted for mining activities such as:
  - Schedule 4 land (see the Crown Minerals Act);
  - Department of Conservation public conservation areas;
  - and, other areas of significant native vegetation or waterways.
- The model takes into account the different land access restrictions with appropriate weightings in the model.

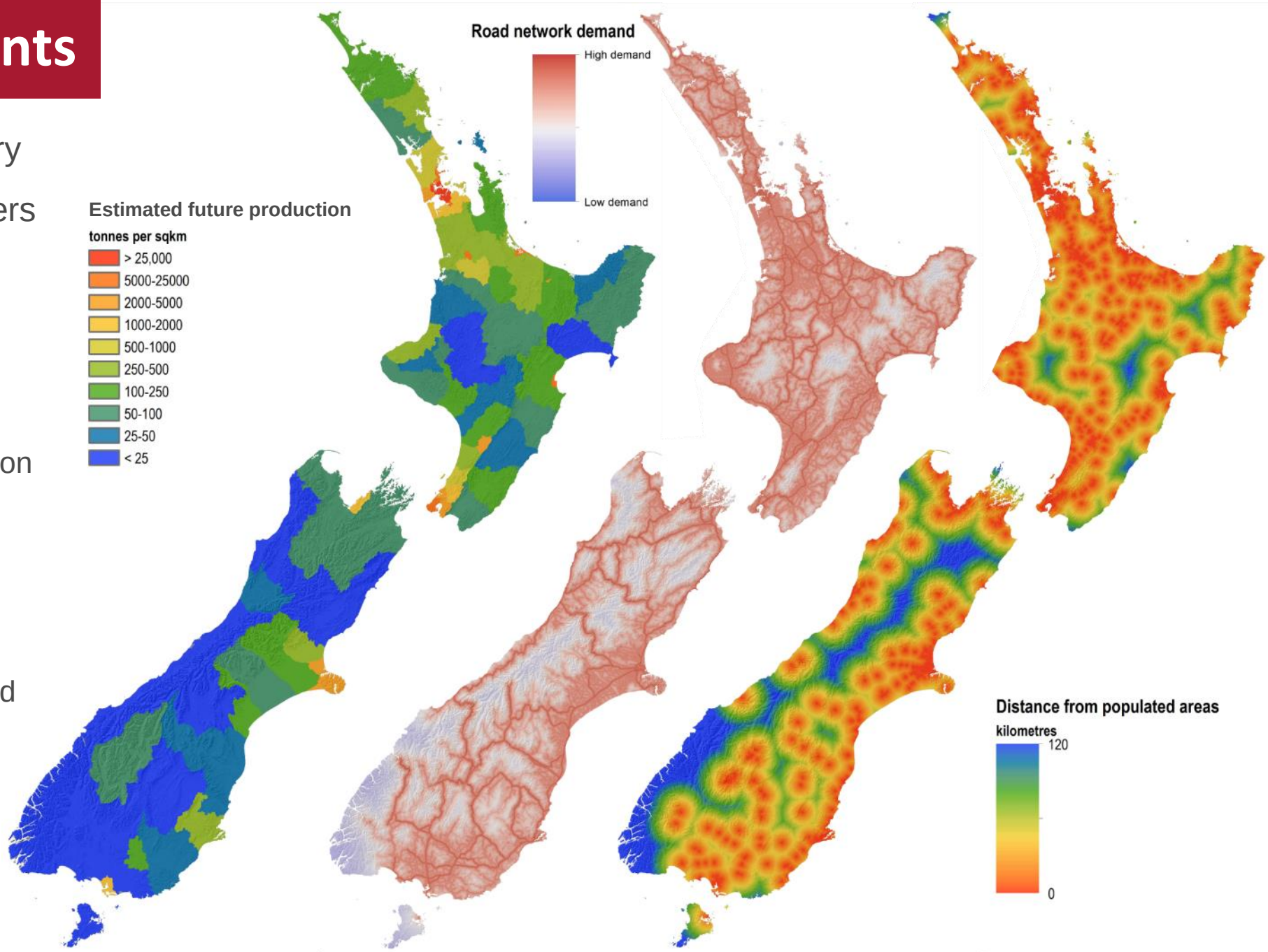


- This map shows the main areas of environmental land categories.
- Each area is weighted in the final model with Schedule 4 land the most restricted, classes of DOC land restricted, areas of native vegetation possible restriction, and other areas that have easier access.
- Future models will benefit by including data from local and regional councils on parkland and reserves.



Demand Requirements

- It is important that future quarry locations are near the end-users and demand markets.
- For our model we map four factors representing demand:
  1. Estimates of future production based on population and regional growth;
  2. Our roading network;
  3. Proximity to future populated centres;
  4. And, forecast regional construction and building.



National Construction Pipeline Report 2020

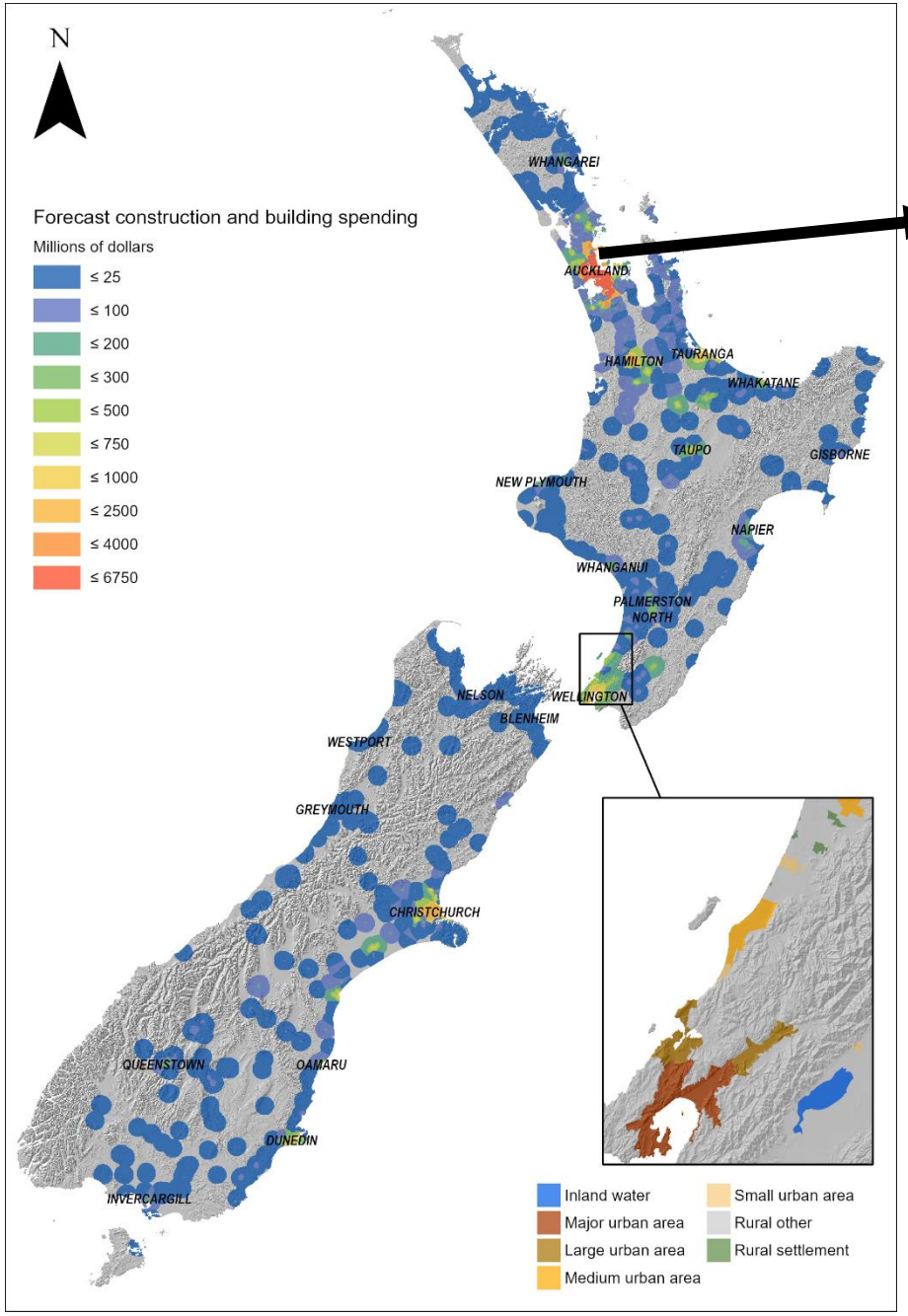
A Forecast of Building and Construction Activity

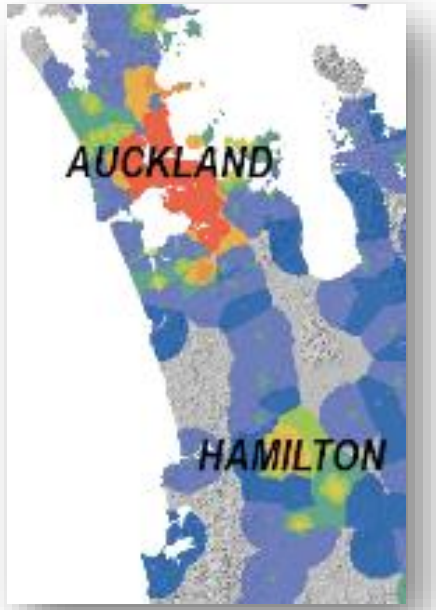
8th Edition

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

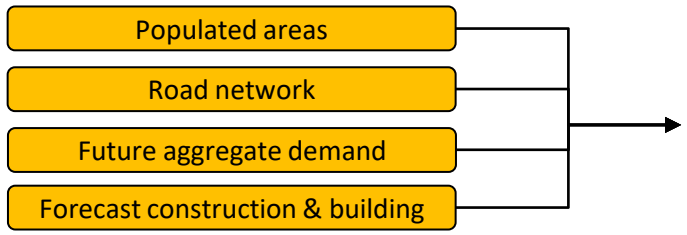
BRANZ

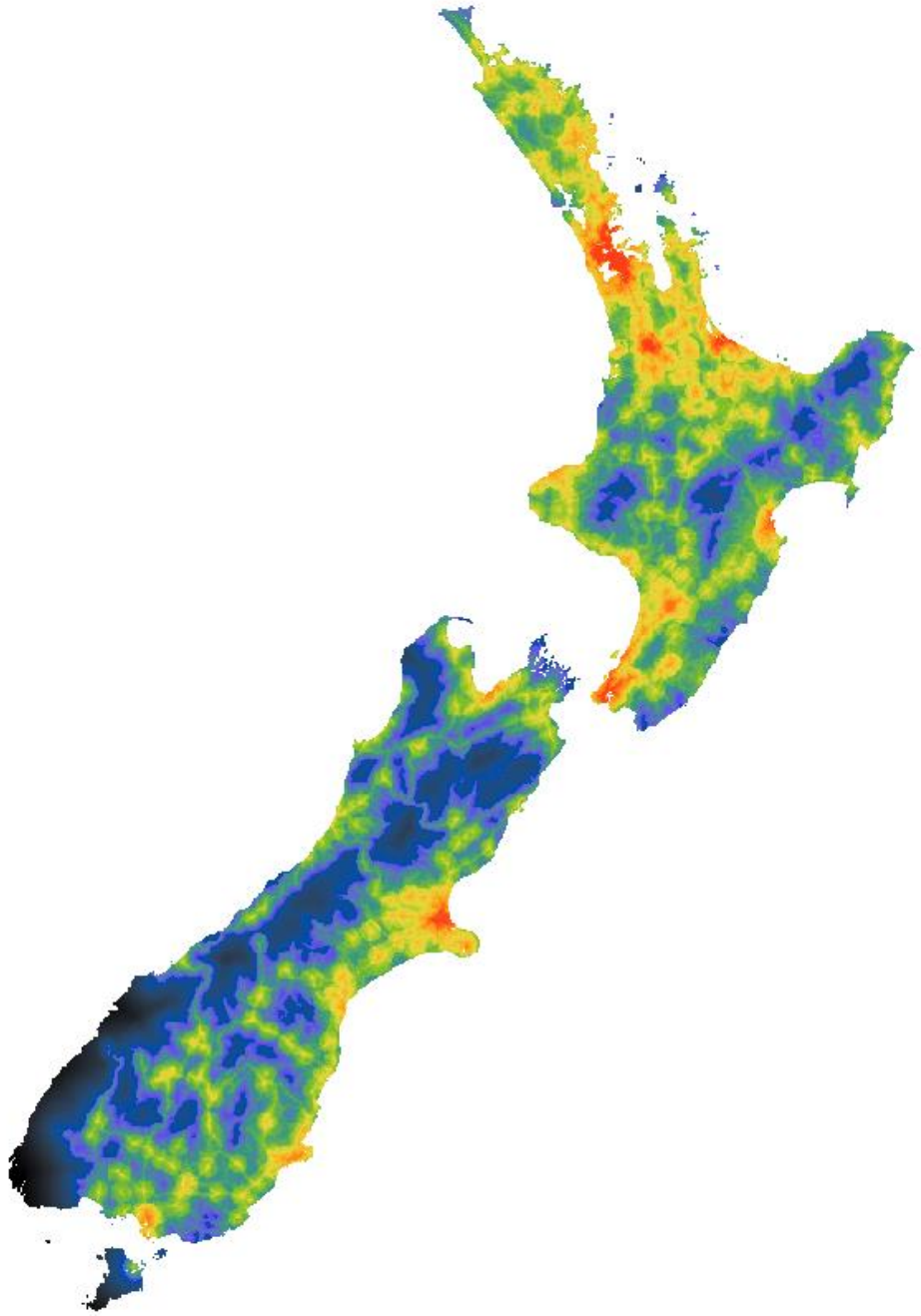
Pacifecon
Building Intelligence





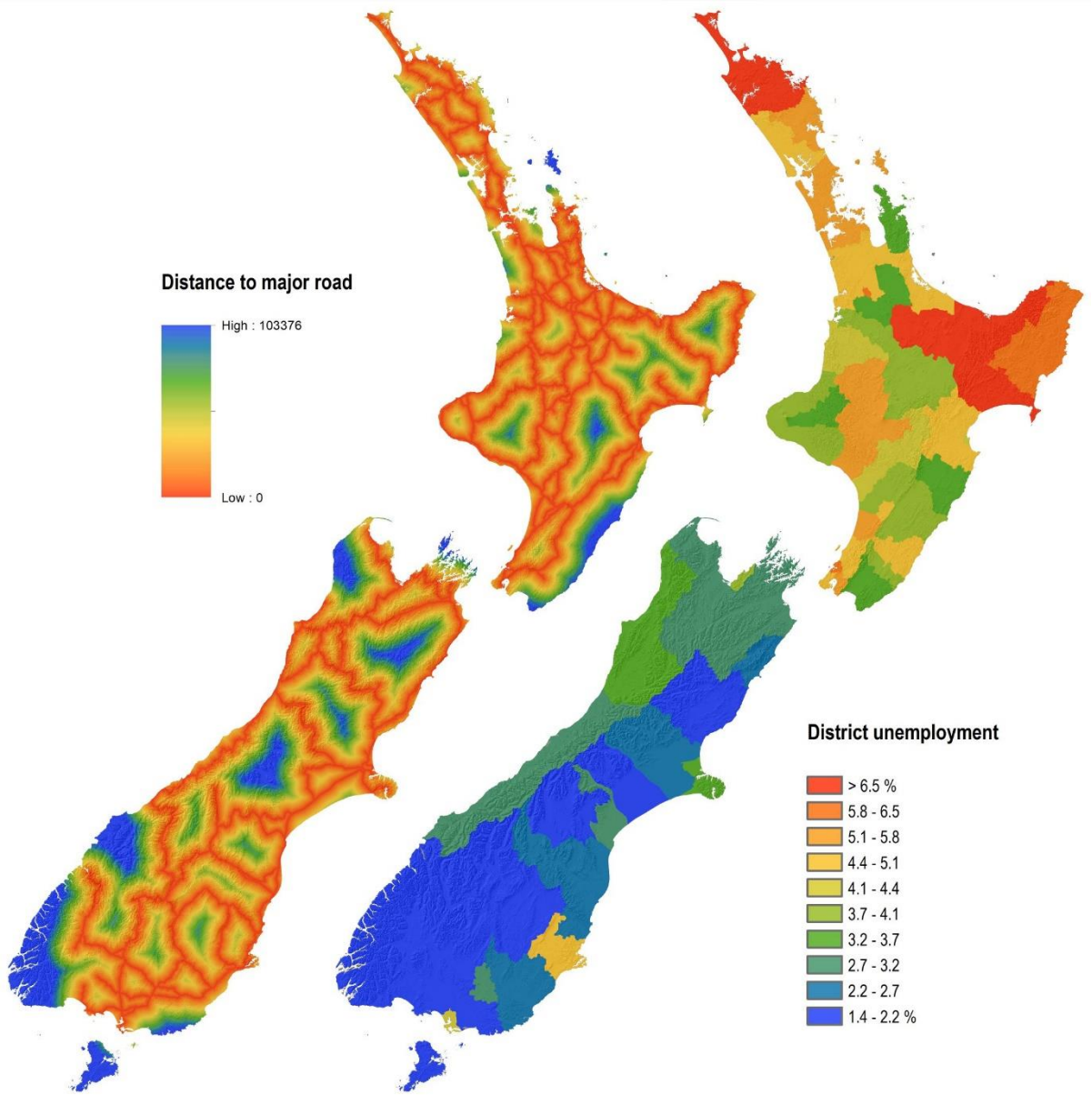
- Areas of high demand are located along the main road networks and near populated areas.
- Future demand is predicted from Statistics NZ population estimates for 2028 and for regional growth and major roading and development projects.
- The future demand also includes a factor based on industry perceived future demand.
- Data is weighted in the model by the distance from these features.
- The model could be improved by using more data from the NZTA on future major infrastructure projects.



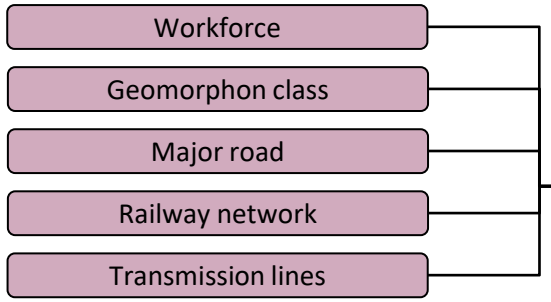


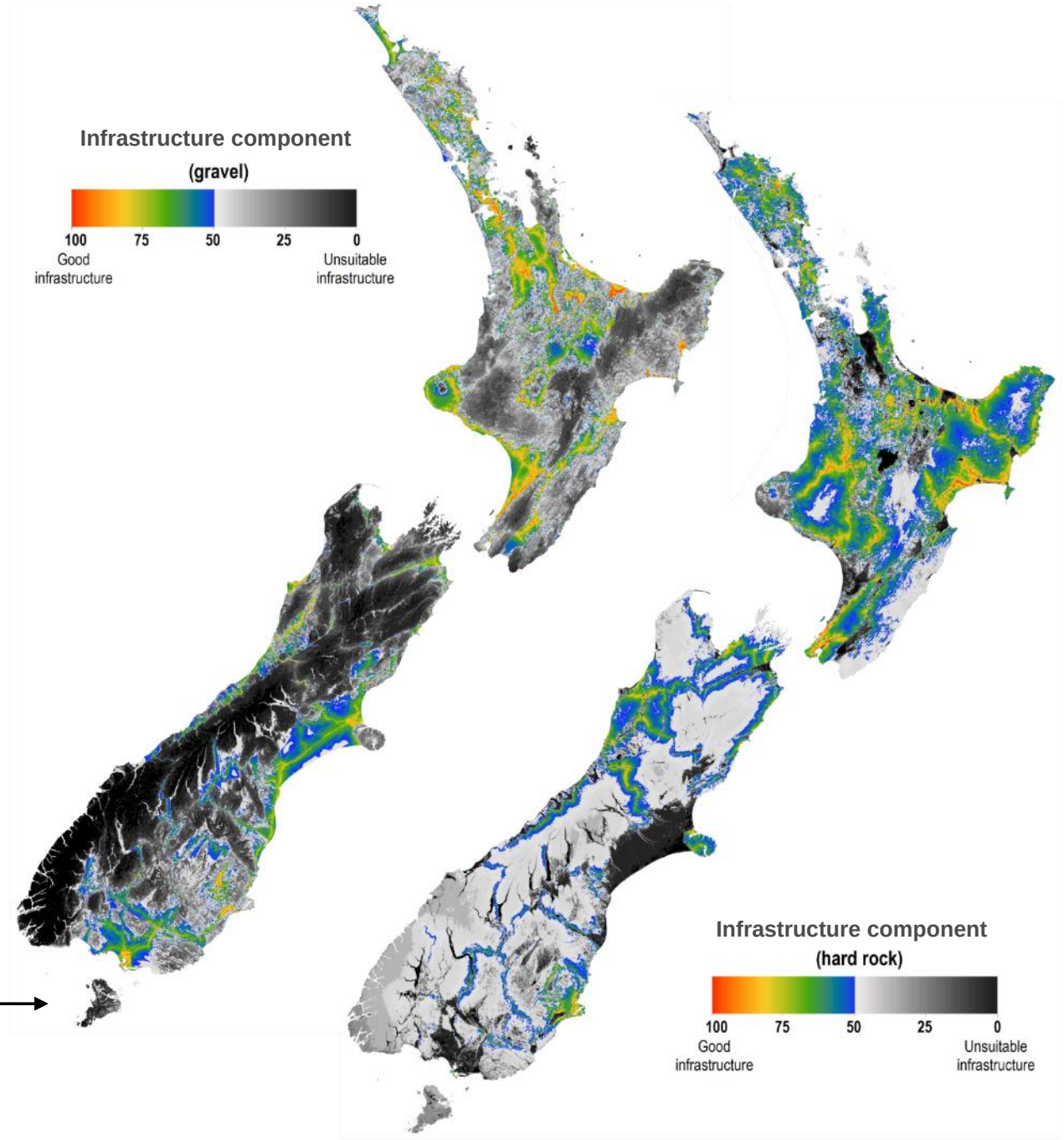
Infrastructure

- Development of a quarry is ideally close to existing infrastructure.
- These include facilities such as:
  - Large roads;
  - The railway network;
  - Transmission lines for power;
  - and, labour market supply.
- The terrain is also considered and mapped using geomorphon modelling.



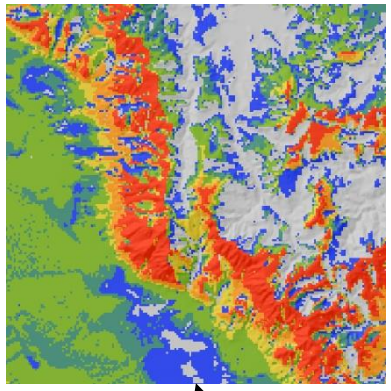
- Fortunately, many of the key areas of infrastructure are already near areas of high demand.
- Each layer in the model is weighted based on a distance classification.
- Information on the load-bearing capability of roads (suitability for use by aggregate carrying trucks) will be useful in future models.





Cultural Sensitivity

- As with all extractive activities consideration for the local cultural sensitivity is important.
- It is unfortunate that the demand for aggregate from urban areas and the urban populations' sensitivity to mining often clashes and places limitations on operators.
- We include cultural artefact sites as well as distances and visibility from where people live in our model to take this into consideration.
- Existing quarry density is also a good indicator of mining sensitivity.
- Future maps could include areas of Iwi interest and places of high scenic or tourism value.



Visibility analysis

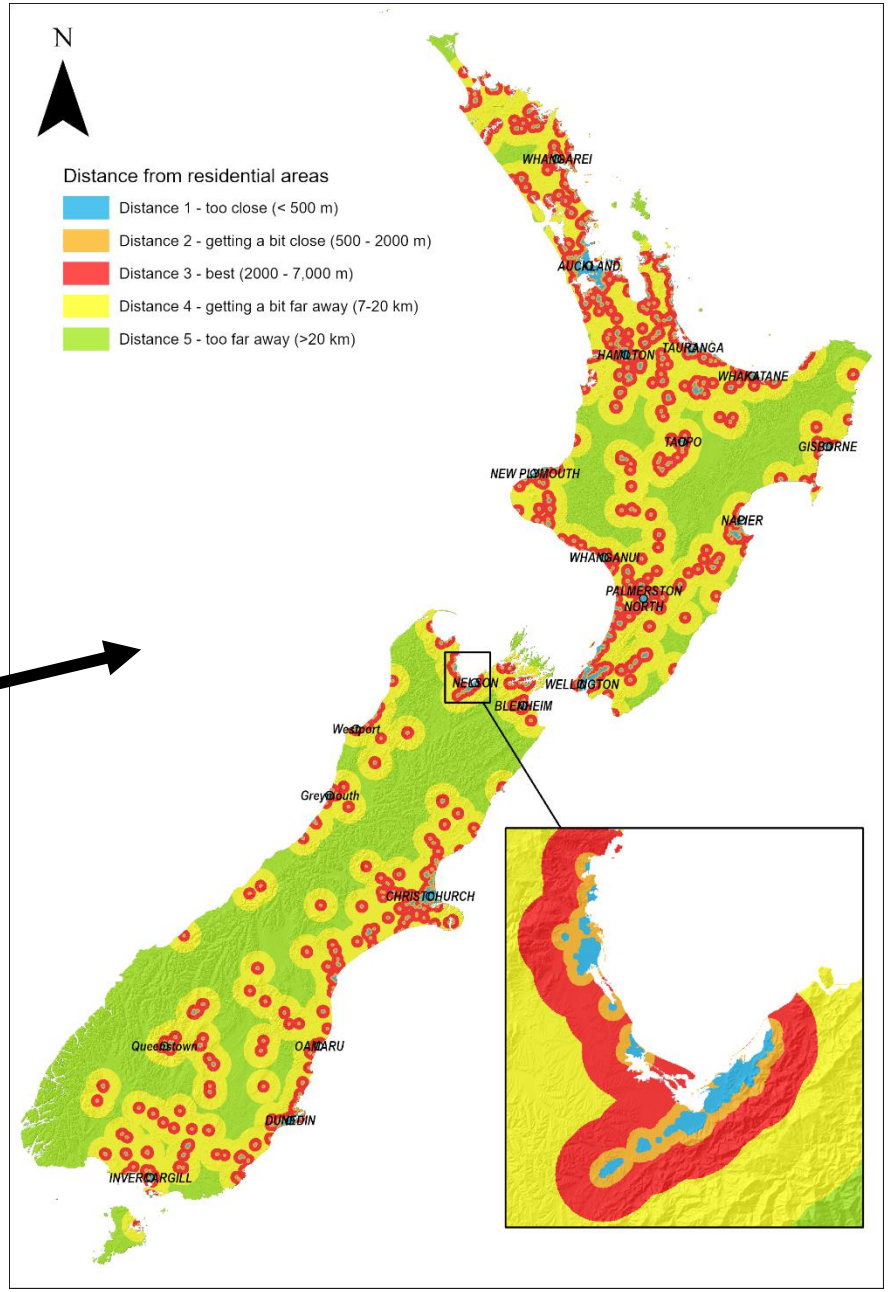
Cultural artifacts

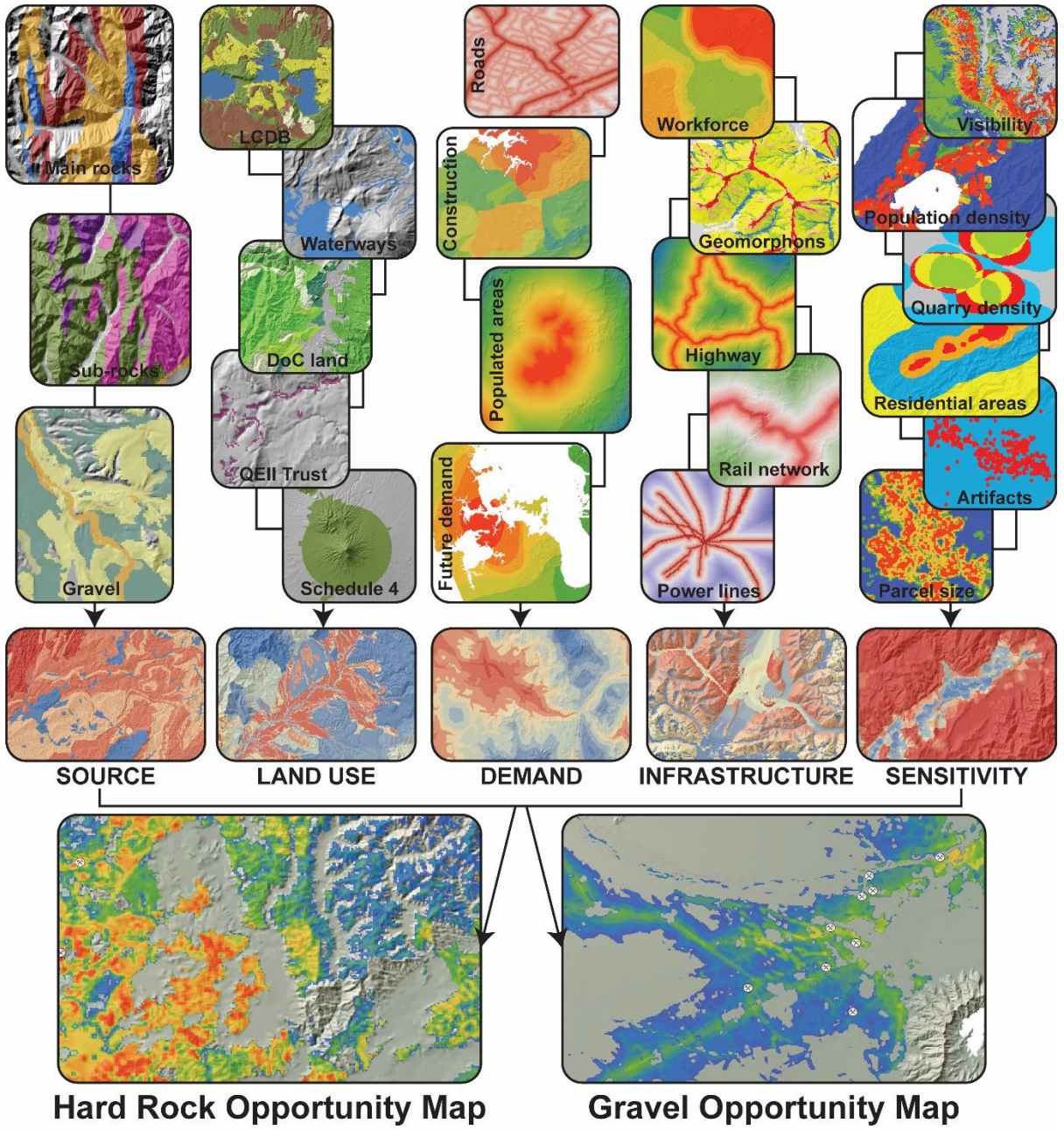
Quarry density

Residential areas

Cadastral parcel size & population

e.g. wind turbines, golf courses, cemeteries, airports, archaeological and historic sites, sports fields, & vineyards.





LEVEL 1:
Mappable criteria layers

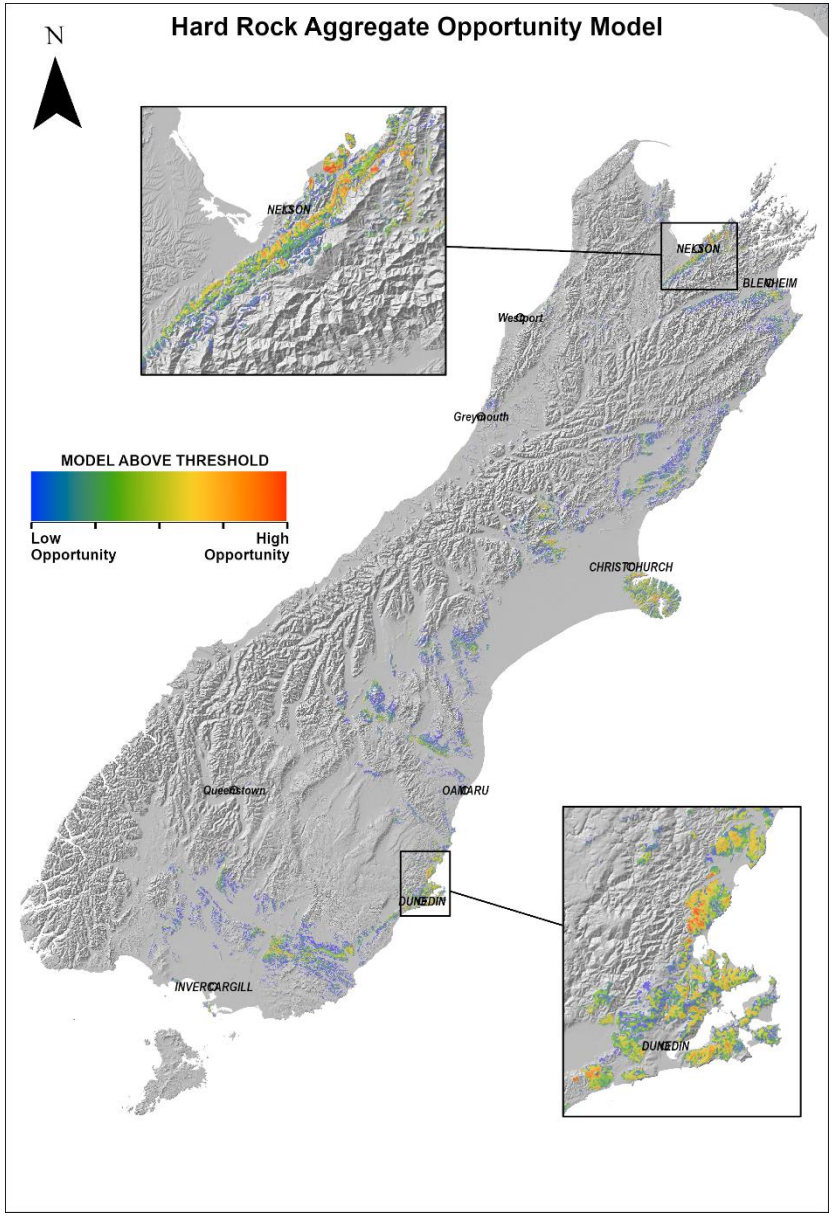
These are maps of source data that are classified and weighted.

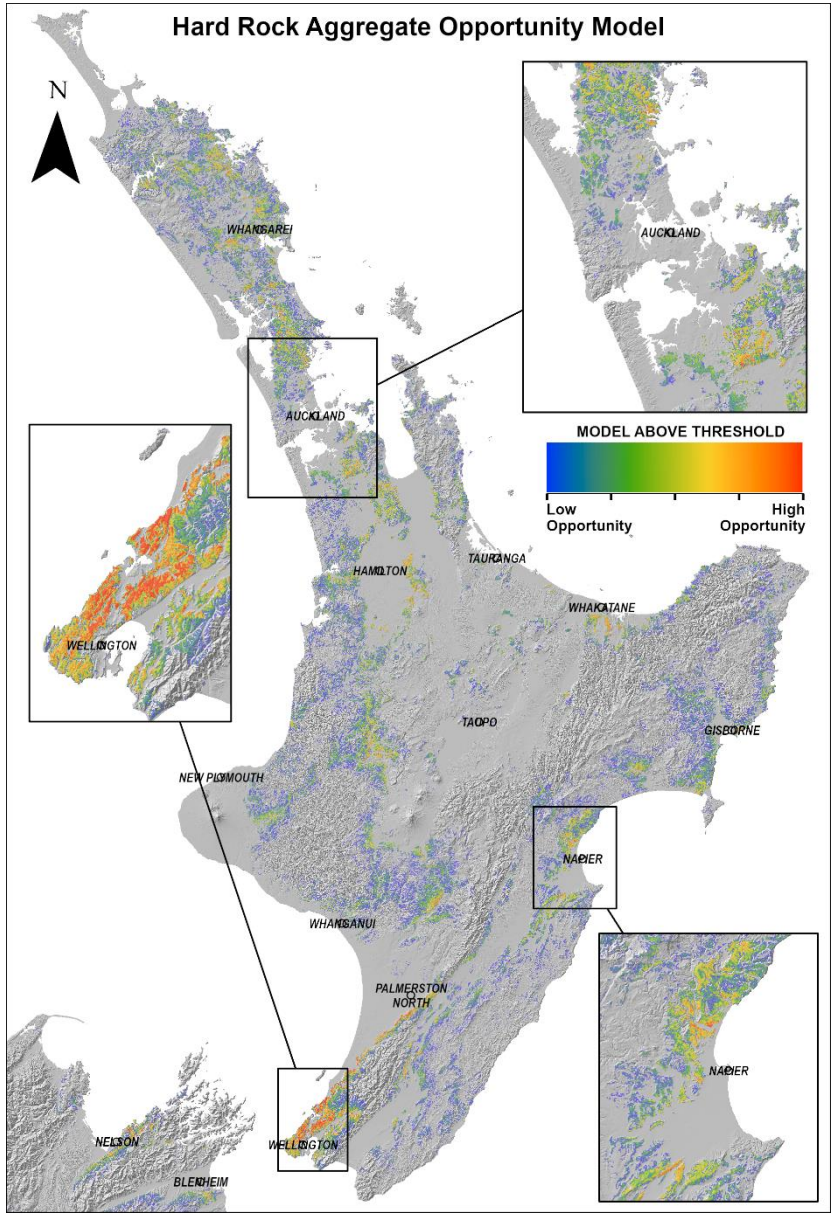
LEVEL 2:
Predictive model components

The five components of aggregate opportunity in this model.

LEVEL 3:
Final models for aggregate

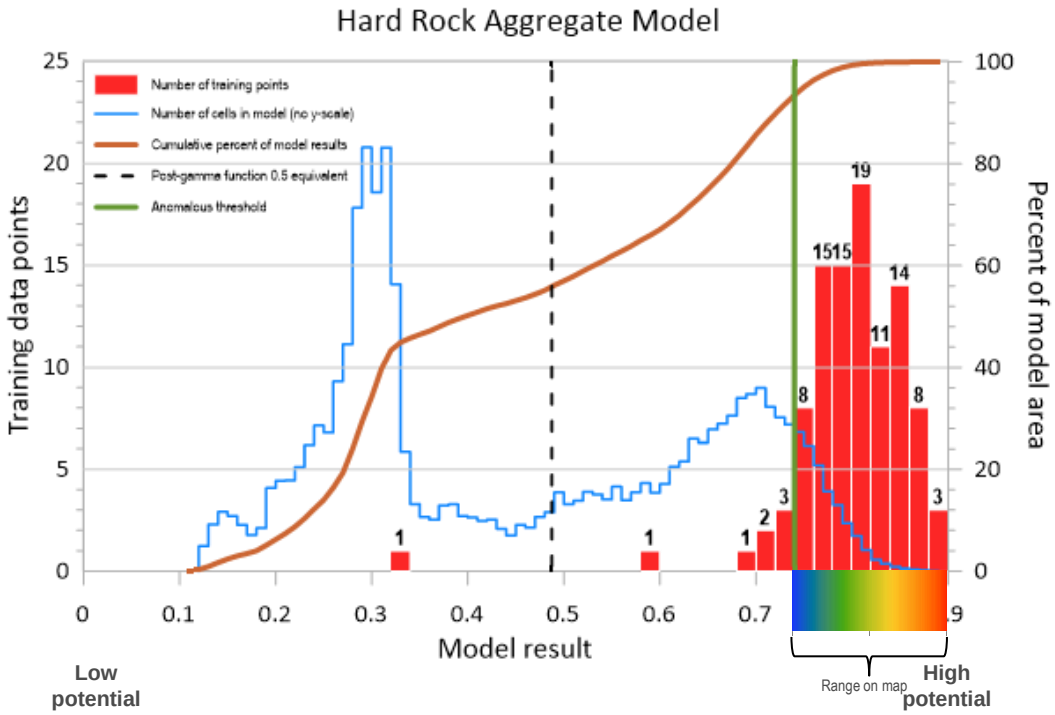
Aggregate Opportunity Model – Hard rock

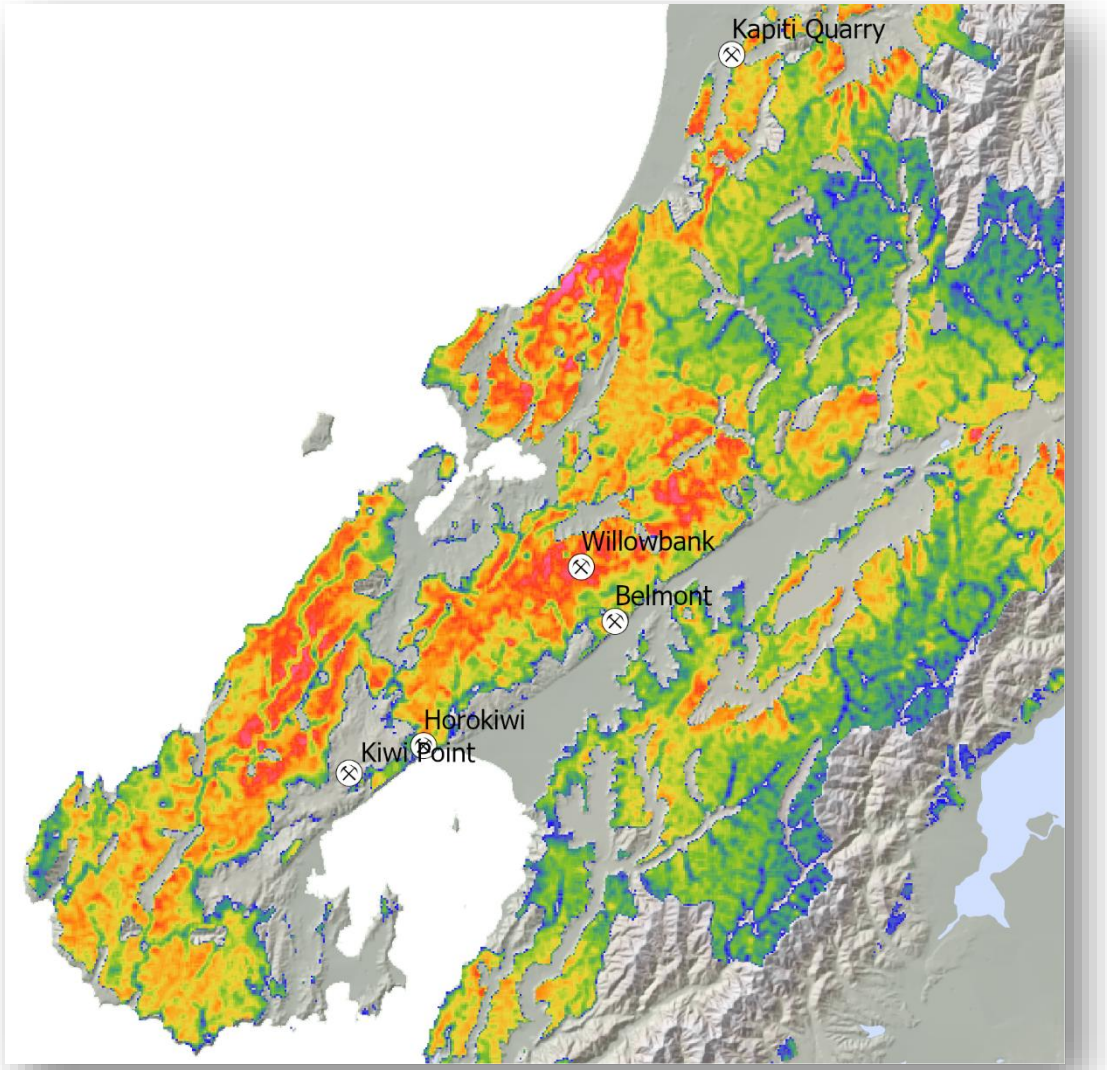




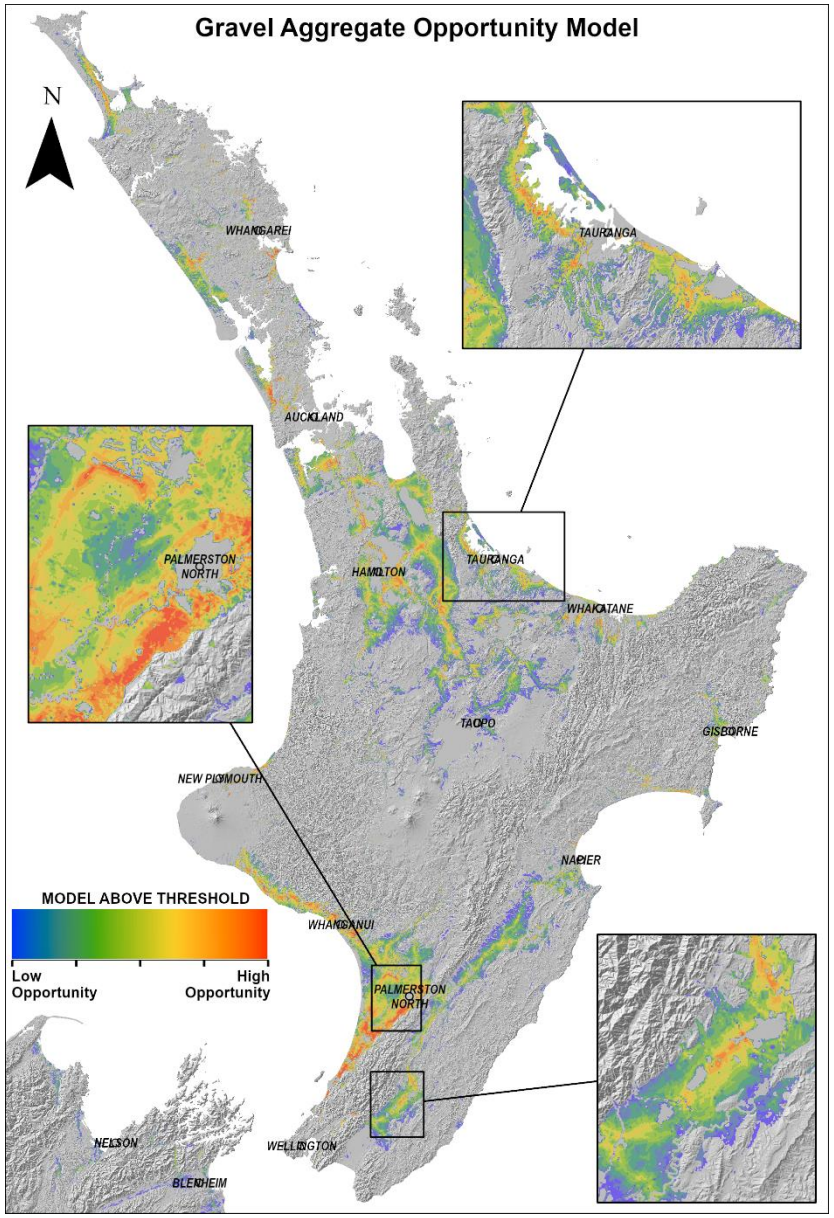
- Modelling of the hard-rock aggregate resources was made from 22 maps that are important to these deposits.
- The results show areas that are the most favourable for exploration and future research.

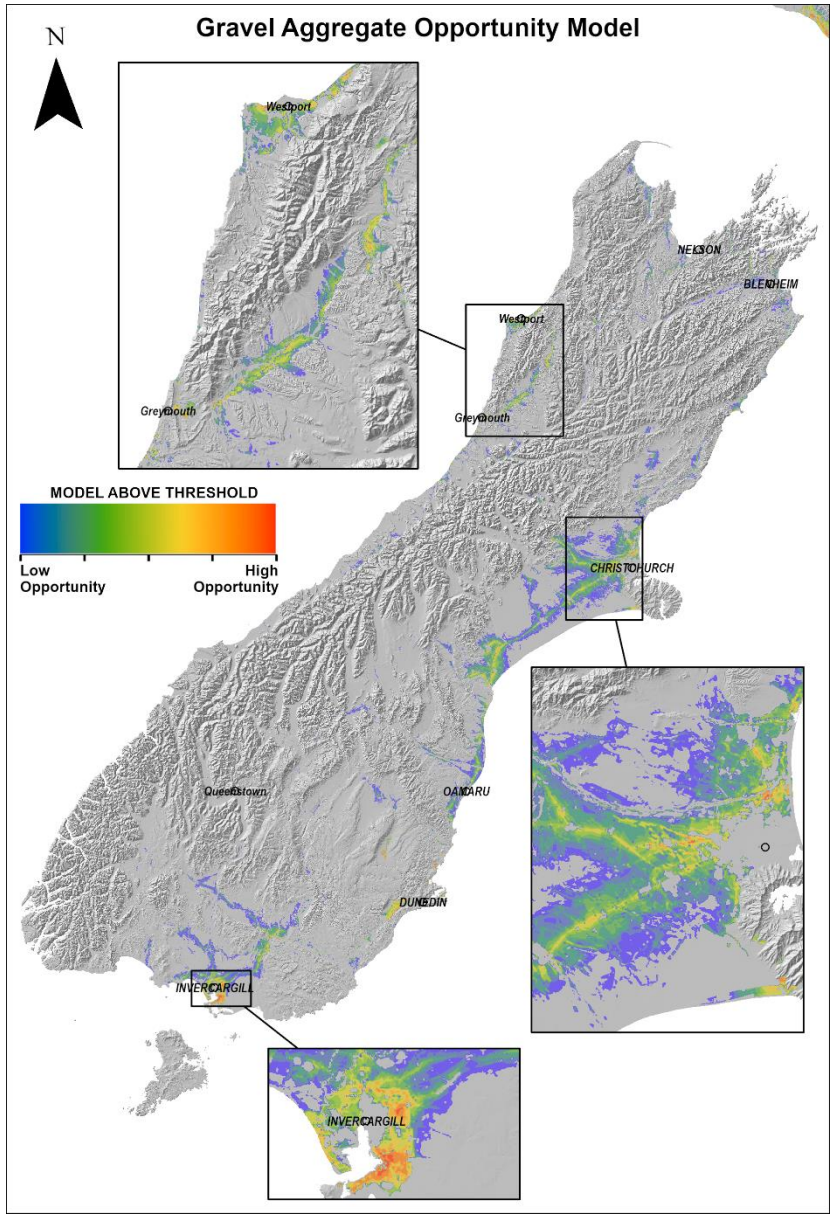
- We can test our model by checking how well it locates existing hard rock quarries.
- We've used a set of 100 operating quarries.
- The model predicted these as good sites on most occasions.





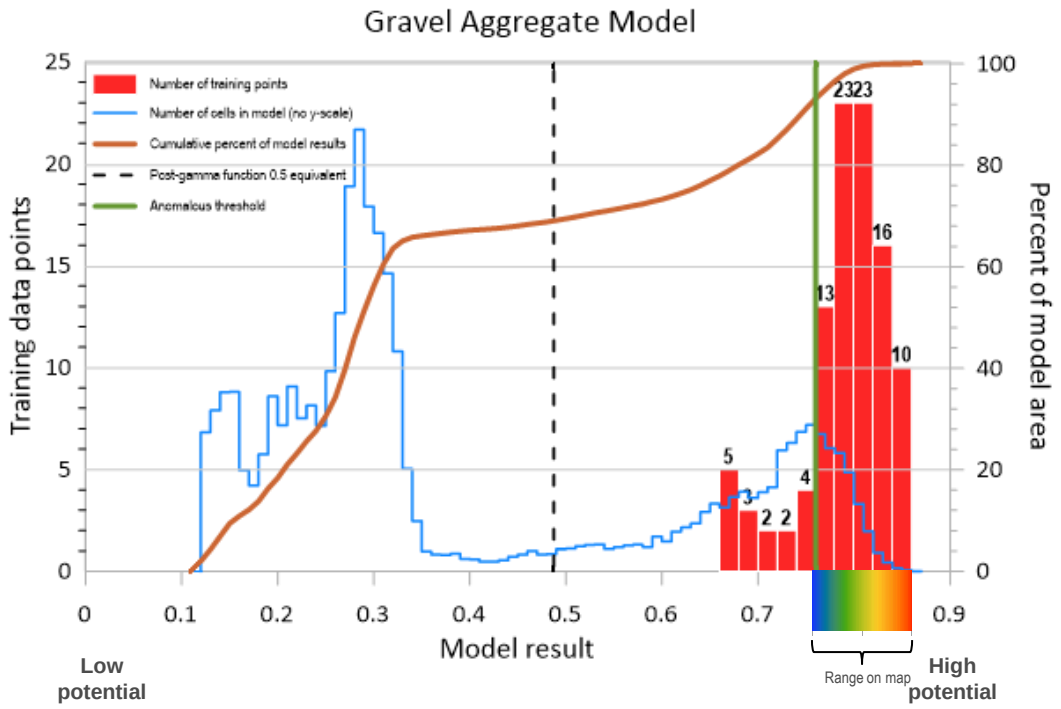
Aggregate Opportunity Model – Gravel and Sand

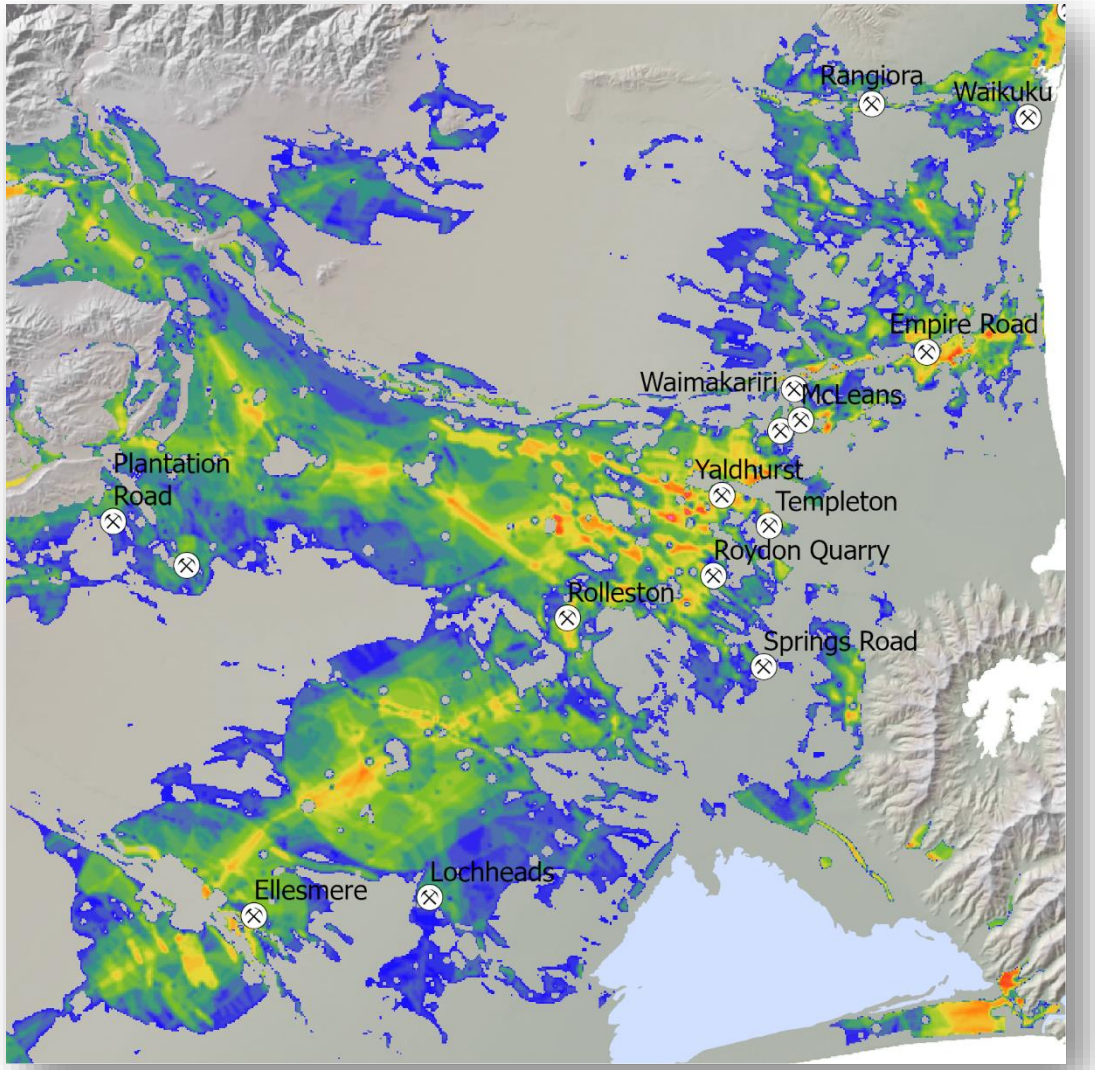




- Modelling of the gravel and sand aggregate resources was made from 21 maps that are important to these deposits.
- The results show areas that are the most favourable for exploration and future research.

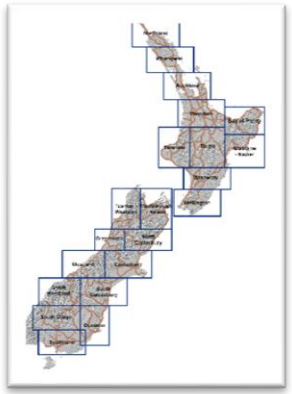
- We can test our model by checking how well it locates existing gravel quarries.
- We've used a set of 101 operating quarries.
- The model predicted these as good sites on almost all occasions.

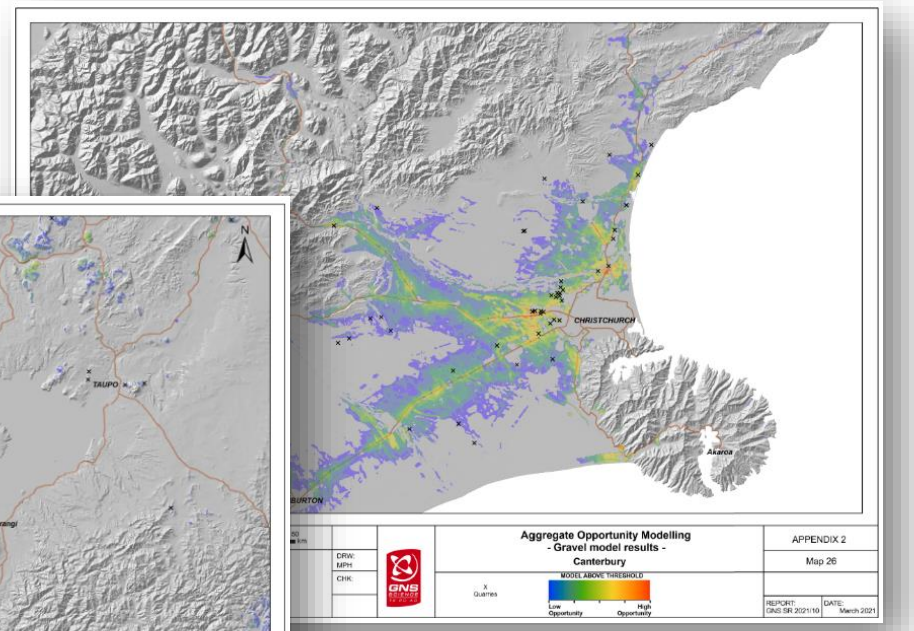


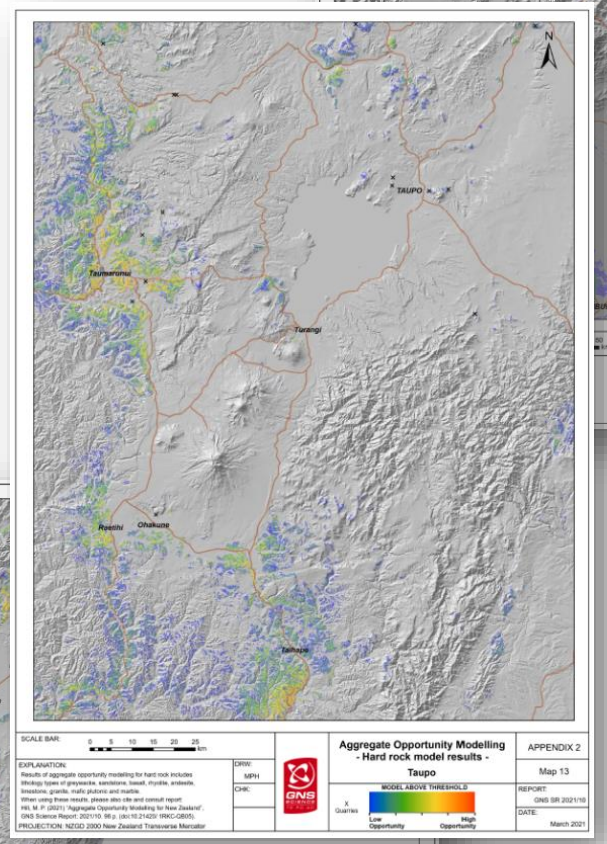


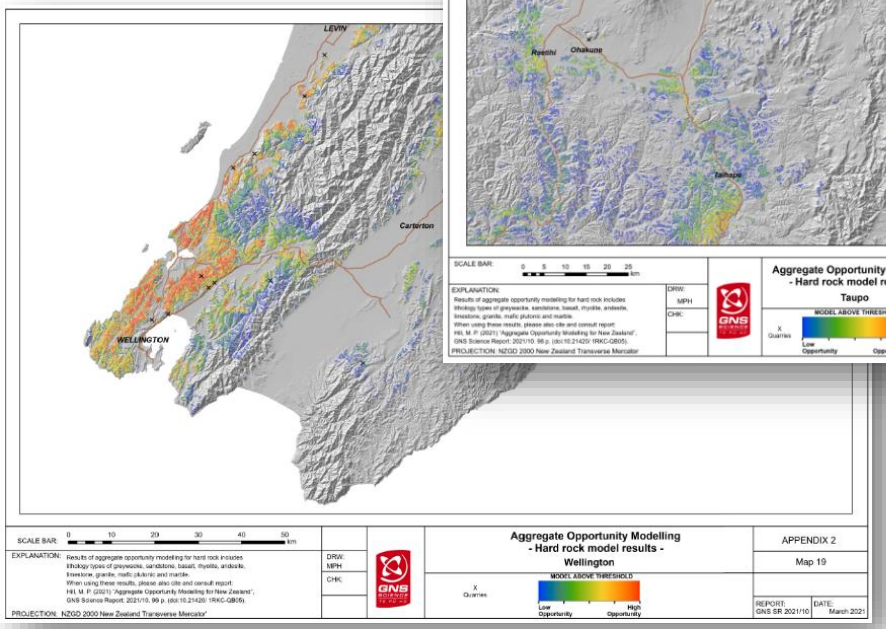
Aggregate Opportunity Model Results

- The model results are provided as a set of figures in the report, an appendix of region maps, and as a digital GIS file.
- The model is divided into gravel and hard rock aggregate types.
- 42 printable map sheets covering the entire country
- The digital data for the model and maps is available in GIS files for ArcGIS or the freely available QGIS







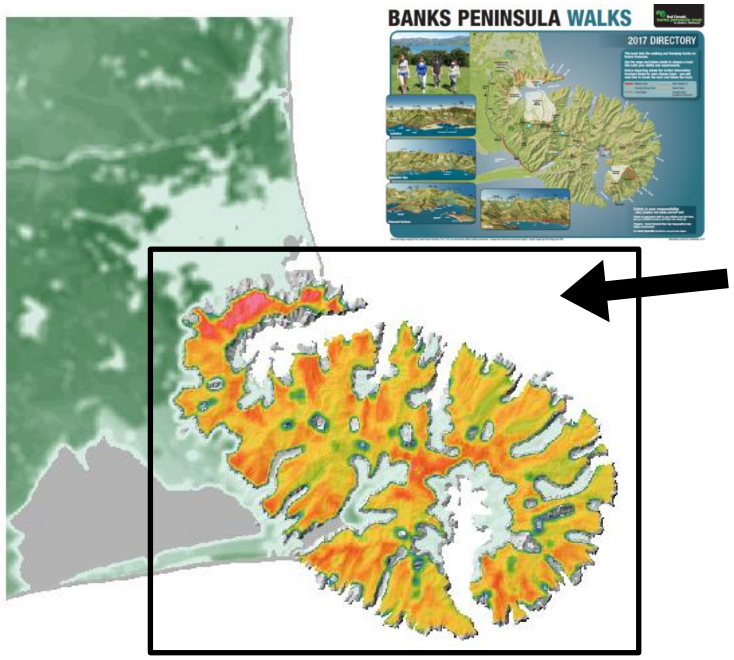


QGIS

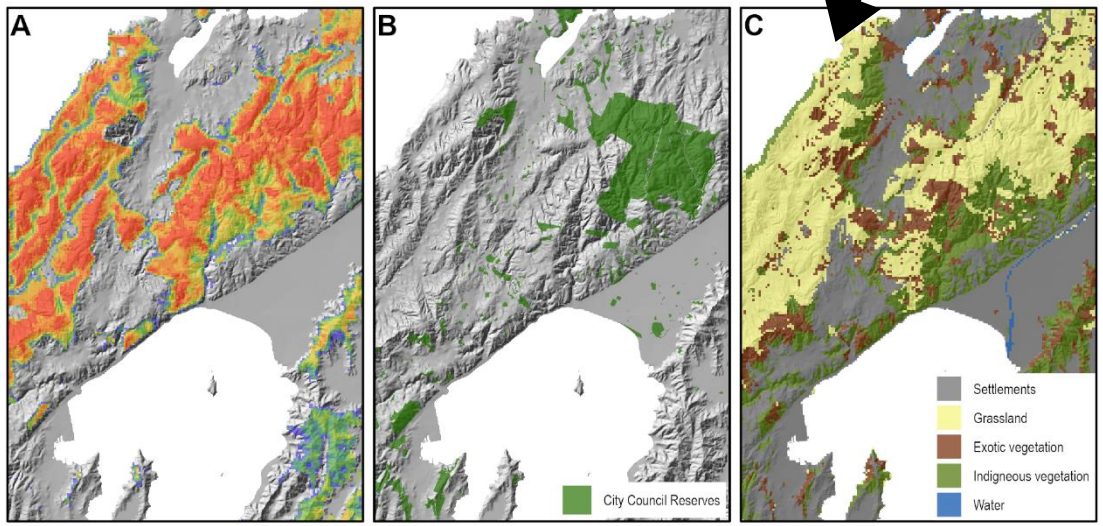
Report

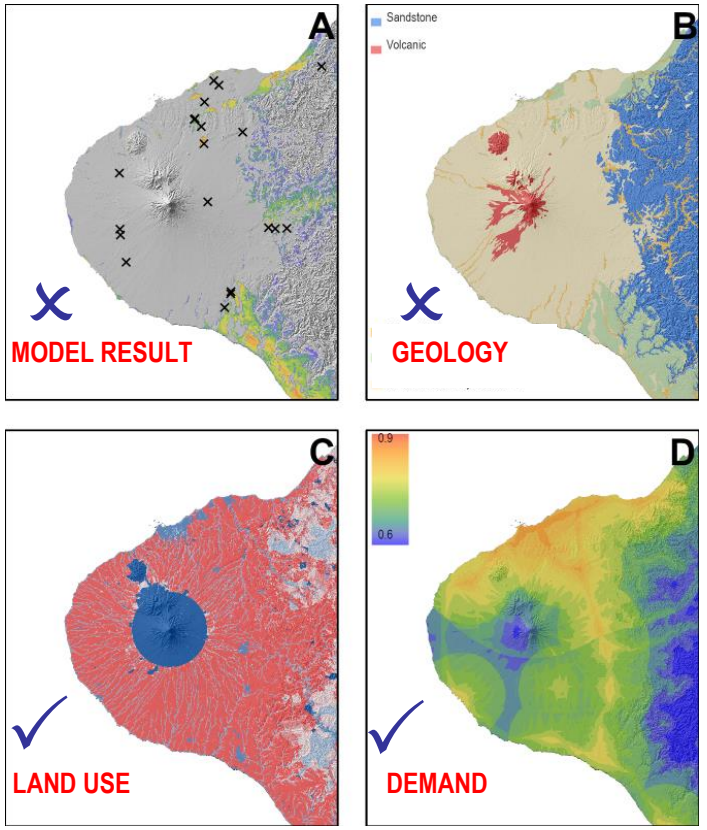
Maps & data

Model analysis: Missing data



Examples of where more information is required in the model about land use.





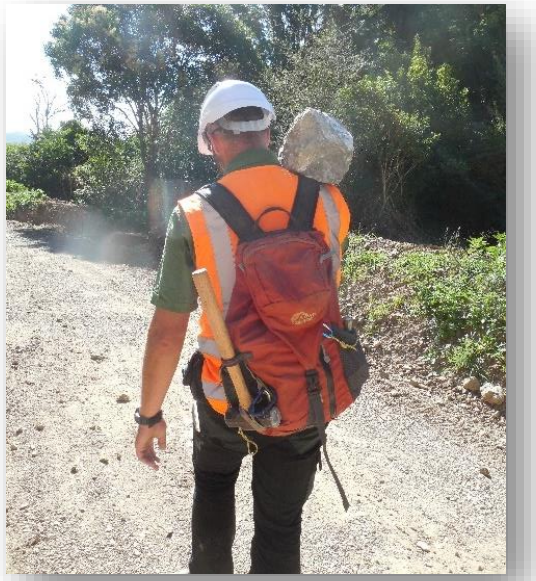
Example of where sub-Quaternary geology needs to be integrated into regional-scale modelling studies.

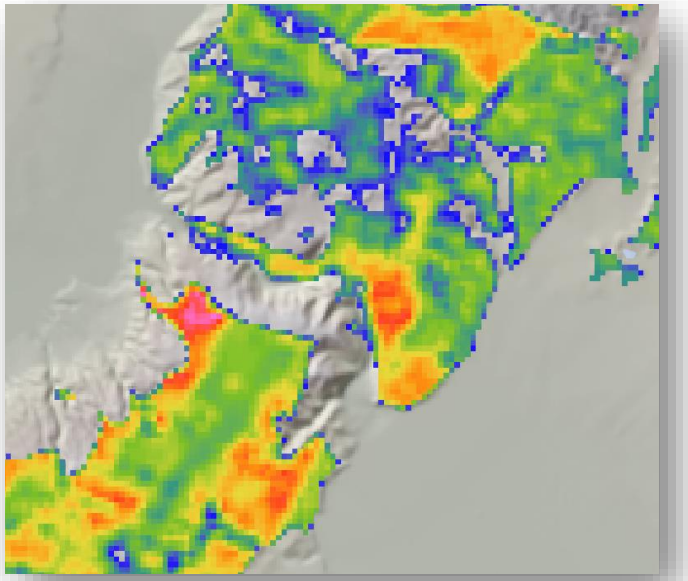
Additional data that would improve model could include:

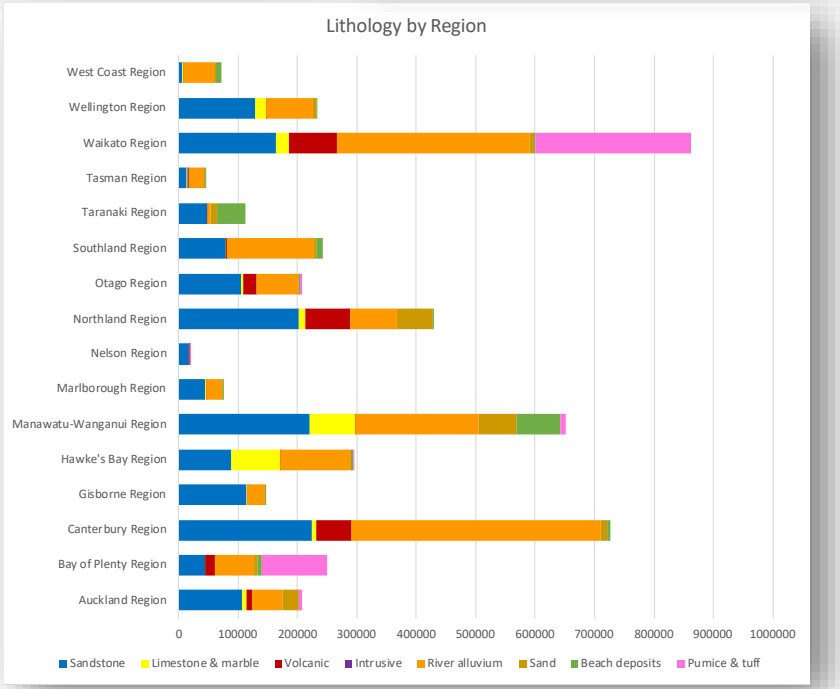
- Rock engineering properties
- Consideration of land value to Iwi
- Location of future large national roading projects

Using the Model

1. The aggregate model can be used to locate areas for sampling and specific material tests or where to first focus exploration activities and more detailed studies.
2. It can be used to evaluate future aggregate opportunity to determine regional import demand or export potential.
3. Understand, plan and utilise our aggregate resources to ensure our infrastructure providers have a reliable and affordable supply.
4. A council could use the maps as a first step towards protecting land for future extraction.





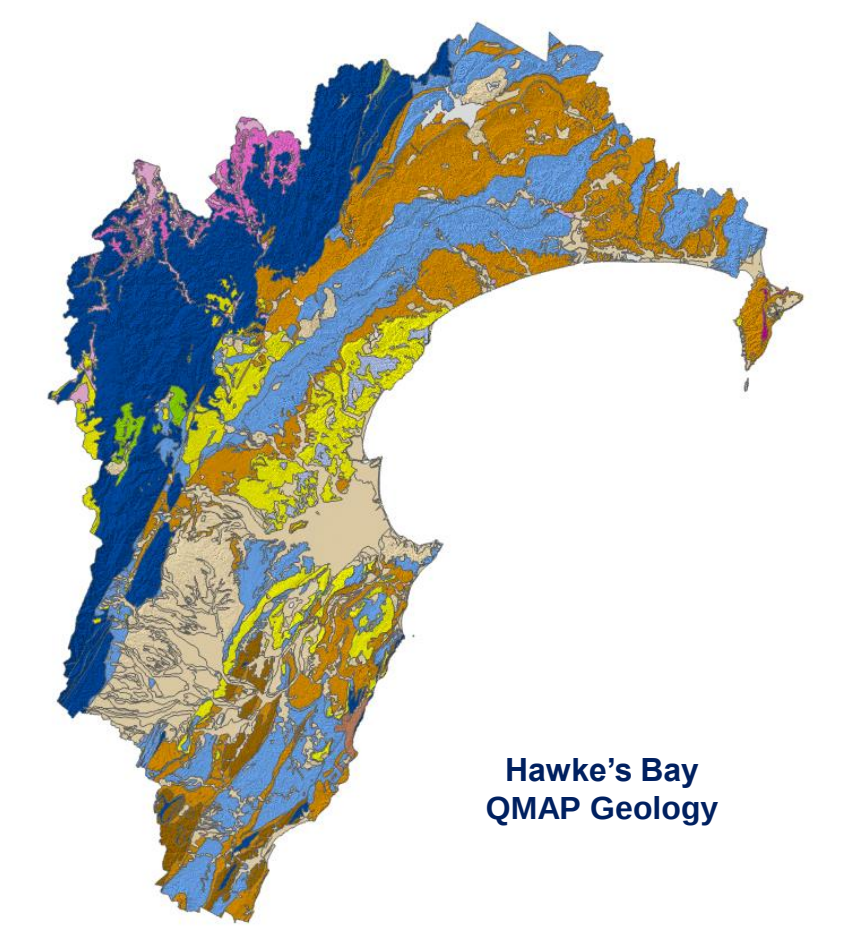


Hawke’s Bay Regional-scale Modelling

> “ INSIDE RESOURCES
> MINING AND QUARRYING INTELLIGENCE
> **Hawke’s Bay gravel suppliers 'blindsided' by allocation changes** ”
> *Shannon Williams* - Wed, 16 Jun 2021
> Gravel suppliers in Hawke’s Bay have been blindsided by the regional council’s adjustments to river allocations.

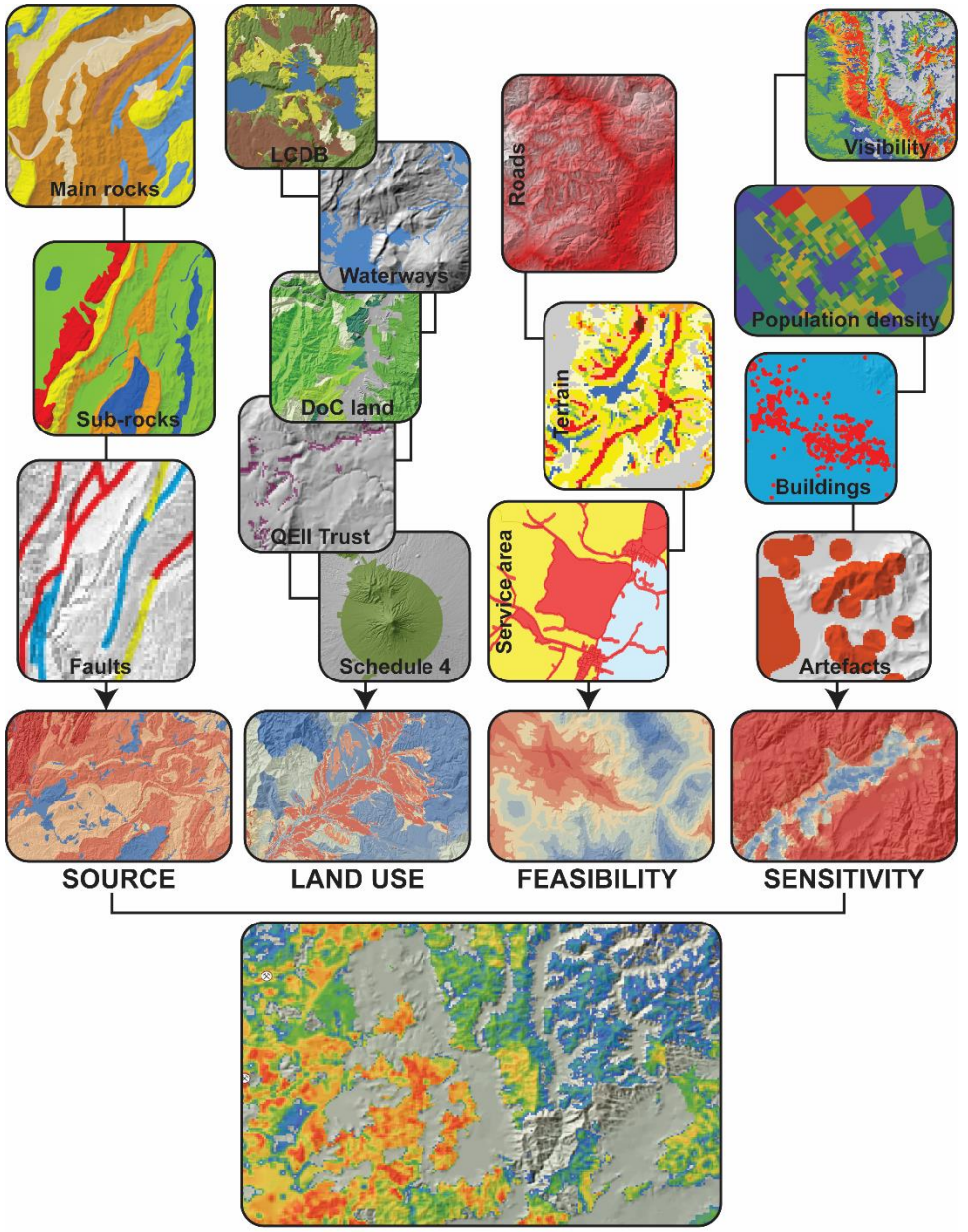
The reduced allocations of gravel that could be taken from Hawke’s Bay rivers proposed the question:

Where are potential hard rock opportunities in the region that could replace the gravel supplies?



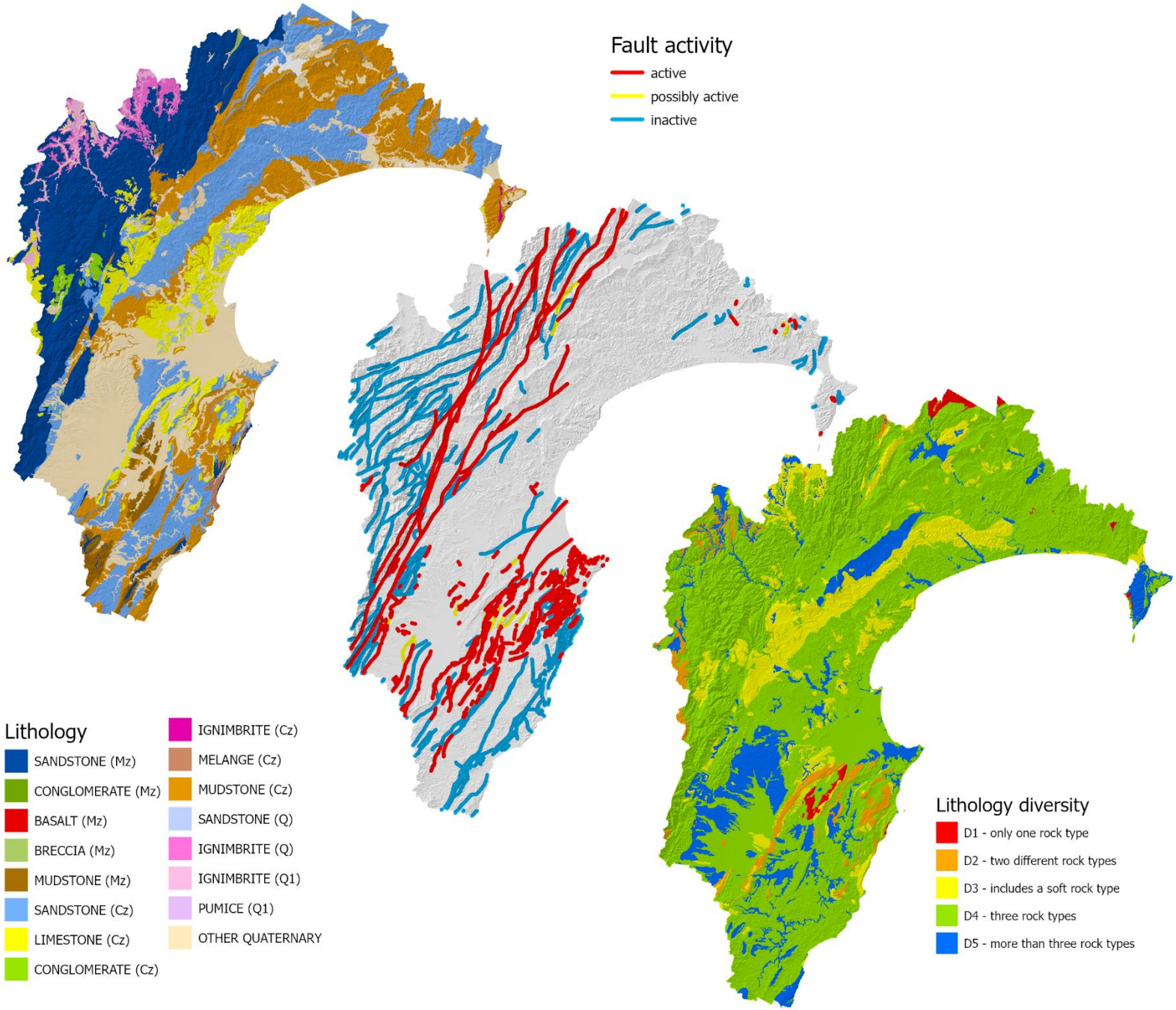
Hawke's Bay – Map layers

- This regional-scale modelling typically uses fewer map layers.
- Maps such as demand and infrastructure that were used in the national model are redundant at this scale as we have generally already taken that into account when choosing to model at a larger scale.
- Regional-scale modelling can include more detailed analyses of:
  - The local geological maps;
  - Road infrastructure and truck travel paths;
  - Terrain and visibility analyses;
  - And, region-specific cultural sensitivities.



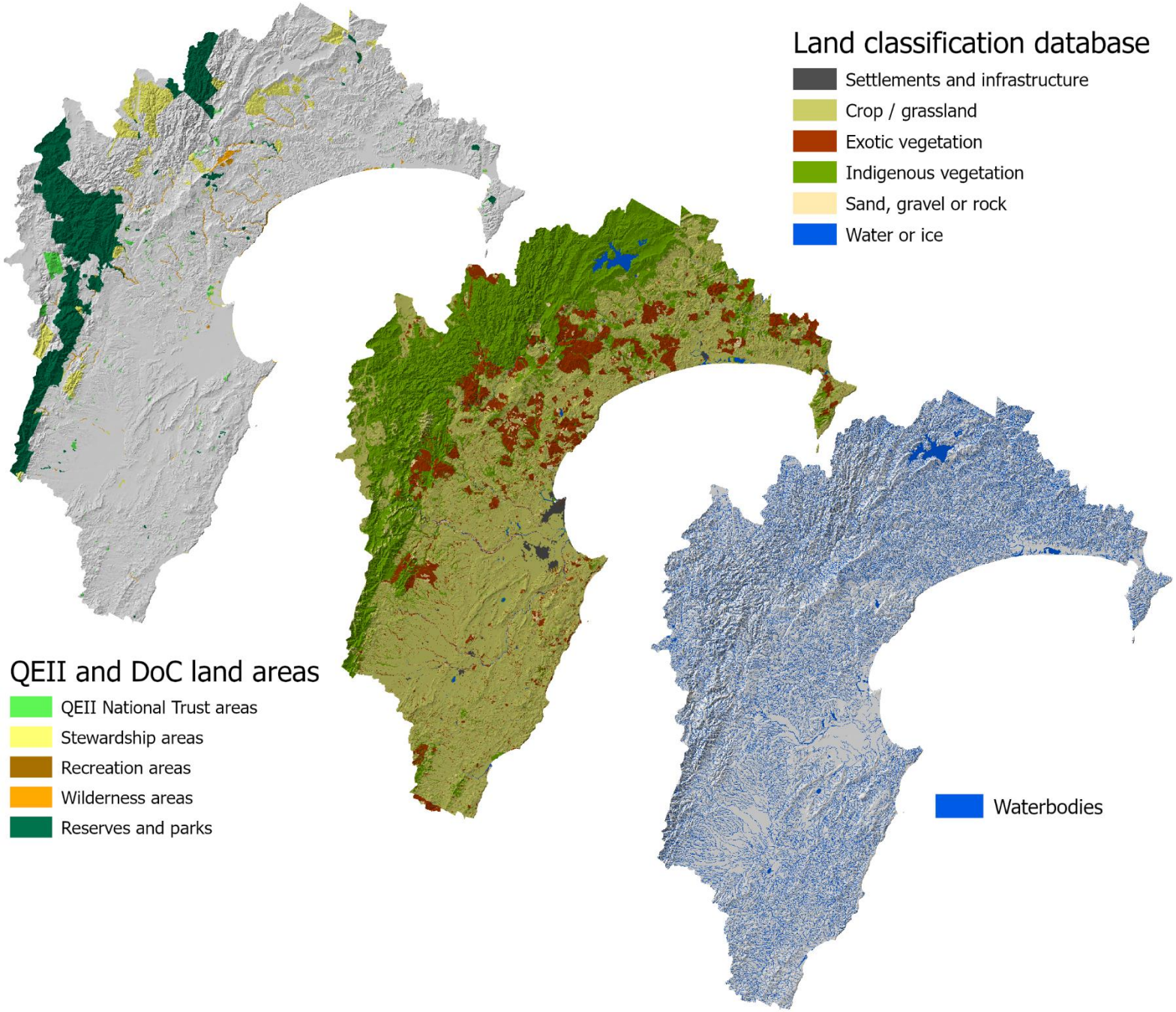
Hawke's Bay – Geology

- In the regional-scale model lithology can be modelled using locally specific lithological classes and features.
- We have only modelled for hard rock aggregate types.
- In this study we have used:
  - Lithology classes of sandstone, limestone, and volcanics.
  - Fault locations and their activity classification.
  - And, lithological diversity; how many different rock types are listed for each map area.



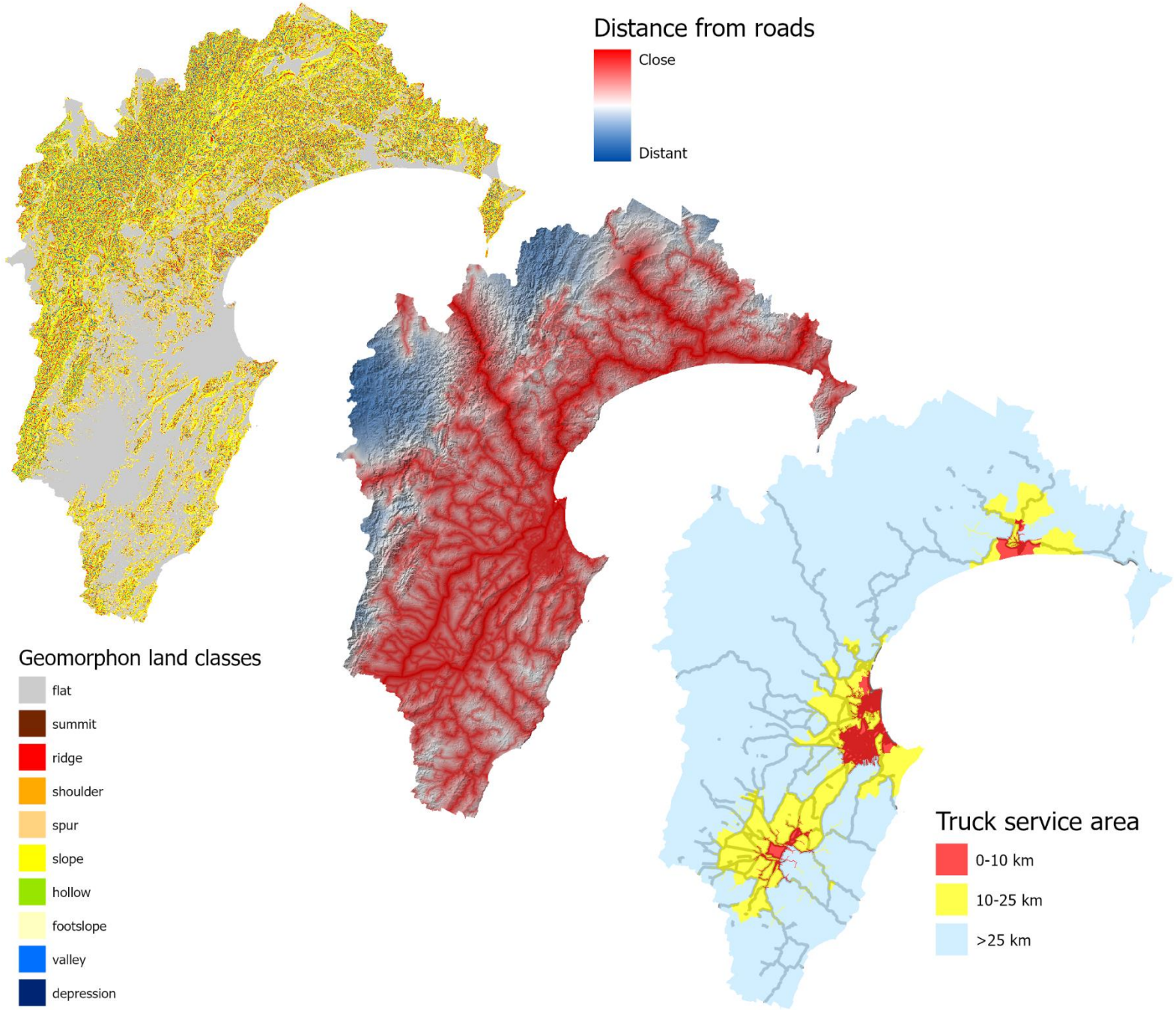
Hawke's Bay – Land Use

- This map is created the same was as it is in the national-scale model.
- However, we can map the features at a 10 times better resolution in this model.
- Data in this model includes:
  - DoC conservation land areas.
  - Land use classifications (LCDB)
  - QEII National Trust areas
  - And, waterbodies (rivers and lakes)



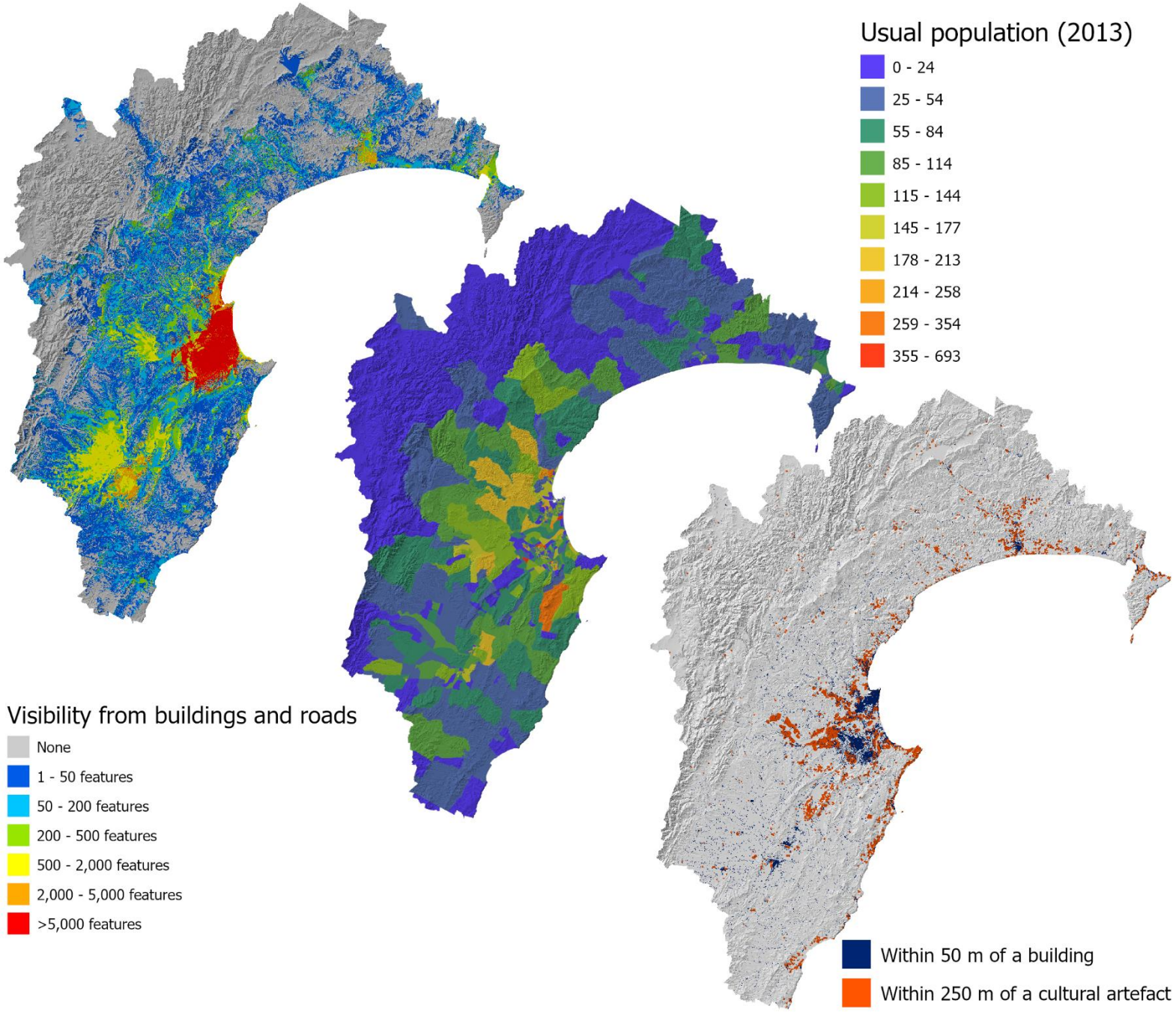
Hawke's Bay – Feasibility

- A new component is created for this model and it is maps describing the feasibility of quarry operations.
- Maps include:
  - Terrain types mapped by geomorphon classes.
  - Distance from roads and road types.
  - And, service areas that trucks can access from the end users.

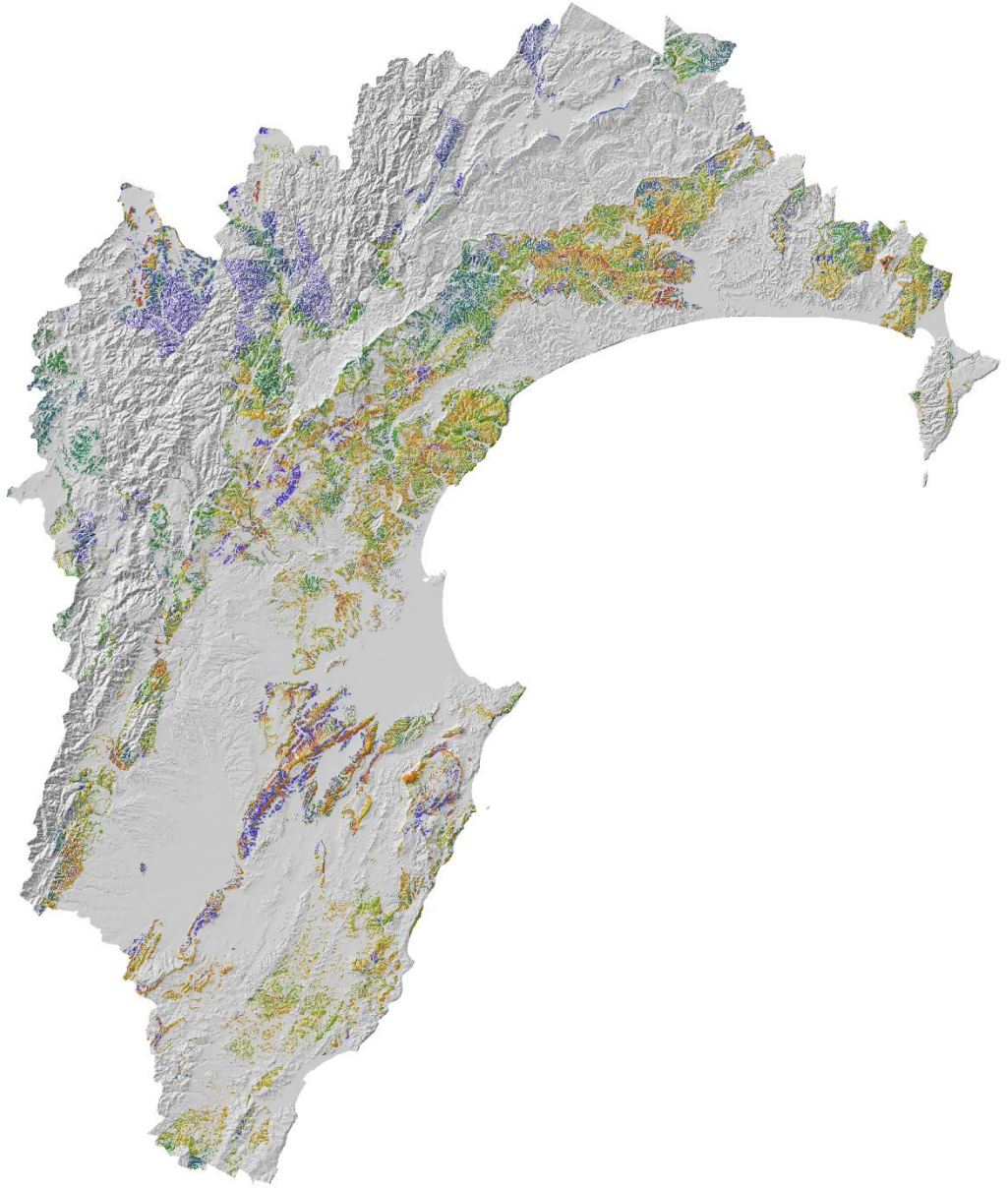


Hawke's Bay –Sensitivity

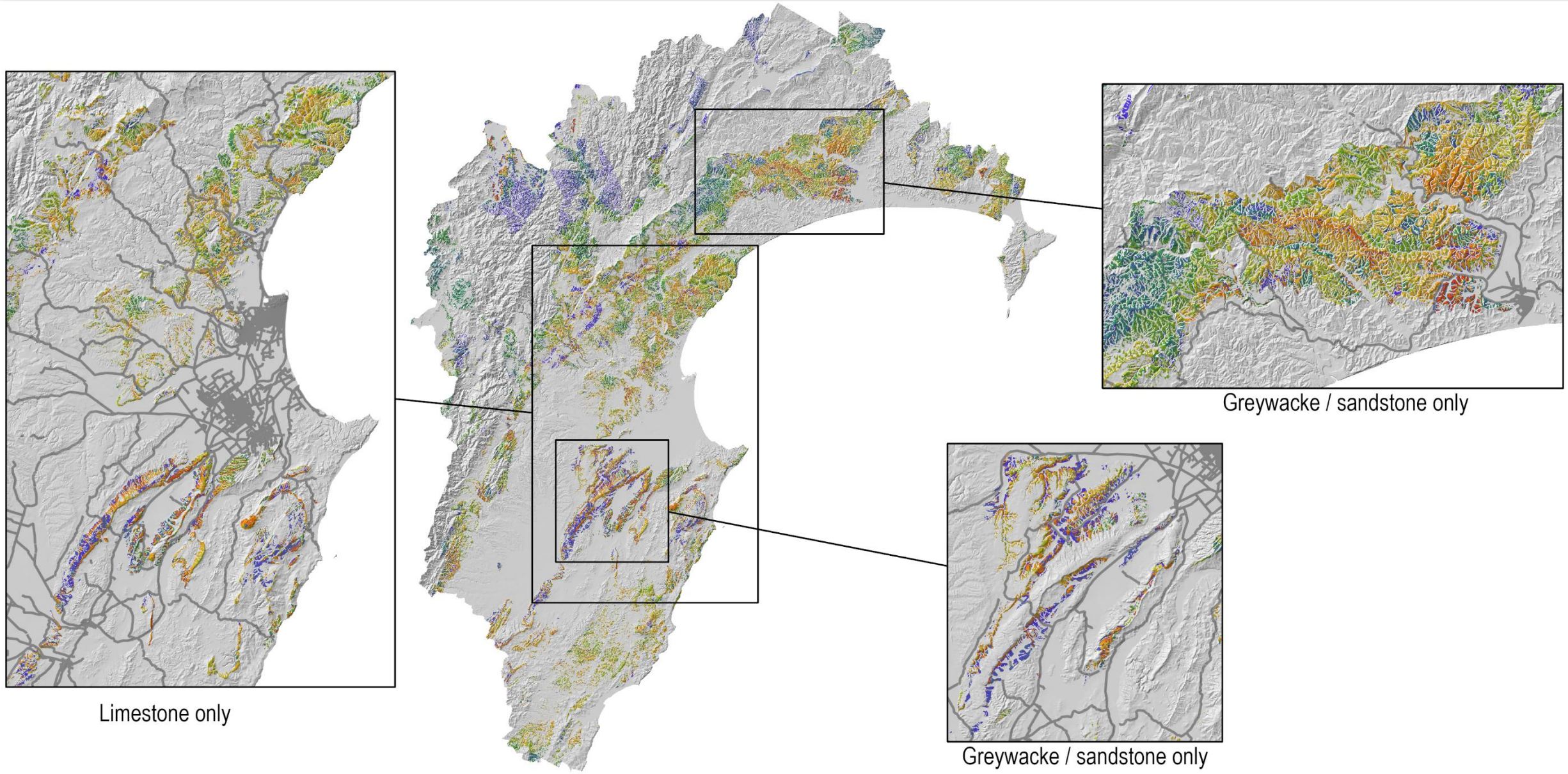
- We still need to consider the sensitivity of populated places in our modelling.
- The sensitivity maps in this model include:
  - Building locations
  - Cultural artefacts (vineyards, golf courses, cemeteries, etc.)
  - Highly populated areas
  - And, a detailed visibility analysis to determine what can be seen from roads and buildings.



Hawke’s Bay Model Results:



Hawke's Bay Model Results:



New Rock Property Maps

GNS are working on developing a process and information for new rock property maps.

The national / regional opportunity models only provide target areas based on general geological classifications.

Improving the granularity of geological map units is a logical next step.

In targeted areas physical rock property data can be compiled and used to understand the resource potential.

1. Information Compilation

a) Compilation of accessible geological and geotechnical information from industry, government and academic sources.

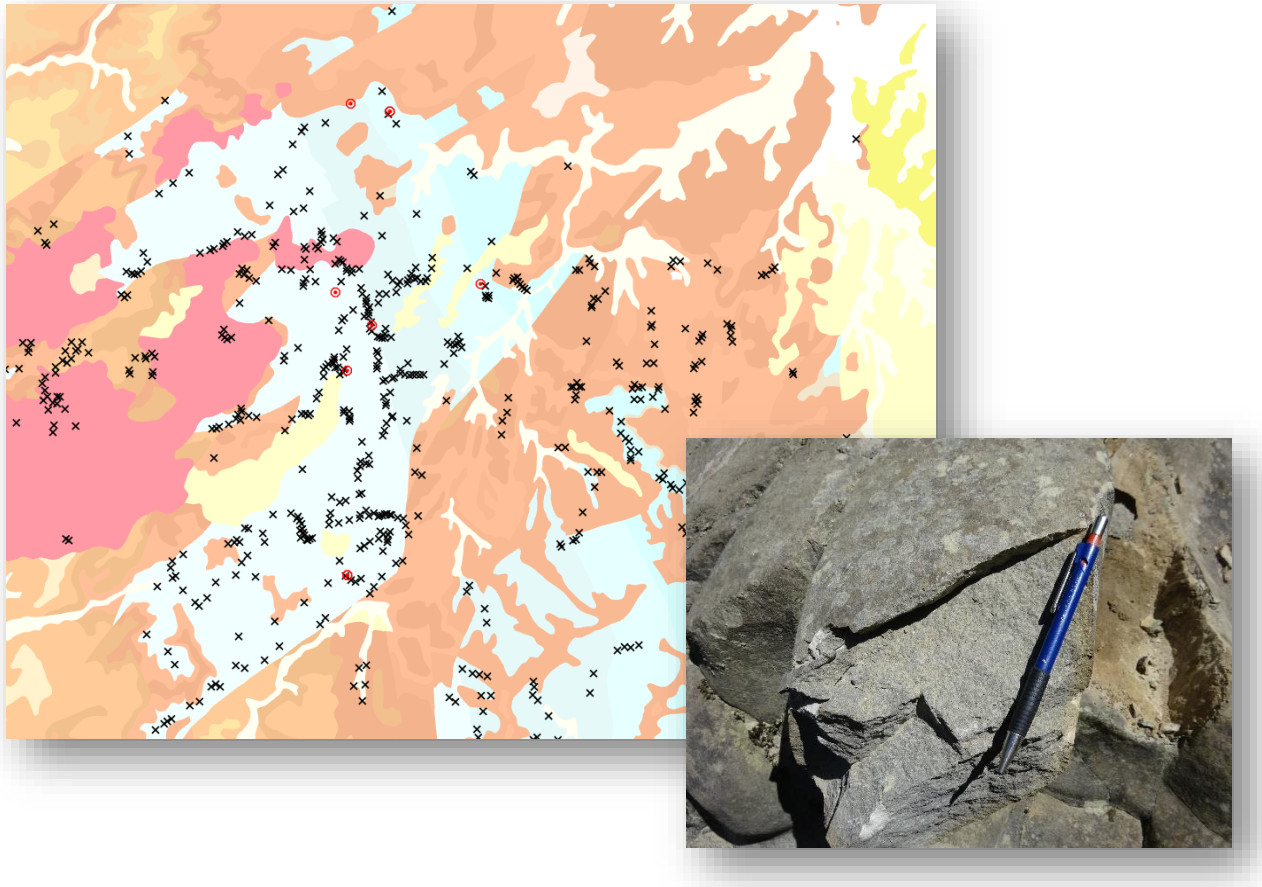
b) Integration of geological mapping from various scales and subdivision of the map units based on aggregate-relevant rock properties.

c) Establishing a database of rock property information.

2. Data Acquisition

a) Field collection of new sample and rock property information.

b) Sampling programme designed of fill in missing information at key targeted locations.



New Rock Property Maps

Rock unit properties:

- Subdivided map units (facies variation)
- Density
- Impurity minerals (veining and minerals)
- XRD / XRF geochemistry
- Fracture density
- Weathering / weathering resistance
- Hardness
- Clay content
- Particle size

Do you have priorities for exploration data or is there other information you would like to see included?

Summary

- GNS Science, the New Zealand Infrastructure Commission, and the AQA have worked together on a study to improve our understanding of the best areas for aggregate opportunity throughout the country.
- The model has created maps that identify potential future quarry developments.
- These areas need to be investigated in more detail to protect the resources for future generations and are potentially a catalyst for new industry exploration.
- Regional-scale modelling can improve the detail in our modelling and include region-specific data layers.
- Our next step is to start collecting information for more detailed geological mapping and creating maps or advanced rock and engineering parameters.

I would like to thank:

New Zealand Infrastructure Commission for supporting the publication of this research and Ross Copland, Brett Woods and Rob Addison for advice on aggregates role in future infrastructure.

Mike Chilton (AGGREtech); Mark Rattenbury, Tony Christie (GNS Science); and Wayne Scott (AQA) for advice on the aggregate industry and elements of the exploration concept utilised in this study.

And, industry experts who have provided advice on extraction activities and those who completed in the future demand survey.

Contact: m.hill@gns.cri.nz

Initial modelling and early versions of this research have been supported by the Strategic Science Investment Fund to GNS Science.