WISE V1.4 – REFERENCE SCENARIO KEY ASSUMPTIONS

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The assumption below are represented by the settings and parameters used within the sub-models in WISE V1.4 and linkages between them. The totality of these assumptions (parameter settings) makes up what is referred to as the current *'Reference scenario'* within WISE V1.4.

Note there are also a number of other assumptions for how the sub-models and linkages will interact as WISE runs but these are consistent for any scenario run in this version of WISE. See the WISE Technical Specifications document (WRC Doc# 3560882) for more information on these. Also see WISE website www.creatingfutures.org.nz

KEY MODEL PARAMETERS:

The parameters[1] and settings are generally based on historic calibration and expected future developments (includes policies that have already been approved), and assume no extreme exogenous changes in economy and demography. These could be considered as a continuation of 'status quo' settings and behaviour under expected trends in economic, environmental and social drivers. The main parameters that drive the model are:

Parameters	Definition Process and Assumptions
Population	
Annual Growth	Population, defined in single year cohorts, starts from 2013 census base data and annual changes are driven by net migration, birth rates and mortality parameters (set for each council area) in the population model.
Net Migration	Net migration figures are based on population growth rates between 2006-2013 census figures.
Birth Rates	These rates are based on the fertility series in Statistics NZ sub-national population projections out to 2043, after this rates are assumed to be constant.
Mortality	Mortality rates are based on the life expectancy series in Statistics NZ sub-national population projections. These are also out to 2043, after this rates are assumed to be constant.
Economics	
International Exports	Projected exports are based on national long-run average growth rates by industry. Assumes no 'step-change' in exports from any sector.
Inter-regional Exports	Baseline inter-regional trade values are taken from the Waikato region estimates based on a multi-regional interregional trade input-output table (MRIO) developed for New Zealand.
Gross Fixed Capital Formation	Based on Statistics NZ National Accounts, analysed for long-run average and projected forward. Again no 'step-change' assumed for any sector.
Regional Household Consumption	Future household consumption are assumed to be driven primarily by future population. Each person is assumed to consume a constant mix of goods and services (with some adjustment for aging effect).
Land Use	
2013 Land Use	Created through a GIS analysis of 2012 Land cover, 2013 Valuation and 2013 Agribase databases. Assumptions made where conflict between codes in databases occurred define 2013 land use.

[1] A parameter is defined as

Zoning	District plan zones, growth strategy areas, and relevant regional and national spatial restrictions used. Degree of restriction based on Resource Management activity statuses. Expert opinion used to refine these settings.
Suitability	Suitability of land for specific land uses defined by range of 'geophysical' characteristics (i.e. erosion, flooding). Characteristics used for each land use type based on expert input.
Accessibility	Road network used is same as Waikato Transport model (all public roads and planned road developments to 2041) Also includes railways and private road network (assumed as Topo50 roads less public road network).
Climate	
Annual average: - Temperature - Rainfall - Potential evapotranspiration	Modelled for Waikato Region based on 'medium' emissions projection from IPCC 5th Assessment Report (2013). Climate anomalies from 1972-2013 used in projecting climate variable forward to 2064

ASSUMPTIONS BY MODEL AREA

The key assumptions are outlined for each of the sub-models contained within WISE (Figure 1). The assumptions relating to main linkages are between these sub-models are also described.

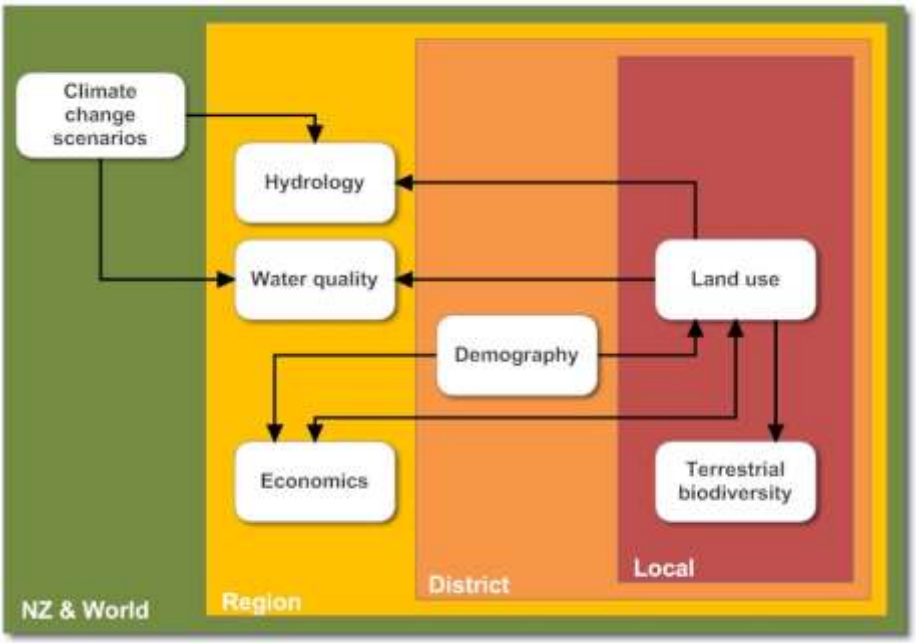

Figure 1: Sub-models and Linkages within WISE

ECONOMICS – ECONOMIC FUTURES MODEL (EFM)

The Waikato region Economic Futures Model (EFM) is an input-output model that consists of three sub-modules: Demand-side, Supply-side and Reporting. Input data to the EFM is based primarily on an analysis of economic activities within the Waikato region, with all economic activities categorised into one of 48 industry types.

The demand-side module estimates demand by industry, which is the sum of four external economic drivers and regional household consumption (demand). For the Reference scenario these "Demands' are derived by:

- International Exports (i.e. demand outside New Zealand) – Baseline projections for future international exports were generated by applying the national long-run average growth rates for export commodities by industry to the Waikato region's 2013 international export estimates.
- Inter-Regional Exports (i.e. demand within New Zealand from other regions) – The baseline inter-regional trade values were derived from the Waikato region estimates produced from Market Economics multi-regional input-output table (MRIO) for New Zealand (Smith *et al*., 2014).
- Gross Fixed Capital Formation (GFCF) (e.g., new buildings, equipment, plant and machinery etc.) - Baseline data for 2013 are provided directly into the Waikato region EFM. Future growth rates were determined, as with international exports, through statistical time series (econometric) analysis using national long-run averages. Data used in the time series analysis are derived from Statistics NZ National Accounts Gross Fixed Capital Formation by Industry.
- Changes in Inventory (e.g., changes in goods not yet sold) - Baseline 2013 data are provided directly into the Waikato region EFM by Market Economics Ltd. Note: for many industries changes in inventory are very small compared with international exports, inter-regional exports, and GFCF.
- Regional Household Consumption (Demand) - estimates of future household consumption are primarily though estimates of future population. It is assumed that each person within the Waikato Region consumes a constant mix of goods and services (with some adjustment for aging effect). Population inputs are provided by the Demography sub-model.

To establish land use demand an eco-efficiency index (e.g. hectares required / $ economic output) for each economic industry is applied. These are set in the Reference Scenario based on analysis of industry productivities within Waikato Region. It is assumed that the eco-efficiency index will change into future based on recent historic trends. This demand for land is presented to the Land Use Change model in WISE.

Although the EFM defines an annual 'demand' for each land use the Land Use Change model determines the actual land supplied to the EFM. The EFM then adjusts final economic activity to reflect that supply. The outputs of the Land Use Change model act as an input to the EFM Supply-Side module.

In addition to modelling economic activity, the Waikato region EFM also models the employment, provided as Modified Employment Counts (MEC's). These are based on employment rate per industry factored with changes in industry size. Further multiplication is also applied based on projected changes in labour force productivity.

The reporting module provides information and indicators related to the economy (e.g., final demand in constant $\$NZ_{2007}$ mil), environment, (e.g., resource use or residual outputs in appropriate units), or labour markets (e.g., employment, labour force productivity).

DEMOGRAPHY

POPULATION MODEL– WHOLE-OF-WAIKATO (WOW)

The WOW (Whole of Waikato) population model generates possible future populations, referred to as population projections, starting from a given base population (2013) and assumptions about the demographic processes of fertility, mortality and migration. The methodology used is broadly that of the standard cohort-component model that is also widely used by other agencies, including Statistics NZ.

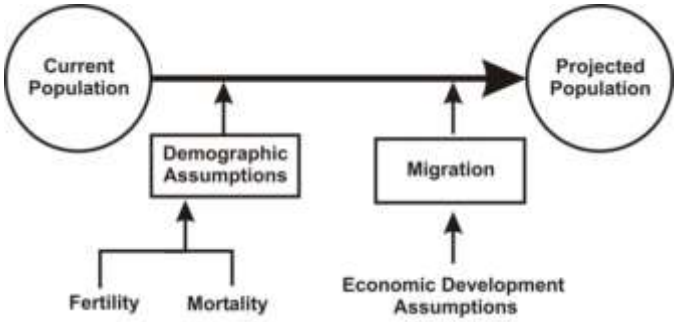

Figure 2: Whole of Waikato (WOW) Population Model.

The Whole of Waikato (WOW) demographics model consists of 11 1-year age-sex cohort component models, one for each district or part district in the Waikato region. The model includes information on fertility, mortality, net migration among districts, and net migration to/from each district to outside the region. Users may vary global fertility and mortality (i.e. adjusted each up/down for each age-sex cohort) and vary net migration for each district individually to create different scenarios.

The assumptions for the input parameters to the WOW Model are:

- Fertility – Fertility rates are based on historic trend data for all females aged 13+ by single-year-of-age for each district. The model uses a birth gender bias towards boys of 0.51338 for all districts
- Mortality – Survivorship rates are based on historic trend data for single-year-of-age and gender for each district.
- Migration - Net in migration rates are based on historic trend data for single-year-of-age and gender for each district

The Reference scenario is based on figures for these input values that have been derived from 2013 census data and projected annually out to 2064 by the University of Waikato (Cameron and Cochrane, 2015).

The population outputs from the demographic model directly drive the allocation of residential land uses in each district via the Land Use Change Model. Population is also used to calculate labour force participation rates in the economic (EFM) models.

RESIDENTIAL LAND USE DEMAND

The other key demographic parameters that drive outcomes in the WISE model are settings used for population densities in each of three residential land use classes and the proportion of district population living in each of these land use classes. The derivation of the starting figures and assumption for changes into the future are discussed

Population Densities for Residential Land Uses

Starting densities for each residential land use type are derived from an analysis of 2013 Regional Valuation database and 2013 census data and starting 2013 land use layer. This creates district wide averages for each of the three residential land use types (Table1).

District	Residential – lifestyle blocks	Residential – low density	Residential – med – high density
Thames-Coromandel	1.1	11.2	30
Hauraki	1.6	18.7	60
Waikato	2.1	25	111.3
Matamata - Piako	2.2	27.7	75.4
Hamilton City	2.5	32.7	107.3
Waipa	2.2	24.9	70
Otorohanga	2.2	22.9	73.1
South Waikato	1.9	24.7	100
Waitomo	1.8	19.4	60
Taupo	0.8	16.8	55
Rotorua	2.8	28.3	70

Table 1: Starting population densities (people/ha) of residential land uses

These values can be varied into the future as part of scenario setup. For the Reference Scenario these are set up to reflect:

1. an expected decrease in household sizes based on Statistics NZ 2013 household projections
2. expected changes in property sizes or intensification of existing areas based on policies in a District Plan.

Proportion of District Population Living in Each Residential Land Use Class

The setting of the proportion of population living in each residential land use class is important as this directs how future projected population growth or decline will be distributed between the three classes. These starting proportions (Table 2) are based on the area of each land use type in 2013 and calculated density figures in Table 1, sum up to 1 for each District.

District	Residential – lifestyle blocks	Residential – low density	Residential – med – high density	Other land uses
Thames-Coromandel	0.089	0.707	0.036	0.168
Hauraki	0.186	0.654	0.010	0.151
Waikato	0.447	0.392	0.008	0.153
Matamata - Piako	0.139	0.708	0.018	0.135
Hamilton City	0.012	0.880	0.068	0.040
Waipa	0.227	0.636	0.042	0.096
Otorohanga	0.312	0.462	0.023	0.203
South Waikato	0.095	0.824	0.009	0.072
Waitomo	0.164	0.559	0.000	0.276
Taupo	0.091	0.764	0.048	0.097
Rotorua	0.549	0.104	0.000	0.347

Table 2: Starting population proportions residing in each residential land use class

The population proportions in the Reference scenario are varied into the future to reflect the expected changes in residential land use based on district plan provisions (i.e. more Med-Hi density housing in Hamilton).

CLIMATE CHANGE

For the Reference scenario the climate change inputs are set to the 'medium' emissions projection defined by IPCC 5th Assessment Report (2013) without any annual variability.

The medium IPCC projection predicts 1.65°C global mean warming by 2100. These input data are provided to other sub-models (Hydrology, Water Quality) as three climate variables: average annual temperature (°C), average annual rainfall (mm), and average annual potential evapotranspiration (mm).

HYDROLOGY

This model in WISE consists of a simple hydrological simulation model developed specifically for WISE. The model simulates total annual surface runoff (mm/year) and summer flow yields (litres/second/km^2) based on inputs of rainfall, potential evapotranspiration and land use. So if there are changes in the modelled climate or vegetation, then the model outputs will respond to this.

The Hydrology model assumes that climate varies smoothly during each year, and that within this smooth seasonal variation, rain falls in random pulses. Calculations are made separately for a 500 m × 500 m grid using a simplified set of analytical solutions. These are calculated from spatially varying climate, soil and vegetation hydrological responses.

The rainfall interception capacity[2] of the canopy is determined from a look up table based on current land use from the Land Use Change model. Soil water holding capacity[3] comes from the Fundamental Soils Layer, which is found in the New Zealand Land Resource Inventory. The water holding capacity value is adjusted to account for increased rooting depth of tall vegetation.

Type	Model Component	Data Passed	Comments
Inputs	Climate Change Scenarios	Rainfall	Weighted average of the 4 nearest grid cells
		PET	Weighted average of the 4 nearest grid cells
	Land Use Change	Land Use	Land use determines the canopy capacity w_{cm} (mm) via a look-up table

Table 3: Input Values to Hydrological Model

[2] The rainfall interception capacity is the amount of water from a rainfall event that the vegetation's canopy can hold preventing it from reaching the ground.

[3] The soil water holding capacity is the volume of water a soil can hold within its pores before further water input from rainfall begins to drain from the base of soil profile.

WATER QUALITY

The Water Quality model is an adaptation of the U.S Geological Survey SPARROW model calibrated on Waikato regional data and on data from the nationwide National Rivers Water Quality Monitoring Network.

The model estimates mean pollution loads (over a 5-year period) of nitrogen and phosphorus (tonners/year) for each individual reach as defined within sub-catchments of the Waikato Region as a function of climate, land use, soils, and point-source pollution sources. It does not explicitly consider long-term lags attributable to groundwater storage and release.

The model is calibrated using point sources of nutrients (from Regional Council data, consultancy reports, and informed estimations), land use and land cover data, and mean stream flow using rainfall and evapotranspiration modelling. These calibrated coefficients within WISE are static and are not dynamically recalculated/recalibrated during a model run.

The model utilised equations to account for nutrient sources, source modification, attenuation and routing loads through catchments.

They dynamic inputs to the Water Quality model are rainfall from climate change scenarios and from the Land Use Change Model land use which determines the source coefficient via a look-up table. Land use also determines the value of the rain exponent and drain exponent for N loading.

LAND USE CHANGE MODEL

The Land Use Change model dynamically models land-use change over time based on demand for residential land uses generated by the WOW (population) model and demand for economic land uses generated by the Waikato region EFM. For each year (2013-2063) the model evaluates the potential for land use at each 100 × 100 m grid cell to transition to every other land use (25 Classes). For each grid cell the model ranks the **transition potential** of all the land uses based on a combined score from four factors (See Figure 3):

- **Accessibility** – assesses the attractiveness of a location for different land uses based on the proximity to desirable or undesirable features (e.g., roads, factories, residential centres).

  The Accessibility inputs in the Reference scenario are represented by spatial layers of current and future infrastructure. These include current (2013) railways, private and public road networks, planned future major road improvements (e.g 2021, 2031, 2041), and current residential centres (i.e Hamilton CBD). The relative 'scale' of desirability attributes to these features is set based on their importance to a land use type. Initial setting are adjusted during calibration of the Reference scenario. Zonal accessibility[4] is set for each district by functional land use type to represent accessibility influences from outside the Waikato region, mainly the attraction of Auckland (less than 1 value used to represent lower accessibility).

- **Neighbourhood (Local influence)** – This assesses the attractiveness of a location (grid cell) for a land use based on the composition of land use in the surrounding neighbourhood.

[4] Zonal Accessibility is a static multiplication parameter that represents for each District relative accessibility influences outside the Region.

The Neighbourhood (Local influence) settings in the Reference scenario are set for each pair of land uses (i.e. Local influence of commercial on low density residential). These are set as a specific function defining the strength (high, low, none) and direction (positive/negative) of any interaction out to a maximum distance of 8 grid cells (800 m) from the cell of interest. This represents a total of 195 cells or 195ha in WISE model. The model sums up the weights of all the cells in the surrounding neighbourhood are used to produce a composite score for each cell of interest. Also each land use has a transition value at distance 0, i.e. the cell itself, which determines how easy or difficult it is to change from that land use.

The assumption behind the allocation of attractiveness between land uses include:
- 'Like attract like' – new residential or commercial is likely to develop adjacent to existing area – if zoning and space exists
- Services occur close to demand – commercial, community services for example will occur near or adjacent to residential land use

The specific functions are defined are set and then refined as part of the calibration process during development/revision of WISE model versions.

- **Zoning** – This represents the potential for future development to occur at a grid cell based on knowledge of regional and district plans and other statutory requirements.

The zoning tool is a specific interface within WISE that allows users to input individual zoning rules and regulations. Zoning indicates where different land uses may or may not occur. Different rules or regulations can apply to different areas and also be in force for different periods of time.

The zoning in the Reference Scenario is set up to best represent the current rules and regulations at start of modelling period (2013). Generally this represents that zoning as defined in operative District Plans. The behaviour of these rules in the Reference scenario has been validated with Council staff to identify and correct any anomalies. All the District Plan rules from across the region, some regional rules (Lake Taupo) and national restrictions (DoC estate, QEII covenants) have been included and setup in WISE. These are according to their RMA Status:

RMA ACTIVITY STATUS	SCORE
Actively Stimulated	1.2
Permitted	1.0
Controlled	0.8
Discretionary	0.6
Restricted Discretionary	0.4
Non-complying	0.2
Prohibited	0.0

In addition to RMA rules defined in District Plans, Regional Plans and Regional Policy Statements the zoning tool has also been used for the Reference Scenario to load 'Future Zoning' areas that are defined in specific District growth strategies. These growth areas have been loaded and are 'turned-on' in WISE to represent the change in zoning status that could occur in the future. Most of these growth areas are within the Future Proof area (Waikato DC, Hamilton City Council and Waipa District Council).

- **Suitability** – The estimated suitability of land for different uses based on various geophysical factors considered relevant to a particular land use.

  Similar in concept to the zoning tool, the suitability tool is a specific interface within WISE that allows user to users to create an overall suitability rating at each cell for each land use type. This suitability is related to geophysical restrictions that can apply at a specific site (i.e. flooding, drainage, rainfall, growing days, erosion risk). Suitability is scored from 0 (unsuitable) to suitable (1) based on different combinations of factors.

  The suitability factors and settings for each land use type used in the WISE Reference scenario are based on expert input from Landcare Research (Rutledge et.al, 2014).

Potential figures (1833, 1082)

Land use	Total potential	Neighbourhood potential	Suitability	Numerical zoning	Accessibility
Residential - Lifestyle Blocks	490.641	224.802	0.945742	1	0.993926
Residential - Low Density	2378.82	1270.2	0.945742	1	0.964093
Residential - Medium to High Density	430.006	475.11	0.945742	0.6	0.967068
Commercial	296.812	510.055	0.945742	0.4	0.964772
Community Services	445.698	449.604	0.945742	0.6	0.976797
Horticulture	0	0	0.694283	0.2	0.657101
Biofuel Cropping	0	0	1.06945	0.2	1
Vegetable Cropping	0	0	0.708046	0	0.81132
Other Cropping	0	0	0.812641	0	1
Dairy Farming	0.023562	0.10393	0.796844	0.2	0.934134
Sheep, Beef or Deer Farming	0	0	0.909768	0.2	0.620926
Other Agriculture	0	0	0.909768	0.2	0.495696
Forestry	0	0	0.758169	0.2	0.702143
Manufacturing	0	487.734	0.945742	0	0.986485

Figure 3: Example of Transition Potentials for a single cell at a time step during modelling (currently in Low Density Residential – note zoning prohibits manufacturing and cropping).

The Land Use Change model attempts to meet the demands by assigning cells with the **highest transition potentials** to the appropriate land use until the demand is met.

The WISE Model uses three classes of land use types: *Land-use functions* which are dynamic and active (demand driven by population and economics) in the modelling (e.g. residential, commercial, forestry); *land-use vacant states* which are dynamic and passive (can be allocated based on other factors – zoning, suitability) in modelling (e.g. Indigenous forest, wetlands); and *land-use features* which are static (do not change during the simulation, eg. marine, urban parks).

TERRESTRIAL BIODIVERSITY

Threatened Environments are an indicator of ecosystem representativeness based on a combination of biodiversity condition (land cover), protection (New Zealand Protected Areas Network), and Land Environments of New Zealand (LENZ) (Leathwick et al. 2003).

The Terrestrial Biodiversity sub-model is set in Reference scenario to track changes in regional threatened environment status for Land Environments of New Zealand (LENZ) Level II land environments (100 environment classes nationally) represented at 100 m × 100 m resolution. Layers of alternate LENZ levels could be applied.

In the Reference scenario the sub-model applies a Landcare Research derived New Zealand Protected Areas Network (PAN-NZ) layer derived in 2008.

The model accepts land use from the Land Use Change model as input, translates land use into land cover (native or non-native), and then determines the amount of native cover remaining by LENZ land environment and amount protected to calculate each land environments threat status.

KEY REFERENCES:

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