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Sustainability Stocktake of Nelson City

RESEARCH BASED SOLUTIONS

Sustainability Stocktake of Nelson City

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Prepared for

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EXECUTIVE SUMMARY

This report, commissioned by the Nelson City Council, uses The Natural Step processes of *the funnel* and *the sustainability principles* to identify and discuss sustainability challenges facing Nelson City. Fourteen challenges were identified based on the research team's knowledge and confirmed with national and international sustainability indicators. The challenges are: air quality, atmosphere (greenhouse gas and ozone), biodiversity, coasts, consumption, energy security, externalisation of environmental impacts, food security, freshwater (quality and quantity), land cover and land use, population, societal impacts, transport and waste disposal. The challenges are not necessarily independent of each other and overlap and interact in complex ways. There may be challenges not identified in this list that will emerge as the Council's *"Framing Our Future"* process advances.

The challenges were combined with the analytical tool driving force-pressure-state-impact-response (DPSIR) model and each challenge was classified based on its position in *the funnel* and the DPSIR model. The challenges were also classified by which *sustainability principles* were applicable to them and it was found that all but one of the challenges impacted on, or was impacted upon, by all four of the *sustainability principles*.

In general, this research shows that, while there are many aspects of the lifestyles and actions of Nelson residents that are positively contributing to sustainability, there are also many challenges for Nelson City to become sustainable. Each sustainability challenge is briefly discussed in turn, with challenges of supply listed first and challenges of demand second. It became apparent during the research that not all challenges could be quantified locally. Challenges have therefore been classified by how quantifiable they were, with challenges either A (those with local data available) or B (those without local data).

The A Supply Challenges

Air quality: Since regulations placed restrictions on open fires in homes in 2007, air quality statistics have shown significant improvements. However, Nelson still exhibits one of the most polluted airsheds in the country.

Atmosphere: This includes climate change and ozone. The threats derive from the projected impacts of climate change include: altered weather patterns causing more intense storms and longer droughts; increased abundance and diversity of introduced pests; and sea level rise. These projected impacts could greatly affect Nelson's economy, society and environment.

In terms of ozone, the hole in the Antarctic is clearly a global issue; however this challenge is an example of where action at a local level can contribute globally. For example, the reduction of ozone depleting substances locally, such as Port Nelson's capture and storage of methyl bromide, is contributing to the gradual repair of the ozone hole.

Biodiversity: The Ministry for the Environment's 1997 *State of New Zealand's Environment Report* identified the decline of indigenous biodiversity as New Zealand's "most pervasive issue". Biodiversity has an important role in terms of New Zealand's economy, quality of life and identity as a

nation and many initiatives, both nationally and locally, have been undertaken to halt the decline. The key challenge remains however, to enhance these initiatives and ensure that the values of biodiversity are maintained into the future.

Freshwater: Quality of streams in Nelson varies greatly and while some Nelson streams are showing a trend of improvement, a larger number are experiencing a decline in water quality. Freshwater quantity is also valuable in supporting human wellbeing, with recreational, spiritual and cultural values intricately linked to freshwater. The challenge is to ensure the quantity and quality of freshwater are maintained and improved in the face of the threats confronting them.

Land cover and land use: Land cover and land use are intertwined challenges and relate to the way we treat our land. The main impacts of which, and of relevance to Nelson, are urban and rural run-off polluting waterways, coasts and estuaries and urban expansion leading to the loss of plant and animal habitats. There is a close connection between changes in land cover and land use and declining ecosystems and biodiversity, the challenge of land cover and land use is therefore closely linked to biodiversity and is to ensure that the decline in biodiversity caused by land cover and land use is reversed and biodiversity is maintained into the future.

Waste disposal: Reducing waste to landfill is another sustainability challenge for Nelson City. Although the amount of waste added to landfill has been reducing annually since 2005, the reason for this reduction is unclear.

The B Supply Challenges

Coasts: There are a complex myriad of ecosystems that make up the coastal environment, with 65 human induced stressors having been identified that impact on these systems. While Nelson City's management responsibility extends only 12 miles from the coastline, 61of the 65 stressors impact on the shallow coastal habitats. Indeed reports have found many of these same stressors are occurring in Nelson's marine environment. However, while some regular monitoring of the coasts does occur around Nelson more work is required to gauge the ecological trends of the coastal habitats.

Externalisation of environmental impacts: These are impacts experienced elsewhere in New Zealand or the world but caused by the lifestyles of Nelson residents. For example increased electricity demand in Nelson requires new generation somewhere, resulting in habitat destruction from damming wild rivers. At the international level environmental externalities include, *e.g.* pollution from the transport of exported products from, or imported products to, Nelson, or the habitat destruction caused by mining for products used in Nelson.

The A Demand Challenges

Consumption: One way to measure consumption is with an ecological footprint, which measures consumption of a given geographic area, compared with its ability to produce goods. The Centre for Ecological Economics measured Nelson's ecological footprint and found that at 76,901 hectares, it exceeds the available land area in Nelson by 41,930 hectares or 2.18 times. As a result, Nelson is reliant on other regions and countries for its lifestyle. However, Nelson is also part of Tasman Bay and the South Island, this wider region is not in deficit, and is a surplus provider of goods. As such, the ecological footprint can provide an incomplete picture of consumption, nevertheless, the point remains that Nelson's reliance on others places it at risk from future global changes.

Energy security: Issues discussed with regard to energy pertain to supply of electricity and oil. In terms of electricity, a significant natural disaster, such as an earthquake, could disrupt Nelson's electricity supply. With regard to oil, the Nelson economy relies heavily on imported petroleum, with all major economic sectors in Nelson and Tasman using oil as an integral part of their operations. A disruption to supplies, for whatever reason, or future rises in oil price is therefore a threat to all economic sectors of the region.

Population: Although Nelson's population is increasing, the biggest challenge for Nelson relates to the changing demographics of the populations, with the largest increase in those aged over 65. Such changes can have a range of impacts on a community, one example is homeownership. As Nelson's population ages and their children leave home, houses once fully inhabited become mostly empty. Inefficient use of housing stock can result in increased house prices, a housing shortage and a pressure to build new homes.

The B Demand Challenges

Food security: The issue with food security is not just having access to sufficient food, but also being able to afford the available food. Research in New Zealand has found that between 20% and 25% of families sometimes or often find the variety of food they have access to is limited by lack of money and that the most deprived families were the most likely to have difficulty with food affordability. Regardless of being a major exporter of primary produce, food prices in Nelson follow global prices which look set to continue increasing, meaning the strain on consumers will remain.

Societal impacts: The social challenge for Nelson is its widening socio-economic gap. Data shows that the average decile rating of Nelson communities has steadily declined since 1990, and as of 2007 was below the New Zealand average. There are nine measures comprising a decile rating, and these include income, employment, qualification and living space. Further research is required to establish the present status of this trend.

Transport: The Nelson transport sector is heavily reliant on oil, and future price rises will affect the nature of this sector. Sustainability impacts of transport include air pollution, noise, pollution of waterways and greenhouse gas emissions. Traffic volumes have decreased in recent years, and are expected to continue to do so. The sustainability challenge for transport, therefore, involves reducing the negative impacts of driving motor vehicles, while at the same time enabling transition to a future in which people are driving less.

With regard to the impacts of these challenges on the four sustainability principles, examples of the contributions to or violation of these principles are as follow:

1. To be sustainable, a community must eliminate its contribution to the accumulation of material from the Earth's crust. With the accumulation of such material in Nelson's

environment, the assimilative capacity of the natural environment is put under pressure, resulting in impacts on people and the environment. Examples of material accumulating in nature include heavy metals as used in electronic equipment, coal as combusted for energy and oil, the incomplete combustion of which can cause negative health effects.

2. To be sustainable, a community must eliminate its contribution to the accumulation of substances produced by society. The accumulation of synthetic substances in Nelson's environment results in the assimilative capacity of the environment being put under pressure. There are some positive stories regarding efforts in Nelson to minimise such accumulations – the containment of methyl bromide during log fumigation, for example, has reduced the health risks associated with accumulation of the gas in the Nelson environment. However, harmful synthetic substances are imported into Nelson, and then accumulate within the municipal boundary. Examples include (i) plastics accumulating in landfills that bio-accumulate when burned, as in the case of agricultural plastics, and (ii) pharmaceuticals and chemicals commonly found in household products accumulating in waterways and coastal environments.

3. To be sustainable, a community must eliminate its contribution to the physical degradation of nature. With an ecological deficit of 41,930ha, Nelson is using natural resources at an unsustainable rate exceeding the available land within the district by 2.18 times. Compounding this is the growing population of the city which will place added stress on natural resources and ecosystem services in future. Nelson is therefore reliant upon other regions and nations to supply it with the land area it needs to support its way of life. This reduces Nelson's resilience and makes it more vulnerable to unexpected future changes.

4. To be sustainable, a community must eliminate its contribution to conditions that undermine people's capacity to meet their basic human needs. While some of Nelson's residents enjoy a high quality of life, there exist some aspects of their lifestyles that pose risks to this. Such as, the widening socio-economic gap, low participation rates in local democracy, health issues and crime.

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1. INTRODUCTION

In July 2010, Nelson City Council (NCC) resolved to lead the development of the sustainability strategy, *"Framing Our Future"*, for Nelson City. To develop this strategy it was decided to adopt a Strategic Community Planning Framework devised by the international non-governmental organisation The Natural Step (TNS), and defined as "a planning and decision-making framework that allows individuals to understand the root causes of unsustainability and then move strategically toward sustainability" (The Natural Step 2009).

TNS, which was founded by Dr. Karl-Henrik Robèrt in Sweden in the 1980s, has a vision for creating a sustainable society (The Natural Step 2009) and has grown to have offices in 11 countries, including New Zealand. The organisation has worked with some of the world's leading brands including Nike and Interface Inc, and has been used by a number of communities in New Zealand including Hastings City, Christchurch City, Central Otago and Queenstown. Internationally it has been used by communities in Sweden, Ireland and Canada, with perhaps the best known of these communities, Whistler in British Columbia.

Cawthron has been contracted to identify sustainability challenges facing Nelson to inform the development of *"Framing Our Future"*.

2. SUSTAINABILITY DEFINED

Establishing a definition for sustainability is important for any discussion involving the term, as there is a broad spectrum of definitions which are outlined in the box below. Drawing on such work, TNS developed and uses a simple definition for sustainability: "meeting human needs, without overwhelming nature and society" (The Natural Step 2009). This describes the "state of being" referred to by Missimer *et al.* (2010) below. The behaviour to attain that state is therefore "sustainable development", which The Natural Step defines as "the process by which we get there [to sustainability]" (The Natural Step 2009). This report uses these definitions when referring to sustainability or sustainable development.

Finding a definition for sustainability and sustainable development

Since the World Commission on Environment and Development met in 1987, the concept of sustainability has become a key political principle of governments worldwide (Rametsteiner *et al.* 2011). At the same time the term attracts such an array of different meanings that some argue it is in danger of becoming meaningless. Different groups even claim it to be consistent with completely contrasting values, such as, "liberal principles of justice and fairness" and "neoconservative small government-dogma" (Zencey 2010).

The World Commission on Environment and Development provided what has perhaps become one of the best known definitions. Widely known as the Brundtland definition, it is as follows:

> *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED cited in Patterson 2002; 8).

It is important to note, however, that the Brundtland definition does not define sustainability, but sustainable development. To some extent it appears the terms have become interchangeable. However, sustainability and sustainable development are not the same thing. While sustainability is a state in which society can be self-sustaining, sustainable development is the way to get to that state (Robért *et al.* 2002). Missimer *et al.* concur, stating that "semantically, the term sustainability describes a stage (or state of being), while sustainable development points at processes towards or within that state of being" (Missimer *et al.* 2010; 210).

3. RESEARCH QUESTIONS AND SCOPE

3.1. Research questions

This report is stage one of a three stage programme being undertaken by Nelson City Council. The aim of this programme is to identify the sustainability challenges facing Nelson, and any gaps between these challenges and the work being undertaken locally to address the challenges.

Stage one utilises TNS concepts, "*the funnel"* and *"the sustainability principles"*, to assess Nelson City's sustainability performance and identify some of the sustainability challenges Nelson is facing.

Stage two involves consultation with stakeholders in the community to identify the sustainability actions occurring in Nelson.

Stage three will analyse the results of the previous two stages to determine where Nelson is currently heading in relation to the TNS sustainability principles. This will help identify where further action, research or data is required and indicate the priorities *"Framing Our Future"* needs to address.

The research questions within each stage of the research programme that were collectively agreed between NCC and the Cawthron research team are as follows:

Stage One	What are the sustainability challenges facing Nelson City? And How sustainable is Nelson's lifestyle?
Stage Two	What activities are being undertaken or planned, that aim to improve Nelson's sustainability?
Stage Three	Are Nelson's current sustainability activities effectively addressing its sustainability challenges, or are there gaps between activities and the challenges?

This report addresses the questions in stage one of this research to provide baseline information on Nelson's sustainability performance and identify some of the sustainability challenges facing Nelson. It is important to note however that the list of challenges is not exhaustive. As such, the challenges need to be periodically reviewed to ensure they remain relevant and to identify any missing challenges.

3.2. Scope

The scope of this report relates to the communities living within NCC's boundaries and their impacts in terms of sustainability. These impacts can be directly created and felt within Nelson through, for example, pollution of waterways, or created indirectly through Nelson's importation of goods or services in which case the impact is felt elsewhere. Therefore, although the primary focus of the report is the area within Nelson City boundary, at times sustainability impacts extend beyond this boundary to national and global scales.

The method we have used for defining the scope of Nelson's sustainability impact is based on the ISO 14064 standard for measuring business greenhouse gas (GHG) emissions. The method we have used categorises sustainability impacts into three "scopes", the definitions for which are as follows:

- Scope one *local* impacts are those resulting directly from the community's activities including vehicles, factories and farms owned and operated within the community.
- Scope two *local* impacts are indirectly created by the community through the importation of energy, such as electricity, which is generated elsewhere.

- Scope three impacts are indirectly caused by the Nelson community through the purchase of goods and services whereby the *impact is felt beyond Nelson's borders*. Examples include air travel, and imported food and technologies with an environmental or social impact at the point of production or during transportation.

This report aims to produce a picture, or snapshot, of Nelson in relation to sustainability. The level of detail provided is a "satellite view" as opposed to that of a more detailed state of the environment report. On occasion specific data for Nelson have not been available in which case regional data have been utilised to provide a richer "snapshot".

This report does not provide recommendations to address the sustainability challenges identified. Rather, it serves as a scoping exercise that highlights some the of most pressing sustainability challenges to inform future strategic planning tasked with addressing these.

4. METHODOLOGY

4.1. Step 1 – Applying the funnel to Nelson

The sustainability challenges were initially selected by metaphorically placing Nelson in *the funnel* and the research team, comprising of three Cawthron staff, brainstormed challenges that may cause Nelson to "hit the funnel walls". *The funnel* is shown in Figure 1 and is a metaphor TNS uses to visualise growing environmental, social and economic pressures on natural resources, ecosystem services and society as the driving forces of population and consumption grow. TNS described *the funnel* as follows.

> *"Imagine looking at a giant funnel from the side. The upper wall is the availability of resources and the ability of the ecosystem to continue to provide them. The lower wall is our demand for these resources which we need to make clothes, shelter, food, transportation and other items and the ecosystems that create them. As our demand increases and the capacity to meet this demand declines, society moves into a narrower portion of the funnel. As the funnel narrows there are fewer options and less room to manoeuvre. [Communities] that continue business-as-usual are likely to hit the walls of the funnel, and fail"* (The Natural Step 2009).

The funnel, therefore, represents the carrying capacity within which a community's lifestyle can be sustained. It aims to help a society recognise the challenges it faces, and, through innovation and careful management, to overcome these challenges and shift towards sustainability. Ultimately the goal is that society will find a way to open the walls of the funnel and become restorative (The Natural Step 2009), putting back rather than taking.

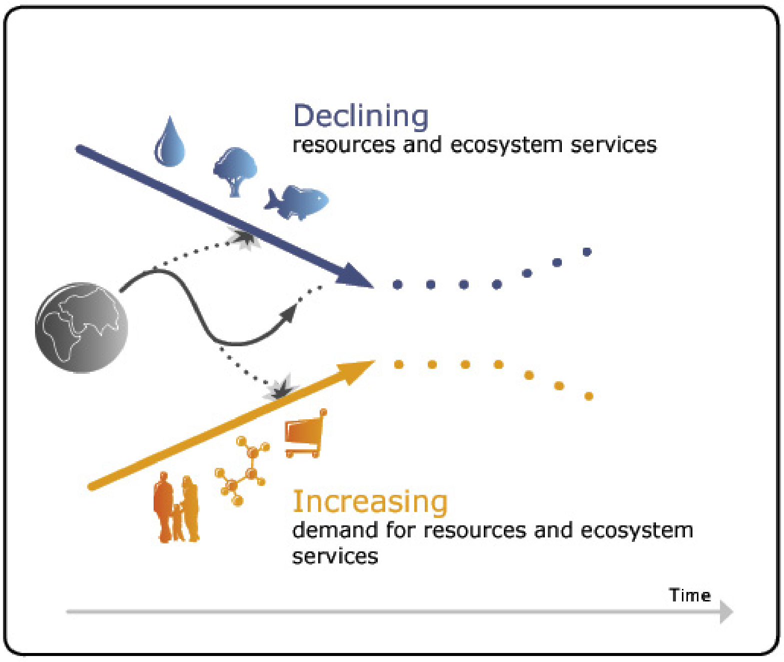

Figure 1. The funnel: heading towards unsustainable resource use (The Natural Step 2009).

Whistler, the Canadian resort in the Rocky Mountains, provides an example of how this can occur in reality. It adopted a sustainability strategy called *Whistler 2020* and used *the funnel* to assess the challenges it faced. One challenge Whistler faced related to resource use and the continued pressure to push urban expansion into natural areas surrounding the town, thus, eroding one of the main factors attracting visitors to Whistler. At the same time, local people were finding it difficult to afford to live in Whistler, as increased visitor demand raised prices for local housing, and the cost of living in general (Resort Municipality of Whistler 2007). From this the community were able to visualise what "hitting the walls of the funnel" might look like for Whistler, and by implementing their sustainability strategy, this issue is now being averted.

The line at the top of Figure 1, the decline of natural resources and ecosystem services, represents the declining supply of resources that society needs to function. The lower line, increasing demand for resources and ecosystem services, represents the increasing demand of resources that society wants in order to function. A challenge will collide with one of these walls only depending on if the challenge relates to ecosystems or society. The challenges that the research team identified through this process were as follows: air, climate change, coasts, energy, externalisation of environmental and social issues, food, freshwater, population, soil health, social vulnerabilities, transport and waste.

4.2. Step 2 – Comparisons to existing indicators

It is important to note however that *the funnel* is not a method but a metaphor and through brainstorming alone, challenges could easily be missed. Especially as the research team was unlikely to represent all views of the community.

In an attempt to overcome this limitation the challenges were compared with the national environmental indicators used by the Ministry for the Environment (MFE) in *Environment New Zealand 2007* (Ministry for the Environment 2007), the Statistic New Zealand's (Stats NZ) indicators from *Measuring New Zealand's progress using a sustainable development approach* (Statistics New Zealand 2008), the planetary boundaries developed by Rockstrom *et al.* (2009) through the Stockholm Resilience Centre and issues identified by TNS (The Natural Step 2009).

Based on these sources, combined with the list developed by the research team, a final list of challenges was formulated and is shown in Table 1 along with the secondary sources confirming their selection. We recognise that the challenges are not necessarily independent of each other, but may overlap and interact in complex ways. However, we consider the list to be adequate for the purposes of this report. Further challenges may be identified as NCC's three stage programme advances.

Table 1. Sustainability challenges for Nelson.

Sustainability challenge	Sub challenge	Confirmation Source	Supporting source
Air quality		Ministry for the Environment	Statistics New Zealand & Planetary Boundaries
Atmosphere	Greenhouse gas and ozone	Ministry for the Environment	Statistics New Zealand & Planetary Boundaries
Biodiversity		Ministry for the Environment	Statistics New Zealand & Planetary Boundaries
Coasts	Quality	Ministry for the Environment	Statistics New Zealand & Planetary Boundaries
Consumption		Ministry for the Environment	
Energy security	Supply and demand	Ministry for the Environment	Statistics New Zealand
Externalisation of environmental issues		The Natural Step	
Food security		Ministry for the Environment	
Freshwater	Quality and quantity	Ministry for the Environment	Statistics New Zealand & Planetary Boundaries
Land cover and land use	Land use and cover and biodiversity	Ministry for the Environment	Statistics New Zealand & Planetary Boundaries
Population		Statistics New Zealand	
Societal impacts	Domestic impacts, international impacts	Statistics New Zealand	
Transport		Ministry for the Environment	Statistics New Zealand
Waste disposal		Ministry for the Environment	Statistics New Zealand

4.3. Step 3 – Applying an analytical model

To ensure the information gained from these challenges is meaningful, we combined TNS's *funnel* and *sustainability principles* with the analytical model, driving force-pressure-state-impact-response (DPSIR) (Smeets & Weterings 1999). DPSIR shows how human activity (the *driving force*) puts *pressure* on the environment and as a result changes the *state* of the environment. The state of the environment can have an *impact* on ecosystems, natural resources or people's health and people *respond* with management approaches to alter the driving force and ultimately the environmental state (Smeets & Weterings 1999).

Indicators can be categorised as a driving force, pressure, state, impact or response depending on the information each provides. For example greenhouse gas is a pressure as increased emissions puts pressure on the atmosphere and changes the climate. Water quality on the other hand is a state, as it measures the condition of a waterway (Smeets & Weterings 1999). Table 2 below describes the DPSIR conditions in more detail.

Table 2. Descriptions of DPSIR conditions (Smeets & Weterings 1999; Ministry for the Environment 2007).

Condition	Description
Driving force	The social, demographic and economic development drivers of change in a system. The primary drivers of changes are population growth and in people's needs and activities. This results in changed lifestyles and thus levels of production and consumption, thereby putting pressure on the environment.
Pressure	The monitoring of people's use of natural resources, land, production of waste and chemical emission. Such pressures change the state of an environment.
State	Describing the quantity and quality of the environment and natural resource (such as, water, air, land cover).
Impact	Describing the impact of the environmental conditions on human health or that of the environment.
Response	Describe the management responses undertaken to prevent, compensate, ameliorate or adapt to environmental changes (for example, legislation or actions by community groups).

The concept of *the funnel* fits well with DPSIR, as the sloping walls of the funnel represent the declining *state* of the environment or increasing *state* of human demand. The conditions that create these states are the *driving forces* and the *pressures;* as such the challenges that we are primarily concerned with identifying are the driving forces and pressures. As can be seen from Table 3 however, in this instance we have included three *states* in the list of challenges (air, biodiversity and coasts). It was decided to include these states because as they are either challenges that Nelson City Council, as a unitary authority, has a responsibility to manage or are recognised as significant by the presence of a strategy to include.

During the process of analysing each of these challenges, it became evident that while it was possible to quantify the impacts of some of these challenges locally, it was not possible in all cases either because of a lack of data or because of the lack of recognised and measureable indicators. In comparison *Environment New Zealand* 2007 and *Measuring New Zealand's progress using a sustainable development approach* were able to quantify their indicators, or challenges, with one of the selection criteria for their indicators being that it must be possible to collect data for each of them.

Although it was not possible to quantify data for every challenge it was felt that it was important to discuss each challenges, but at the same time acknowledge where additional research was required to be able to assess the significance of the challenge. To these ends each challenge was classified according to whether it could be quantified, using two classifications as follows:

- Classification A – the challenge could be quantified for example, air quality.
- Classification B – the challenge could not be quantified for example, food.

Table 3 identifies the classification of each sustainability challenge and sub challenge, by its position in the DPSIR model, the funnel and its amenability to quantification.

Table 3. Classification of sustainability challenges by DPSIR, the funnel and ability to quantify.

Sustainability challenge	Sub challenge	Position in DPSIR	Position in the funnel	Quantifiable status
Air quality		State	Supply	A
Atmosphere	Greenhouse gas	Pressure	Supply	A
	Ozone			
Biodiversity		State	Supply	A
Coasts		State	Supply	B
Consumption		Driving force	Demand	A
Energy security		Driving force	Demand	A
Externalisation of environmental issues		Pressure	Supply	B
Food security		Pressure	Demand	B
Freshwater	Quality	State	Supply	A
	Quantity	Pressure		
Land cover and land use	Land use	Pressure	Supply	A
	Land cover	State		
Population		Driving force	Demand	A
Societal impacts	Domestic impacts	Driving force	Demand	B
	International impacts			
Transport		Driving force	Demand	B
Waste disposal		Pressure	Supply	A

4.4. Step 4 - The four principles of sustainability

The final step in this process is to match the sustainability challenges with the four principles of sustainability. The four principles were developed by TNS to define the conditions that are necessary to enable the continuation and wellbeing of life on Earth and, therefore, human life (Robért *et al.* 1997). Fundamentally, their aim was to describe the state of being, or the basic conditions required for a system to be sustainable (Missimer *et al.* 2010). If the principles were to be positioned in DPSIR they would describe the state of the environment, not the drivers or pressures on the environment.

The sustainability principles (also known as the "four system conditions") state:

In a sustainable society nature is not subject to systematically increasing;

1. *Concentrations of substances extracted from the Earth's crust,*

This principle relates to the extraction of material from the earth's crust. This system condition addresses those materials (such as heavy metals and chemical compounds) previously "locked" in the crust that ecosystems are unable to break down. As a result these materials will accumulate in the biosphere (Robért *et al.* 1997). The extraction of substances from the earth's crust does not occur in Nelson (aside from minimal quarrying). However, Nelson is still contributing to the accumulation of substances extracted from the Earth's crust due to the importation and use of such materials within the city's boundaries.

2. *Concentrations of substances produced by society,*

This is closely related to the first principle in that it relates to the accumulation of chemicals that nature does not know how to break down. For this condition however, the chemicals are either synthetic or have been altered by humans to the extent where the chemical occurs in un-natural concentrations. Natural systems, therefore, have not encountered such substances previously, meaning they cannot break down quickly and instead accumulate in natural system - DDT is one of the best known examples (Suzuki 2010). Sustainability, in terms of principle two, then, requires a consideration of whether these products are accumulating in our environment, or whether, through the choice of products we purchase and the way in which we dispose of or recycle them, we can halt their accumulation.

3. *Degradation by physical means.*

This principle relates to the destruction of nature through the removal of forests, damming of rivers, over fishing or harvesting of species and introductions of pests and cultivating monocultures. The basis for this is that nature and biodiversity provides the human species with considerable assistance in the form of ecosystem services such as the creation of oxygen, absorption of carbon dioxide, and the filtration of water and waste water (Suzuki 2010). While nature can adapt to some degradation, the extensive destruction that has occurred in the past 50 years is impacting on nature (Millennium Ecosystem Assessment 2005) and its life supporting capacities.

And, in that society,

4. *People are not subject to conditions that systematically undermine their capacity to meet their needs* (Robért *et al.* 1997).

This principle relates to the undermining of the needs of people to live and prosper in society. The definition of needs is drawn from eminent sociologist Manfred Max-Neef and his colleagues (Max-Neef *et al.* 1991). According to Max-Neef *et al* (1991), all people on earth, regardless of race, culture, age or gender, share certain common needs that hold constant throughout the ages. These fundamental needs, shown in Figure 2 (and elaborated in Table shown in Appendix 1) are non-substitutable and an absence of one represents an impoverishment of some kind.

Figure 2. Max-Neef's fundamental human needs (The Natural Step 2009).

Therefore, for society to be sustainable, it must:

a. *Eliminate its contribution to the progressive buildup of material from the lithosphere;*
b. *Eliminate its contribution to the progressive buildup of chemicals and compounds produced by society;*
c. *Eliminate its contribution to the progressive physical degradation and destruction of nature and natural processes; and*
d. *Eliminate its contribution to conditions that undermine people's capacity to meet their basic human needs.*

These principles identify what the environment should look like for a society to be sustainable. They are aspirational and simple while at the same time embracing the complexity of sustainability (Craig 2004). It is important to note however that the principles do not preclude an activity from occurring *per se*. While they are phrased in the negative *i.e.* informing us of what activities humans must *not* do (Robért *et al.* 1997) the key words are "systematically increase". Thus an activity is acceptable if it is not allowing a substance to accumulate in nature or preventing people from meeting their needs. As a result if a society does not carry out activities that violate the four sustainability principles then, by definition, it is living within its means and is sustainable.

Table 4 links the sustainability challenges as defined above with one or more sustainability principles.

Table 4. Position of sustainability challenges in sustainability principles.

Sustainability challenge	Sub challenge	Position in DPSIR	Position in the funnel	Quantifiable status	Sustainability Principle
Air quality		State	Supply	A	1,2,3,4
Atmosphere	Greenhouse gas	Pressure	Supply	A	1,2,3,4
	Ozone				
Biodiversity		Pressure	Supply	A	1,2,3,4
Coasts		State	Supply	B	1,2,3,4
Consumption		Driving force	Demand	A	1,2,3,4
Energy security		Driving force	Demand	A	1,2,3,4
Externalisation of environmental issues		Pressure	Supply	B	1,2,3,4
Food security		Pressure	Demand	B	1,2,3,4
Freshwater	Quality	State	Supply	A	1,2,3,4
	Quantity	Pressure			1,2,3,4
Land cover and land use	Land use	Pressure	Supply	A	1,2,3,4
	Land cover	State			1,2,3,4
Population		Driving force	Demand	A	1,2,3,4
Societal impacts	Domestic impacts	Driving force	Demand	B	4
	International impacts				
Transport		Driving force	Demand	B	1,2,3,4
Waste disposal		Pressure	Supply	A	1,2,3,4

As can be seen from this table, in all but two cases, these challenges impact on all four of the sustainability principles, in each case this impact is for a different reason. For example, among other things, greenhouse gases are a chemical by-product of the burning of coal thus they are an issue for principle 1. Petrol is synthetically produced even if oil is natural thus the release of greenhouse gas from driving a car is a principle 2 issue. Greenhouse gas emissions are impacting on the planets biodiversity which makes it a principle 3 issue and the impacts of rising temperatures will reduce the capacity of human's to meet their needs and thus it also has relevance to principle 4. This crisscrossing of principles across sustainability challenges highlighting just how complex sustainability is (see Appendix 2 for a life cycle analysis of an ordinary plastic bottle to further highlight this complexity).

5. SUPPLY CHALLENGES

There are eight challenges relating to supply of ecosystem services facing Nelson City, which have been subdivided according to the quantifiable status of each. The category A (*i.e.* quantifiable) supply challenges are discussed first followed by the category B challenges. It should be noted that for many of the challenges, the discussion is relatively superficial, providing examples rather than comprehensive discussion, reflecting a dearth of information, budgetary constraints for the project, or both.

Nelson's environment provides many ecosystem services that help to maintain the region's high quality of life, and the health of its residents. The term "ecosystem services" describes the many functions nature provides for the ongoing maintenance of life on earth, and the many services used by people. Indeed, everybody on the planet is dependent on ecosystem services to sustain life. As described by the Millennium Ecosystem Assessment, who popularised the term:

> *"Whether you are a subsistence farmer or a high-tech executive, you rely on natural systems to provide the food you eat, the water you drink, and the air you breathe. And, despite the invention of many synthetic materials, nature still provides the stuff of life: trees bring us wood and paper, clothing is made from plant and animal fibre, and many life-saving medicines are derived from plants"*(Millennium Ecosystem Assessment 2007; 4).

Maintaining well-functioning ecosystem services, therefore, is crucial to ensure the ongoing capacities of nature to support human existence.

As well as providing the basic requirements of life, ecosystem services underpin all economies. Nelson's economy is no exception, with its major industries (tourism, commercial fishing, food processing, agriculture and forestry) all requiring well-functioning natural systems. Figure 3 shows some of the ecosystem services provided by nature. These are as diverse as the provision of food and drinking water through to recreation, tourism, flood regulation and spiritual values.

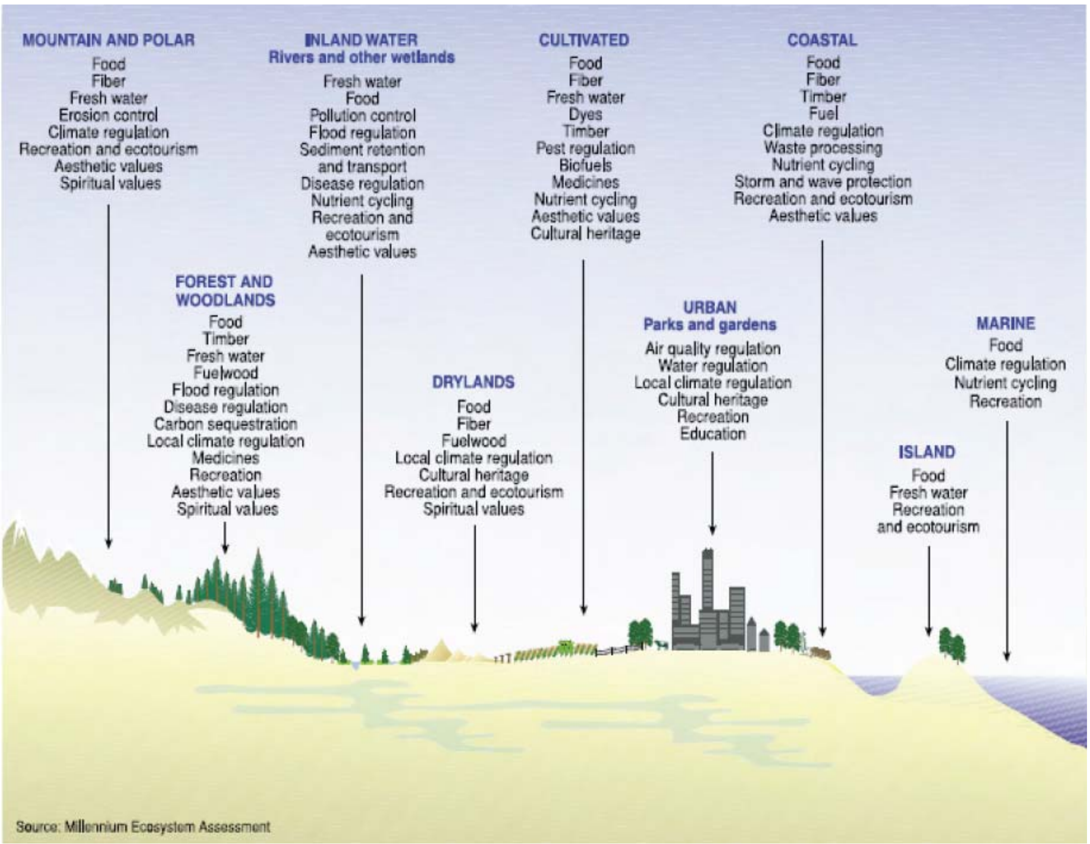

Figure 3. Ecosystems and some of the services they provide (Millennium Ecosystem Assessment 2007).

An economic analysis by Patterson and Cole (1998) for the Waikato University quantified the economic value of ecosystem services for the Waikato region. They found ecosystem services to be worth $19,700ha/year for lakes and rivers, $2,400ha/year for forests and $39,800ha/year for freshwater wetlands. Another report by the New Zealand Centre for Economic Research valued the ecosystem services of the Nelson/Tasman region at $1.1 billion per year, or 56% of gross regional product (GRP) (Cole & Patterson 2008). These two reports highlight the huge economic importance of ecosystem services to regional economies.

While both of these reports point to the high economic value of ecosystem services, neither value ecosystem services at 100% of GRP. With the close link, and indeed total dependence upon local natural resources and ecosystem services, Nelson's economy could not continue without a healthy and functioning environment. Any given environmental shock - toxic pollution, climate change or invasive species - could have a severe effect on the region's primary production with resultant flow-on effects to Nelson's service sector and human health and wellbeing. As discussed by eminent ecological economist Robert Costanza and his colleagues "…the economies of the earth would grind to a halt without the services of ecological life support systems, so in one sense their total value to the economy is infinite" (Costanza *et al.* 1997; 1). Therefore, while the economic analyses of Patterson and Cole (1998) and Cole and Patterson (2008) give arguably useful indication of the value of natural systems, from another point of view, their analyses hugely underestimate the true value, *i.e.* closer to 100% GRP.

5.1. Category A challenges

5.1.1. Air quality

While significant advancements have been made regarding air quality through NCC regulation, air quality remains an issue of environmental and public health. Nelson's airsheds consistently rank among the top ten most polluted in the country. One measure of air quality is the amount of particulate material in suspension (PM_{10}). The national standard for PM_{10} is 50 µg/m^3. Between 2005 and 2009, either the Nelson A (Nelson South), Nelson B (Tahunanui – Stoke) or both airsheds featured in the top 10 airsheds exceeding the PM_{10} standard as shown in Table 5. Nelson exceeded the national standard for annual average PM_{10} concentrations in 2009 by 22 µg/m^3, while Nelson's highest recorded level of PM_{10} was 89 µg/m^3 in the same year - 39 µg/m^3 above the daily standard (Ministry for the Environment 2010).

Table 5. Top 10 airsheds exceeding the PM_{10} standard, 2005–2009 (Ministry for the Environment 2010). Note: numbers in brackets represent the number of times an airshed exceeded the standard during the course of the year.

Rank	2005	2006	2007	2008	2009
1	Nelson A (51)	Nelson A (51)	Otago 1 (55)	Otago 1 (91)	Otago 1 (60)
2	Timaru (46)	Otago 1 (50)	Timaru (36)	Otago 2 (46)	Timaru (38)
3	Otago 1 (42)	Richmond (37)	Rotorua (29)	Rotorua (39)	Otago 2 (35)
4	Richmond (34)	Timaru (36)	Nelson A (26)	Timaru (37)	Nelson A (34)
5	Tokoroa (33)	Kaiapoi (28)	Reefton (24)	Hastings (28)	Rotorua (27)
6	Christchurch (32)	Christchurch (27)	Richmond (21)	Nelson A (25)	Kaiapoi (23)
7	Ashburton (18)	Ashburton (26)	Kaiapoi (20)	Richmond (20)	Richmond (21)
8	Hastings (18)	Nelson B (24)	Christchurch (14)	Kaiapoi (19)	Tokoroa (17)
9	Kaiapoi (17)	Rotorua (23)	Ashburton (13)	Christchurch (18)	Reefton (16)
10	Nelson B (13)	Hastings (18)	Hastings (13)	Reefton (17)	Christchurch (13)

In response, lifestyle changes (including the banning of open fires and the replacement of older wood burners) were necessary, and improvements have been made. Table 5Table 5 shows a decline in the number of days in exceedance of the national standard after the fire ban came into effect in 2007. The Nelson A airshed, for example, shows a clear reduction in exceedance days, while Nelson B does not rank in the top 10 after 2006. The air quality example is important in that it shows the effectiveness of well-targeted interventions, while also highlighting room for further improvement.

Examples of some of the consequences of this sustainability challenge on the four sustainability principles are shown in Table 6.

Table 6. **Examples of positive and negative impacts on the sustainability principles resulting from the air quality challenge.**

Principle		Positive Impact	Negative Impact
1	Increasing concentrations of extracted chemicals from the Earth's crust	Reduced pollution through: • Reduction on days PM_{10} levels exceed standard • Public transport • Non-motorised commuters	• PM_{10} levels still exceeding standard
2	Increasing concentrations of synthetic material		• Air pollution from transport (ozone, nitrogen dioxide and sulphur dioxide)
3	Degradation by physical means		• Runoff of containments into waterways
4	Undermine the capacity of others to meet their needs		• Effects of pollution on human health

5.1.2. Atmosphere

Greenhouse gas

Climate change is a major challenge for Nelson both now and in the future. An exploratory report by Goodwin (2009) outlines the risks posed to Nelson by climate change. These are an increase in temperatures, a rise in annual rainfall, and an increase in intensity and severity of extreme weather events. All of which are likely to result in more severe floods as well as longer and more damaging droughts. Change is also expected to occur in biological systems, due to the dispersion of many species currently being limited by temperature. With warmer temperatures, Nelson can expect an increase in the abundance of pests such as wasps, sandflies, mosquitoes, termites and ants – particularly during warmer winter months when these species are currently much less active. Further, a warming ocean and melting ice-caps associated with a warming climate may, as a worst case, see large parts of the Nelson CBD, the Wood, the Port, and parts of Tahunanui below high tide level by 2100 (Goodwin 2009). In terms of the economy, Goodwin points to Nelson and Tasman's most valuable economic sectors: forestry and horticulture; fishing and aquaculture; and tourism as all likely to be impacted.

Climate change is possibly the most ubiquitous challenge to be faced by coastal settlements around New Zealand. The very global nature of the changes that are to be expected make it easier to concentrate on the "do-able" activities such as those associated with waste management, or cycle lanes *etc*. However, as the Ministry for the Environment document *"Preparing for climate change, a guide for local government in New Zealand"* indicates, there are a number of actions that Councils can take such as allowing for the impact of climate change within council planning documents and in the development of infrastructure (Ministry for the Environment 2008).

Nelson has already taken steps to contribute to solutions at a local level, including monitoring greenhouse gas emissions of Council's and community activities. Figure 4 shows Nelson's contribution to greenhouse gas emissions (Nelson City Council 2008). The largest emitting sectors are industrial and transportation, followed by the waste, commercial and residential sectors respectively.

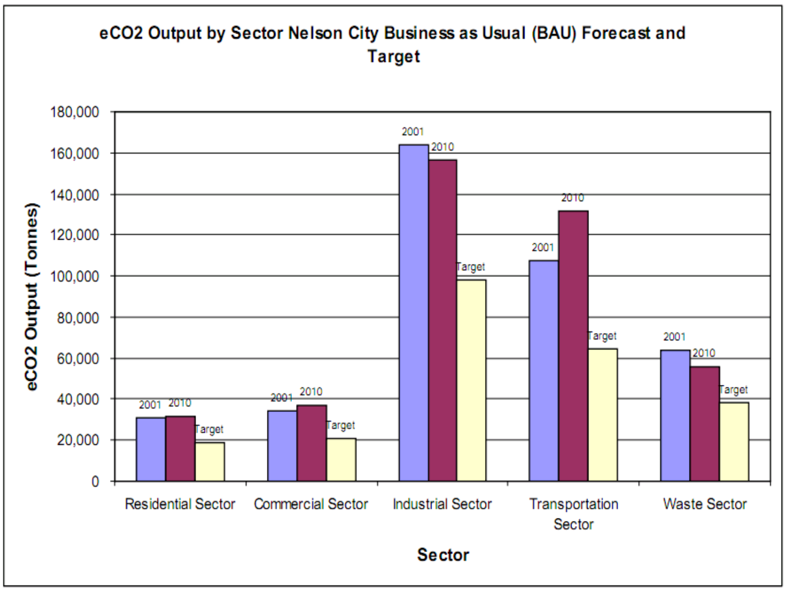

Figure 4. Equivalent CO_2 emissions from Nelson City (Nelson City Council, 2008: 2). Note Nelson's emissions in 2001 are in blue, projected emissions in 2010 in maroon (report written 2008) and the future target in beige.

Stratospheric Ozone

Ozone is a gas that, at the stratospheric level of the Earth's atmosphere, filters ultraviolet radiation from the sun (Rockstrom *et al.* 2009). A thinning of this layer, as has been occurring in the Antarctic (British Antarctic Survey 2007), can have negative impacts on marine organisms and is a risk to human health (Rockstrom *et al.* 2009). This thinning has been occurring for a combination of reasons, an increase in concentrations of anthropogenic ozone-depleting substances, like chlorofluorocarbons (CFC), and an increase in "polar stratospheric clouds" (Rockstrom *et al.* 2009 p 12). In 1987 the *Montreal Protocol on Substances that deplete the Ozone layer* was negotiated and has now been ratified by all United Nation member states. The protocol has been successful in phasing out the production of ozone depleting substances, but as the substances remain in the atmosphere for a long time, it is likely to be 2050 at least before the ozone hole disappears completely (British Antarctic Survey 2007). The challenge is therefore to find ways of reducing the use of such substances that may be occurring in Nelson.

Methyl bromide is an example of an ozone depleting substance (Mellouki *et al.* 1992), which, through good management, is being used in Nelson with greatly reduced environmental harm. Methyl bromide is a colourless and odourless gas that both occurs naturally and is synthesised industrially. Its industrial form is used at Port Nelson as a fumigant on logs bound for export. It persists in the atmosphere for about two years (Oremland *et al.* 1994) until its molecular properties are changed through natural processes (Dungan & Yates 2003). Studies have found negative human health effects through exposure to methyl bromide (Alavanja *et al.* 2004), but by using capture and storage technology, Port Nelson has become a New Zealand leader in best practice for using methyl bromide – it being the only port in the country using such methods.

Examples of some of the consequences of this sustainability challenge on the four sustainability principles are shown in Table 7.

Table 7. Examples of positive and negative impacts on the sustainability principles resulting from the atmospheric challenge.

<table>
<tr><th></th><th>Principle</th><th>Positive Impact</th><th>Negative Impact</th></tr>
<tr><td>1</td><td>Increasing concentrations of extracted chemicals from the Earth's crust</td><td rowspan="4">• Mitigation of greenhouse gas emissions through Council and business and citizen's actions (Solar Saver Scheme).
• Mitigation of ozone depletion through regulation to reduce use.
• Actions of businesses etc. – Port Nelson, to reduce ozone depleting substance use.</td><td>• Emissions from use of fossil fuels (coal).
• Emissions from industry</td></tr>
<tr><td>2</td><td>Increasing concentrations of synthetic material</td><td>• Emissions from transport
• Emissions of ozone depletion substances reduction (refrigeration)</td></tr>
<tr><td>3</td><td>Degradation by physical means</td><td>Emissions contributing to:
• Species extinction through emissions
• Ozone hole</td></tr>
<tr><td>4</td><td>Undermine the capacity of others to meet their needs</td><td>Health effects on humans
• Heat stress
• Ultraviolet radiation effects</td></tr>
</table>

5.1.3. *Biodiversity*

The importance of the issue of biodiversity[1] is summarised in the *State of New Zealand's Environment Report* which found that declining biodiversity is New Zealand's "most pervasive environmental issue" (Ministry for the Environment 1997). There are many exotic species that have been introduced to Nelson, and many of these have their place. Some species provide the basis of agriculture, horticulture and forestry production in Nelson and the wider region.

[1] Biodiversity is the natural diversity of all life, including diversity in genes, species, population and ecosystems (Nelson City Council 2009).

Others play important roles in terms of their aesthetic qualities, or their uses for recreation. Many of these species pose no serious threat to native biodiversity. At the same time, however, there are many introduced species that do directly threaten indigenous biodiversity. Figure 5 shows the consequences of the introduction of exotic species, and modifications to land cover and human activities since the arrival of people to Nelson.

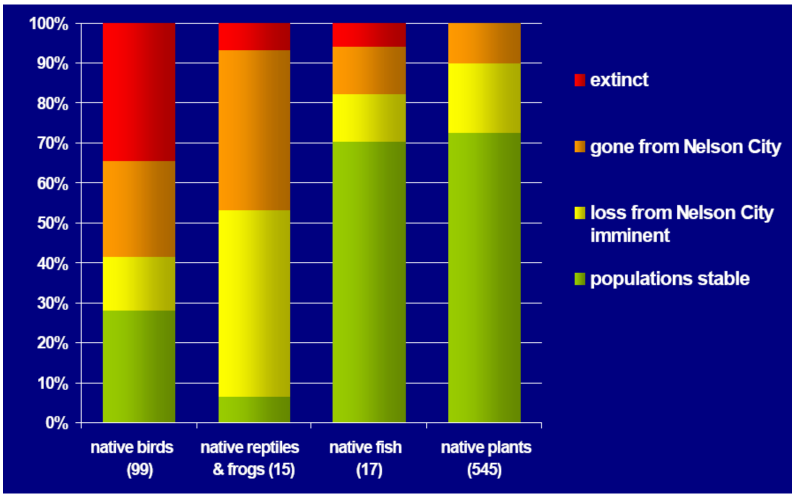

Figure 5. Conservation status of animals and plants native to Nelson City (Nelson City Council 2009a; 29).

In general, indigenous biodiversity in Nelson City has been greatly reduced on land, in freshwater and, to a lesser extent, in the oceans, and all three environments are experiencing ongoing decline (Nelson City Council 2009a). The decline of natural environments in Nelson reflects similar national trends (Nelson City Council 2010b). These declining trends have, in part, led to the creation of the *New Zealand Biodiversity Strategy* (NZBS) which has the vision for “the full range of New Zealand’s indigenous ecosystems and species [to] thrive from the mountains to the ocean depths” (New Zealand Government 2000; 4). The NZBS provides the context for the *Nelson Biodiversity Strategy* – the goals of which are: “(1) Nga taonga tuku iho (the treasured resources), special places, native species, and natural ecosystems of Nelson/Whakatu are protected and restored; and (2) the community has the living resources it needs, and has minimised adverse effects of unwanted biodiversity” (Nelson City Council 2009a; 9).

Biodiversity plays an important role in terms of economy, quality of life and our identity as a nation (New Zealand Government 2000) and many initiatives are in place to stop and reverse the decline of biodiversity in Nelson. Legislation such as the Resource Management Act 1991 and the Conservation Act 1987 protects large tracts of land and biodiversity from unsustainable resource use in Nelson. While at a community level, environmental initiatives, such as the Brook Sanctuary, are engaging community members and enhancing the environment. The key challenge for biodiversity draws from the *Nelson Biodiversity Strategy* and the NZBS, which is, essentially, to enhance such initiatives and reverse the decline of indigenous biodiversity to ensure that the values of biodiversity are maintained into the future.

Examples of some of the consequences of violating the sustainability principles on the sustainability challenge are shown in Table 8.

Table 8. Examples of consequences of contributions to and violations of, the sustainability principles on the biodiversity challenge.

	Principle	Positive Impact	Negative Impact
1	Increasing concentrations of extracted chemicals from the Earth's crust	Mitigation through: • Legislation (RMA, Conservation Act) • Nelson Biodiversity Strategy and Forum • Restoration projects such as, The Brook Sanctuary • Efforts of local parks, reserves and gardener	• Polluted waterways and ecosystems leading to loss of species and habitats
2	Increasing concentrations of synthetic material		
3	Degradation by physical means		• Biodiversity diminished through human activities • Native species out-competed by invasive ones
4	Undermine the capacity of others to meet their needs		Loss of: • Diversity of life • Recreation potential • Tourism/economic potential • Resources

5.1.4. Freshwater

Freshwater Quality

Streams in Nelson vary greatly in terms of water quality. Generally speaking, streams with high water quality in the upper reaches of their catchments support a rich diversity and abundance of in-stream biota, while human influences are lowering streams' water quality in the lower reaches (Crowe *et al.* 2004; Wilkinson 2007a; Nelson City Council 2010a). Causes for the decline are due to factors such as, sediment loading from primary production including, forestry operations and also sub-urban development; nutrient loading from leguminous plants; and chemical pollutants from urban and sub-urban rainwater runoff. There are some noteworthy trends regarding declining water quality over time. In 2009, for example, of the 27 monitored waterways in Nelson, 11 were found to have declined in terms of water quality, while two had improved and 14 stayed the same (TDC *et al.* 2009). The continuation of impacts on the waterways and a changing climate will pose added challenges to water quality in future (Wilkinson 2007b).

Freshwater Quantity

Maintaining sufficient freshwater quantities is important to maintaining the region's economy, society and environment. Freshwater in Nelson takes the form of urban and rural streams, wetlands, reservoirs, groundwater and springs. Freshwater holds economic and supply value, in terms of drinking water, irrigation, and industrial abstraction, and also supports biodiversity in the form of aquatic species, flora and fauna corridors, and wider terrestrial ecosystems that interact with freshwater habitats. Freshwater is also valuable in that it supports human wellbeing through its use for recreation, as well as the spiritual and cultural values intricately tied to rivers and other freshwater landscape features. Low stream flows during dry periods can harm stream ecosystems by raising the water temperature, increasing dissolved oxygen levels, and reducing the physical space for in-stream species (Wilkinson 2007a). Their use value for people during low flows is also reduced, and ceases entirely when streams dry up altogether. Maintaining freshwater in sufficient quantity to ensure its many values continually provided for in future will be the key challenge regarding freshwater. Indeed, this is an important and measurable indicator for which data are available.

Examples of some of the consequences of violating the sustainability principles on the sustainability challenge are shown in Table 9.

Table 9. Examples of consequences of contributions to and violations of, the sustainability principles on the freshwater challenge.

<table>
<tr><th colspan="2">Principle</th><th>Positive Impact</th><th>Negative Impact</th></tr>
<tr><td>1</td><td>Increasing concentrations of extracted chemicals from the Earth's crust</td><td rowspan="4">Mitigation of effects through:
• Legislation (RMA)
• Voluntary accords (Clean Streams)
• Growth in riparian management</td><td rowspan="2">• Polluted waterways and ecosystems leading to loss of species and habitats</td></tr>
<tr><td>2</td><td>Increasing concentrations of synthetic material</td></tr>
<tr><td>3</td><td>Degradation by physical means</td><td>• Species diminished
• Quantity reduced
• Native species out-competed by invasive ones</td></tr>
<tr><td>4</td><td>Undermine the capacity of others to meet their needs</td><td>• Recreational bathing opportunities reduced
• Quantity of water reduced in dry seasons
• Potential health effects from polluted waterways</td></tr>
</table>

5.1.5. Land cover and land use

Land cover and land use are closely intertwined sustainability challenges concerning the way we treat our land. Land cover itself is not a sustainability challenge; rather, it describes a state, with changes in that state both directly affecting biodiversity as well as providing an indication of the extent of human pressures affecting the landscape. Land cover describes the landscape feature atop the land, e.g. pasture. Land use, on the other hand, describes the way in which land cover is used, e.g. pasture can be used for dairying or sheep farming. Activities on land can exert externalities on ecosystems and natural resources beyond the immediate area of the activity. Land use impacts on the environment are discussed in *Environment New Zealand* – the main land use impacts of relevance to Nelson being urban and rural run-off polluting waterways and coasts, and urban expansion leading to the loss of plant and animal habitats (Ministry for the Environment 2007). The Nelson City Council does much work to limit land use impacts through resource consent and planning processes under the Resource Management Act 1991.

Changes in land cover have affected, and continue to affect, native ecosystems and biodiversity in Nelson. Nelson's landscape comprises urban (6%), crop and farmland (13%), exotic afforestation (23%), exotic shrublands and trees (6%), broadleaved hardwoods (6%), herbaceous plants (<1%), native grasslands (3%), indigenous forest (34%), kanuka stands (8%), and coastal sand and gravel areas (1%) (Nelson City Council 2010b). Over half of Nelson's land area is covered in exotic vegetation (Nelson City Council 2009a). Lowland areas have experienced almost a total clearance of native vegetation and a draining of wetlands – these being predominantly replaced by pasture and urban and suburban development. The rate of this change in land cover has slowed in recent years because there is so little lowland native vegetation and wetlands left (Nelson City Council 2010b) and because of a tightening of legal controls. The key challenge for land use and land cover is strongly linked to the biodiversity challenge and draws from the *Nelson Biodiversity Strategy* and the *New Zealand Biodiversity Strategy*. Essentially the challenge is to ensure that the decline of indigenous biodiversity caused through land use and land cover changes is reversed and biodiversity is maintained into the future.

Examples of some of the consequences of violating the sustainability principles on the sustainability challenge are shown in Table 10.

Table 10. Examples of consequences of contributions to and violations of, the sustainability principles on the land cover and land use challenge.

<table>
<tr><th colspan="2">Principle</th><th>Positive Impact</th><th>Negative Impact</th></tr>
<tr><td>1</td><td>Increasing concentrations of extracted chemicals from the Earth's crust</td><td rowspan="4">Mitigation through:
• Legislation (RMA, Conservation Act)
• Nelson Biodiversity Strategy and Forum
• Restoration projects such as, The Brook Sanctuary</td><td rowspan="2">• Polluted land and reducing options for future use</td></tr>
<tr><td>2</td><td>Increasing concentrations of synthetic material</td></tr>
<tr><td>3</td><td>Degradation by physical means</td><td>• Developments "paving over nature"</td></tr>
<tr><td>4</td><td>Undermine the capacity of others to meet their needs</td><td>• Reduced access to:
o Open space
o Recreational spaces
• Possible health impacts</td></tr>
</table>

5.1.6. *Waste disposal*

Another challenge for Nelson is disposal of solid waste which is currently sent to York Valley Landfill. The issue with waste is that the vast array of materials disposed of to landfill, can contain chemicals and heavy metals such as chromium and cadmium (Centre for Advanced Engineering 2000). This is then released over many years as the material, which is sealed under an impermeable layer, slowly breaks down (Centre for Advanced Engineering 2000). The sustainability challenge of the landfill is therefore to prevent material being disposed of to landfill.

Between 1987, when York Valley Landfill opened, and 2005, solid waste increased by 5% annually (Nelson City Council 2005). If this increase were to continue, the landfill would be full by 2023, 11 years ahead of the end of the allowed operating period under its resource consent (Nelson City Council 2005). However since 2005, the tonnage of waste disposed to landfill has decreased (TDC *et al.* 2009) by an average of 6% annually, from 47,752 in 2005 to 33,942 in 2010.

It is unclear why this decrease has occurred, though it is likely it has some connection with increased recycling activities in Nelson. Certainly Nelson residents seem committed to recycling, with the 2010 *Nelson City Council - Residents Survey* indicating that 86% of Nelson's residents recycle at least fortnightly, and 77% of residents agreed with the statement "people have a duty to recycle" (Cullinan & Laugesen 2010).

The decline in waste in recent years is encouraging, and is partially explained by an increase in recycling of 137 tonnes from 3,056 tonnes in 2009 to 3,193 tonnes in 2010. While this increase will have contributed to the decline in waste, as waste declined by 2,753 tonnes in the same period recycling is clearly not the only reason for the decline. There could, in fact, be a number of reasons behind the reduction in waste disposal, and further research is required to fully understand why the reduction has occurred. However, while the reason for the decline in waste disposal is unclear, the sustainability challenges remains not to create the waste in the first place.

Examples of some of the consequences of this sustainability challenge on the four sustainability principles are shown in Table 11.

Table 11. Examples of positive and negative impacts on the sustainability principles resulting from the waste disposal challenge.

Principle		Positive Impact	Negative Impact
1	Increasing concentrations of extracted chemicals from the Earth's crust	• Reduce, reuse, recycle campaigns • Use of methane capture and burning to offset coal use at Nelson Hospital	• Heavy metals in discarded materials • Oil based plastic disposal • Greenhouse gas emissions
2	Increasing concentrations of synthetic material	• Reduce, reuse, recycle campaigns • E-day campaigns	• Leachate and chemical build up in landfills • Pollutants from burning of plastic
3	Degradation by physical means	• Reduce, reuse, recycle campaigns • Composting and growable garden campaigns • Use of waste water on forestry blocks	• Encroaching landfills on "useable" land • Loss of species and habitat from landfill encroachment
4	Undermine the capacity of others to meet their needs	• Employment of staff in recycling operations • Reuse shops	• Wasted useful resources reduces accesses

5.2. Category B challenges

5.2.1. Coasts

To reduce the oceans and coasts, alongside which Nelson has developed, to one simple word, is to say the least misleading, they are in fact a complex myriad of ecosystems some of which are monitored regularly. Placing coasts among the Category B challenges however, suggests that there is no quantifiable data on coasts. While it is true that a lot is known about some aspects of the coastal environment, other areas have less data available as such, more work is needed and for this reason coasts have been included as a Category B challenge.

Nelson's ocean comprises about two thirds of the total area within the city's municipal boundary. Landforms and habitats of the coastal environment include sand dunes, estuaries, rocky coasts, spits, salt marshes, and cliffs. The coastal environment is valuable in many ways. It is home to many species of marine animals and plants; is used recreationally; holds cultural values; contains important ecosystems and habitats; and is fished commercially and recreationally. Maintaining the coastal environment to continue to provide for these values is a challenge, in the face of mounting stressors on the coast.

Since the time of early colonial settlement in the mid-1800's, developments on land as well as direct modifications to the marine environment have changed the natural character of the coast, and continue to do so. A report by MacDiarmid *et al.* (2010) identifies and ranks 65 main human induced stressors on the New Zealand marine environment. The highest threat to marine habitats is rising ocean temperatures and ocean acidification – both resulting from global climate change. The next most pressing threats are of a more local scale - being those deriving from catchments that discharge into coastal environments. These include, from highest to lowest threat, sedimentation from land-use change, sewage discharge, nitrogen and phosphorus loading, and heavy metal pollution. While Nelson City Council's mandated marine area only extends out to 12 miles from the coastline, many of the above mentioned threats are likely to occur within this area. Of the 65 threats identified by MacDiarmid *et al.* (2010), 61 occur in shallow coastal habitats of 50 m depth or less, while only four to five occur in the deep water areas beyond.

Indeed, various reports have found threats specific to the Nelson marine environment to be aligned with the report of MacDiarmid *et al.* (2010). Nelson-specific threats include; invasive pests (such as the Pacific Oyster), sediment loading from forestry operations, faecal contamination, landuse change, land cover change, hardening of intertidal margins, direct modification of the marine environment (dredging), infilling of coastal habitats, noise, nutrient runoff from agriculture, chemical contaminants, runoff from vessel maintenance and repair operations, workshop and other industrial operations (Forrest *et al.* 1997; Sneddon 2005; Morrisey & Miller 2007; Morrisey 2008; Gillespie 2009a; 2009b). Because most of the threats occur in catchments, regional councils and unitary authorities can play a significant role in shared management of marine threats. At present, gauging the ecological trends of coastal habitats is difficult without baseline and regular monitoring (Gillespie 2009a). Monitoring of coastal environment at present is limited but includes regional bathing water quality, targeted surveillance for marine pests and consent monitoring relating to point source discharge.

Examples of some of the consequences of violating the sustainability principles on the sustainability challenge are shown in Table 12.

Table 12. Examples of consequences of contributions to and violations of, the sustainability principles on the challenge of coasts.

Principle		Positive Impact	Negative Impact
1	Increasing concentrations of extracted chemicals from the Earth's crust	Mitigation of effects through: • Legislation (RMA) • Growth in riparian management	• Polluted coasts and ecosystems leading to loss of species and habitats
2	Increasing concentrations of synthetic material		
3	Degradation by physical means		• Species diminished • Native species out-competed by invasive ones
4	Undermine the capacity of others to meet their needs		• Recreational bathing opportunities • Potential health effects from polluted coasts and food sources

5.2.2. Externalisation of environmental issues

Many of the ecosystem services and natural resources Nelson uses are imported from around the country (14,920 hectares) and globally (27,000 hectares) (Cole & Patterson 2008). Thus, many of Nelson's impacts on the environment are either Scope 2 or Scope 3 impacts (see Section 1.2) and externalised beyond the city's boundary. For example, Nelson imports and consumes more oil than the New Zealand average (see Section 6.1.2 below). The geopolitical and environmental implications of the oil industry are large in scale, ongoing and far reaching, with much of the impacts far removed from Nelson residents.

Another example is electricity, with most of the supply Nelson uses, imported from around the country. Hydroelectricity comprises much of this energy source, and to cater for increasing demand, wild rivers such as the Mokihinui are being proposed as potential future dam sites with the potential reduction in both recreational activities and natural habitat for some native species such as the long-fin eel (Brown 2010). Further, part of the electricity mix used by Nelson is generated at Huntly through burning coal. Such combustion degrades the atmosphere by emitting carbon dioxide and other gases.

Examples of some of the consequences of this sustainability challenge on the four sustainability principles are shown in Table 13.

Table 13. Examples of positive and negative impacts on the sustainability principles resulting from the externalisation of environmental issues challenge.

<table>
<tr><th colspan="2">Principle</th><th>Positive Impact</th><th>Negative Impact</th></tr>
<tr><td>1</td><td>Increasing concentrations of extracted chemicals from the Earth's crust</td><td rowspan="4">• Fair trade and buy local campaigns
• Local farmers market</td><td rowspan="2">• Impacts of pollution felt elsewhere (greenhouse gas, ozone)
• Problem sent overseas (plastic and electronic equipment recycling)</td></tr>
<tr><td>2</td><td>Increasing concentrations of synthetic material</td></tr>
<tr><td>3</td><td>Degradation by physical means</td><td>• Internationally, extraction of resources in potentially un-environmentally appropriate ways</td></tr>
<tr><td>4</td><td>Undermine the capacity of others to meet their needs</td><td>• Internationally, potential of poor conditions for workers and local communities (health and safety effects, sweatshops)</td></tr>
</table>

5.3. Hitting the walls of the funnel

The "supply side" issues raised in the preceding pages are summarised and presented in Table 14. For each challenge we have provided examples of some of the potential impacts and the consequences of Nelson "hitting the wall" of the funnel.

Table 14. Nelson's "supply side" challenges, examples of potential impacts and the consequences of "hitting the wall" of the funnel.

Sustainability challenge	Potential effects	Hitting the wall of the funnel
Category A challenges		
Air quality	• Health effects • Tarnished image for Nelson	• More forced changes of lifestyle to meet national standards • Human health lowered
Atmosphere	• Changed weather patterns - more severe floods and droughts • Sea level rise • Increased abundance of invasive pests • Health impacts	• All economic sectors affected • Social unrest due to economic downturn • Cascading environmental response to changes • Ozone hole increasing in size
Biodiversity	• Increased abundance of invasive pests	• Reduced biodiversity of native species
Freshwater	• Natural character lowered • Community identity affected • Recreational and commercial use compromised • Health issues	• Economic impact of scarce water resource • Conflicting demands for water • Human health affected
Land cover and land use	• Infertile soils • Erosion • Sedimentation of waterways	• Lower exports • Food production down
Waste disposal	• Waste accumulation • Leachate • Loss of useful land	• Land shortages • Increased pressure on natural resources • Contamination of neighbouring land
Category B challenges		
Coasts	• Natural character lowered • Community identity affected • Recreational and commercial use affected	• Life supporting capacity diminished • Coast environment unsafe for recreation • Marine industries forced out of business *e.g.* fishing, aquaculture
Externalisation of environmental impacts	• Areas elsewhere affected by Nelson's actions	• National and global scale environmental decline

6. DEMAND CHALLENGES

There are six challenges relating to demand for ecosystem services facing Nelson City, which have been subdivided according to the quantifiable status of each. The three category A challenges are discussed first followed by the three category B challenges. As with the challenges discussed under the "supply side", it should be noted that for many of the challenges, the discussion is relatively superficial, providing examples rather than comprehensive discussion, reflecting a dearth of information, budgetary constraints for the project, or both.

6.1. Category A challenges

6.1.1. Consumption

Nelson is generally doing well in terms of its social indicators (TDC *et al.* 2009). The *Top of the South Indicators Report* paints a picture of Nelson that reflects the high quality of life experienced by many residents. Residents report a high standard of health, higher participation in physical activities, longer life expectancy and healthier diets than other regions nationally. Drinking water meets national guidelines, unemployment is low, participation in early childhood education is high as is educational attainment, and houses are becoming more affordable (TDC *et al.* 2009).

While Nelson generally experiences a high quality of life, the question arises as to whether the level of consumption in Nelson is sustainable. One way to measure this is with an ecological footprint, which measures consumption within a specific geographic area compared to that areas ability to produce goods (Holmberg *et al.* 1999). Nelson has an ecological footprint of 76,910 hectares (Cole & Patterson 2008). Although this is the smallest footprint of any of New Zealand's regional councils, it still exceeds the available land area in Nelson by 41,930 hectares (Cole & Patterson 2008). As a result Nelson has an ecological overshoots that exceeds its available useful land by 2.18 times.

This overshoot is surpassed only by Auckland, with Wellington a close third. Nelson is, thus, living beyond its borders and to provide the resources it consumes, it is effectively importing 14,930 hectares of land from other regions in New Zealand and 27,000 from other countries, (McDonald & Patterson 2003).

However, while as a specific geographic area, Nelson is in overshoot, if Nelson is seen as part of the Tasman Bay region or South Island, then this wider area is not in deficit and is instead a surplus provider of goods. As such, the ecological footprint can provide an incomplete picture, however as the world's population grows and its capacity to meet the needs of communities reduces, communities that can live within their geographic areas will be more resilient to future global changes. If, for example, oil prices continue to increase and Nelson's ecological overshoot also grows, this will create a risk for Nelson as it becomes increasingly reliant on other regions and countries.

Another way to establish if Nelson's life style is sustainable is to examine some of the products that are consumed locally. One example of this is a class of synthetic substances, referred to as 'emerging contaminants' which are included in widely used pharmaceuticals and personal care products (PPCPs) used in New Zealand (Kolpin *et al.* 2002). The antibacterial agent triclosan, for example, is a common ingredient in a large range of household products from hand soap to toothpaste and hair conditioners which are all disposed of through waste water treatment plants and can eventually concentrate into the marine environment. The presence of triclosan in the environment is of concern as it is structurally similar to thyroid hormone and has been found to be acutely and chronically toxic to aquatic organisms. Once in the environment, it can transform into other potentially toxic compounds such as dioxins, which have been found to rapidly bio-accumulate (Hughes & Denver 2006). Further research in the USA has found that triclosan in dishwashing liquid reacts with chlorinated water to produce chloroform, a possible human carcinogen (Hughes & Denver 2006).

A similar issue is that of chemicals that are non-toxic to one species, but toxic to another. For example, from work overseas we know that the drug diclofenic - an anti-inflammatory for humans and cattle - caused a massive decline in the Asian Vulture population when it entered the food chain (Kinver 2008), its numbers decreasing by 99.9% since 1992. Diclofenic is the trade name for the commonly used prescription drugs Voltaren and Catflam.

Examples of some of the consequences of this sustainability challenge on the four sustainability principles are shown in Table 15.

Table 15. Examples of positive and negative impacts on the sustainability principles resulting from the consumption challenge.

<table>
<tr><th colspan="2">Principle</th><th>Positive Impact</th><th>Negative Impact</th></tr>
<tr><td>1</td><td>Increasing concentrations of extracted chemicals from the Earth's crust</td><td rowspan="4">• Increasing demand for organic produce
• Increasing access and demand for locally grown produce
• Increased demand for "natural" synthetic chemical free produce</td><td>• Over consumption can lead to pollution of greenhouse gases and ozone depleting substances *etc*</td></tr>
<tr><td>2</td><td>Increasing concentrations of synthetic material</td><td>• Toxic substances, such as triclosan, released into the environment, impacting on others species and ecosystems</td></tr>
<tr><td>3</td><td>Degradation by physical means</td><td>• Over extraction of resources can lead to a decline in some species (such as Northern Bluefin Tuna)
• Increased use of land for housing, roads, waste absorption from increased population</td></tr>
<tr><td>4</td><td>Undermine the capacity of others to meet their needs</td><td>• Increased reliance on another country leads to reduced resilience</td></tr>
</table>

6.1.2. Energy security

Future changes affecting Nelson are expected to include increases to the price of oil (*e.g.* Kaufmann *et al.* 2010) and these in turn would threaten the energy security of the entire region. The Nelson economy relies heavily on imported petroleum. All major economic sectors in the wider Nelson/Tasman area; forestry, fishing, horticulture, tourism, and agriculture require oil based products to power vehicles, transport products, control pests and more. In the fiscal year of 2008/09, 344,000t of petroleum products were imported to the Nelson region through Port Nelson (Port Nelson Limited 2009). This tonnage supplies the Tasman, Marlborough and Nelson regions, which have an estimated combined 2010 population of 138,000 (Statistics New Zealand 2010). Dividing total imports by population gives the average annual petroleum consumption per person, which is 2.5 tonnes for the Nelson region. On average, New Zealanders each use an estimated 1.42 tonnes of petroleum per year[2] (MED 2010; Statistics New Zealand 2010). Nelson's consumption, therefore, is

[2] This figure is based on a total national petroleum consumption of 255.93Pj in 2009 and a New Zealand population of 4,315,800 million people for the same year.

significantly higher than the national average, meaning the city is vulnerable to disruptions in supply and future price rises. Vulnerability, in this case, may mean being subject to price rises for imported food; increased travel, commuting and business costs; or decreased visitor numbers and decline in exports.

Energy security also depends on a reliable supply of electricity. The El Niño/Southern Oscillation (ENSO) cycle, the Interdecadal Pacific Oscillation (IPO), and human induced climate change is expected to affect the supply of electricity in the future (Renwick 2005). For example, a reduction of rainfall to fill the southern lakes associated with the IPO over the next 20-30 years, would reduce supply, while climate change driven wind, rain and temperature changes to the main centres is expected to affect demand (Renwick 2005). In the face of a changing climate, therefore, the future electricity supply to Nelson is uncertain.

Further, other threats such as earthquakes make Nelson more vulnerable to security of supply. The power lines that transport electricity to the region from the southern hydro lakes run across a number of faults including the Alpine Fault. A rupture on this is a serious risk to the infrastructure, which could result in Nelson being without electricity for six months or more (Kearney 2009; Network Tasman Ltd 2010). Given that the only significant local electricity generation - the Cobb Dam – is insufficient to power the Nelson/Tasman region, there is a risk to Nelson's electricity supply.

To reduce this risk and contribute to the mitigation of climate change, Nelson City Council launched the Solar Saver Scheme in December 2009 with the aims of increasing the uptake of solar hot water in Nelson. Solar Saver allows residents to obtain a solar hot water system, with the initial cost meet by Nelson City Council, the landowner then pays Nelson City Council back (plus interest) through a targeted rate to their property over ten years. In the situation where the landowner sells the property during that period, the rate remains with the property and not the initial landowner. Up until the beginning of 2010, building consents for solar hot water averaged between 40 and 80 installations per year. In 2010 however, 227 consents were issued, with 192 installations as part of Solar Saver.

Examples of some of the consequences of this sustainability challenge on the four sustainability principles are shown in Table 16.

Table 16. Examples of positive and negative impacts on the sustainability principles resulting from the energy security challenge.

	Principle	Positive Impact	Negative Impact
1	Increasing concentrations of extracted chemicals from the Earth's crust	• Energy efficiency initiatives • Micro-scale local production e.g. home hot water solar installations • Nelson City initiatives Council's Solar Saver and Eco Design Adviser • Use of methane capture and burning to offset coal use at Nelson Hospital	• Use of the Huntly coal fired power plant in times of dry weather • Emissions of greenhouse gas from fossil fuel combustion
2	Increasing concentrations of synthetic material		• Emissions from synthetically derived energy sources (petrol, diesel *etc*)
3	Degradation by physical means		• Increased energy demand may result in the damming of wild rivers
4	Undermine the capacity of others to meet their needs		• Externalised impacts on other communities from damming rivers (loss of access to recreation or food sources *etc*)

6.1.3. *Population*

Nelson's population is growing and is expected to continue to do so into the future. As at the 2006 Census, the Nelson population stood at 42,888 (Statistics New Zealand 2010) and is growing at 3% per annum. At this rate, by 2021 the population of Nelson will exceed 50,000 (Figure 6). The population of the Tasman District is also growing, but at 8% per annum, its growth is much faster than Nelson. Future challenges associated with a rising local population are, for example, increased demand on natural resources and environmental services, need for more housing and increased pressure on local infrastructure.

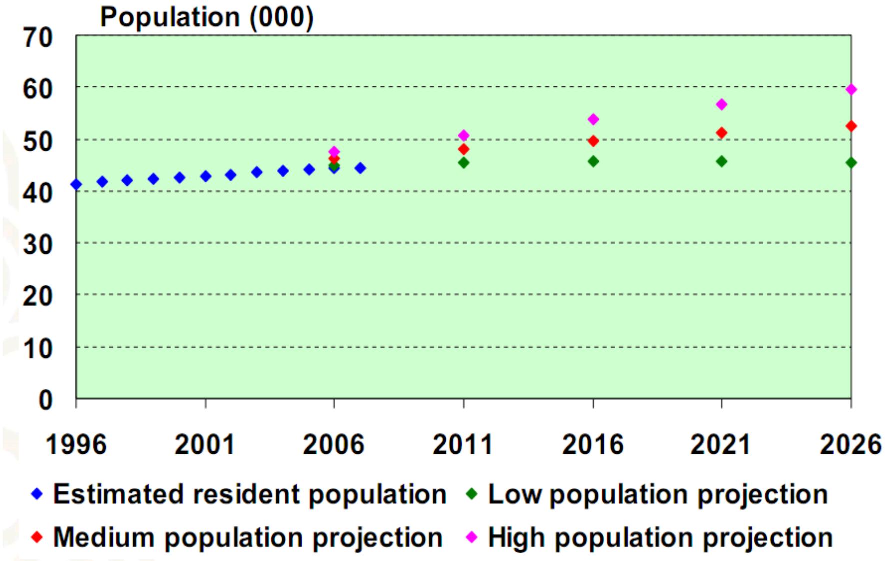

Figure 6. Population projections for Nelson City (Statistics New Zealand 2010).

Understanding the nature in which population growth may occur in future can give a better idea of the strategies needed to ensure sustainability. As shown in Figure 7, when broken down into age classes, the overall population growth rates are expected to be composed almost exclusively of the 40 and older age groups, with a greater increase with those aged 65 and over. The 15-39 year age group is predicted to remain largely constant, while the under 15's are expected to decline.

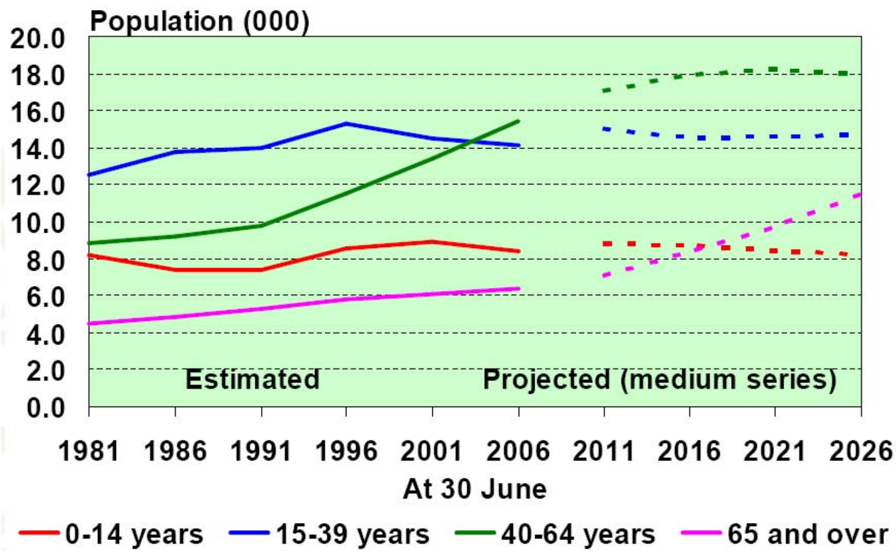

Figure 7. Nelson City population growth rates by age (Statistics New Zealand 2010).

Such changing demographics have many implications for Nelson. In the UK for instance, housing shortages have been found to be, at least in part, the outcome of a generation of aging house owners continuing to live on in large houses long after their children have left home. The result is many empty rooms, which, taken on the scale of a city or country, can cause a shift to housing shortages *even without* population growth (Monbiot 2011). Thus, while an area might be experiencing a housing shortage, it may not necessarily be the result of a lack housing, rather, an inefficient use of the current housing stock.

In terms of consequences of a population increase on the four sustainability principles, population does not cause a violation *per se*. Instead the increased population means that people will consume more either through need or want (affluence) and it is this increased consumption that will lead to a violation of the sustainability principles. As such, examples of violations of the sustainability principles resulting from the challenge of population can be seen in Table 15.

6.2. Category B challenges

6.2.1. *Food security*

Food security is having "access to adequate, safe, affordable and acceptable food" (McKerchar 2006). This definition emphasises the point that food security is not just about there being enough food available, but also that the food is affordable, and with food prices throughout the world increasing (Food and Agriculture Organisation 2011) this is becoming a significant issue. In January and again in February 2011, the UN Food and Agriculture Organisation (FAO) reported that food prices were at record highs, exceeding the previous records set in 2007 and 2008 (Brown 2011).

These price increases are thought to be due to a combination of three factors: increased demand (from a growth in population and affluence), impacts of climate change and over extraction of water resources in some countries (Brown 2011). As a free market economy Nelson is not immune to price increases (Statistics New Zealand 2011)[3]. Despite New Zealand being a major exporter of primary produce (OECD & UNFAO 2010)[4], food prices in Nelson match what is paid on the global market (Fallow 2011; Hembry 2011).

While such increases benefit exporters, the main impact of these food price increases is felt hardest among the poorest of the community. This was highlighted by a 2001 paper in the New Zealand Medical Journal, which stated that at least a quarter of New Zealand's population responded *sometimes* or *often* to the statement "*the variety of food I/we are able to eat is limited by a lack of money*" (Parnell *et al*. 2001). A 2002 Children's Nutritional Survey, contained a similar finding with 20% of New Zealand families stating that they could only

[3] In the 12 months to January 2011, food prices in New Zealand increased by 3.8% (2.2% of which related to the GST rise in October), increases were in all subgroups, with dairy products for example increasing by 8.1%.
[4] New Zealand was responsible for 16% of total world production of whole milk powder in 2010 for example.

afford to eat properly sometimes (McKerchar 2006). The results of both these studies, also found that the most deprived groups, according to the New Zealand Deprivation Index, were the more likely to have difficulty with food affordability (Parnell *et al.* 2001; McKerchar 2006).

The FAO and other have stated that food prices will continue to increase (Brown 2011; Food and Agriculture Organisation 2011; Hembry 2011). Such increases will be of benefit to Nelson's export sector, and thus the local economy, but at the same time will continue the strain on local consumers (Fallow 2011).

Examples of some of the consequences of this sustainability challenge on the four sustainability principles are shown in Table 17.

Table 17. Examples of positive and negative impacts on the sustainability principles resulting from the food security challenge.

<table>
<tr><th colspan="2">Principle</th><th>Positive Impact</th><th>Negative Impact</th></tr>
<tr><td>1</td><td>Increasing concentrations of extracted chemicals from the Earth's crust</td><td rowspan="4">• Increased demand for organic and locally sourced produce
• Home owners producing food
• Household composting increasing quality of local soils</td><td>• Greenhouse gas emissions from fertilizer use
• Loss of soil carbon</td></tr>
<tr><td>2</td><td>Increasing concentrations of synthetic material</td><td>• Accumulation of toxic substances on food and surrounding environment</td></tr>
<tr><td>3</td><td>Degradation by physical means</td><td>• Nitrate rich runoff entering waterways and lake systems</td></tr>
<tr><td>4</td><td>Undermine the capacity of others to meet their needs</td><td>• Imported food reduces local resilience
• Potentially externalises impacts on other communities</td></tr>
</table>

6.2.2. *Societal impacts*

As discussed above with reference to the *Top of the South Indicator's Report,* overall the indicators show that Nelsonians have a high quality of life. Despite this overall positive picture, however, there are also some negative socio-economic trends within Nelson as demonstrated by Nelson's changing decile[5] rating. The decile rating is derived from the New

[5] The decile is a measure of the level of deprivation within a community on a scale of 1 – 10. A decile of 10 indicates that a community is in the 10 percent of the most deprived areas in New Zealand and a 1 indicates a community is in the 10 percent of the least deprived areas in New Zealand.

Zealand Deprivation Index (NZDI) which is a composite of nine dimensions of deprivation such as, income, employment, qualification and living space. It is therefore a measure of the level of poverty or wealth within a community.

The 2006 NZDI divided Nelson into 23 communities, of these 11 have a decile of between seven and ten and only three a decile between one and three, the remaining nine communities have a rating of between four and six. This gave Nelson an average decile of 6.22, compared to 5.77 for New Zealand as a whole (Salmond *et al.* 2007).

Figure 8 shows the change in Nelson's average decile. From 1991 to 2006 Nelson's average decile went from 5.5 to slightly over 6.2 (Salmond *et al.* 2007).

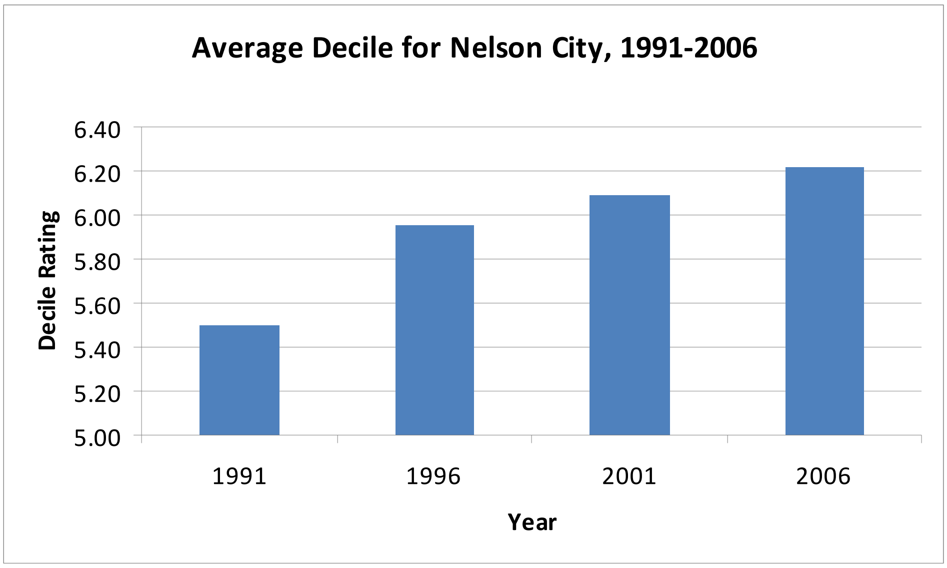

Figure 8. The change in Nelson's average decile from 1991-2006.

Nelson is dependent on imports from regions both domestically and internationally for the resources it needs to maintain its lifestyle, and this can place it at risk to the vagaries of those countries where socio-political insecurity is commonplace. This includes, for example, areas within the Middle East where a considerable amount of the world's oil is obtained.

Civil unrest is expected (as noted with the recent events in Libya) to increase oil prices. There are also continuing threats to shipping to or from Nelson passing through areas where piracy is common place, such as the Horn of Africa (Goodley 2010)[6]. Socio-political insecurity in oil producing countries, and the hijacking of international trade ships are but two of many examples of events that could threaten the supply of resources to Nelson.

[6] 2010 saw 376 attacks and 44 hijackings of ships worldwide. In countries like Somalia, with no effective government for 19 years, people are driven to piracy as it is seen as one of the few ways to make a living.

In addition, through the importation of resources Nelson also externalises social impacts. For example, the consumption and the economic value of coffee is increasing while the grower's share of the value of the coffee trade is reducing making it difficult for growers to remain in business (Trade Aid 2010). This is a good example of a Scope 3 impact - Nelson creating the impact indirectly through its purchase of coffee - with the impact being externalised to the coffee growing communities across the globe. On one level, this is a matter of free market economics, with the Nelson coffee drinker free to decide on the products they consume. However, given that Nelson affects these communities through its purchase decisions, the rubric of sustainability encourages a consideration of extent and nature of these effects (Trade Aid 2010).

Table 18 provides examples of some of the areas where Nelson is contributing positively to, or is in violation of sustainability principle 4, in relation to Manfred Max-Neef's fundamental needs and the needs identified by Nelson City Council and its Social Wellbeing Policy. One area that is not addressed in this table is the externalised impact of Nelson importing goods from communities which do not take as much consideration for human needs as they do in Nelson. To fully understand Nelson's impact in relation to these needs, therefore, a full life-cycle of imported products and the social impacts on the place of origin would be required.

Table 18. The fundamental needs in relation to the needs identified by Nelson City Councils and examples of positive and negative contributions of each need on sustainability principle 4 resulting from the challenge of societal impacts.

Fundamental Human Need	Nelson City Council's Social Wellbeing Policy "Needs"	Positive Performance	Negative Performance
Subsistence	▪ Health ▪ Paid work ▪ Economic standard of living	▪ Employment rate high* ▪ Overall good sense of wellbeing*** ▪ House prices showing signs of improvement*** ▪ Low unemployment rates***	▪ 11 communities decile 7 or worse ▪ Low average incomes* ▪ High house prices that have increased relative to incomes (Motu Project Team 2006)
Protection	▪ Safety ▪ Paid work ▪ Economic standard of living	▪ Road casualties lower* ▪ Residents feel safe*** ▪ High crime resolution rate relative to national average***	▪ High recorded crime rate* ▪ Central city areas after dark are of some concern to some residents***
Participation	▪ Civil and political rights	▪ Organisation of events throughout the year ▪ High participation rate in local elections* ▪ Internet and phone access at home* ▪ Residents believe they should participate in local decision making** ▪ Residents confident they would know how to participate if they wanted to** ▪ Strong sense of community***	▪ Residents not confident they can influence council decisions**
Idleness	▪ Leisure and recreation	▪ High level of recreational activity participation* ▪ High level of cycling for commuting purposes	▪ Residents considered obese* ▪ Number of asthmatics and residents with early onset diabetes
Affection	▪ Social connectedness	▪ Higher level of contact between parents and children*	▪ Divorce rates
Understanding	▪ Knowledge and skill	▪ Access to tertiary education services, colleges, schools and library services ▪ High number of students leaving school with NCEA level 2 or above*	▪ Spending on adult education and school environmental education reduced by Central government ▪ Lower level of adult residents with qualification of NCEA level 1 or above*
Creativity	▪ Knowledge and skill	▪ High artistic population in Nelson ▪ Commitment to arts and culture by council	
Identity	▪ Cultural identity	▪ Large cultural diversity within Nelson	▪ Low level of Maori speakers*
Freedom	▪ Civil and political rights	▪ Freedom to vote and participate in local affairs ▪ Limited suppression of rights	

*As compared to New Zealand (Ministry of Social Development 2010).
** From Nelson City Council's 2010 Residents survey of Nelson (Cullinan & Laugesen 2010).
*** From *Top of the South Indicators Report* (TDC *et al.* 2009).

6.2.3. Transport

Transport is about connecting people and places, economically and socially. A successful transport system is a pre requisite to ensuring the health and success of Nelson (Nelson City Council 2009b). In 2008 and 2009, respectively, the New Zealand Government and Nelson City Council released transport strategies aimed at addressing these challenges. The links between the two were strong and clear. The vision of the New Zealand Transport Strategy 2008 (NZTS) is that *"people and freight in New Zealand have access to an affordable, safe, responsive and sustainable transport system"* (Ministry of Transport 2008). While the Vision in Regional Land Transport Strategy for Nelson 2009 (RLTS) is *"a sustainable transport future for Nelson"* (Nelson City Council 2009b).

With transport come a range of challenges, such as, air pollution. Transport related pollution occurs through oil, petrol, dirt, brake dust and vehicle exhaust that is deposited on the ground and washed into stormwater systems, rivers and estuaries. Such pollutants runoff into rivers and estuaries and can be taken up by aquatic species. Further, smoke from incomplete combustion from inefficient vehicles can contain fine particles and chemicals such as nitrogen dioxide and carbon monoxide. These pollutants can accumulate in the human body, leading to myriad health issues (Nelson Marlborough District Health Board 2010). A study by the Environmental Protection Agency of Victoria, Australia, found an association between hospital admissions and levels of air pollution from cars (Denison *et al.* 2001).

Other challenges include road safety, with Nelson having an unusually large number of pedestrian and cycling injuries (Nelson City Council 2009b). Congestion and the economic cost of people being "stuck" in traffic, and the meeting needs of the "transport disadvantaged" (Nelson City Council 2009b).

With petrol now costing over $2.00 a litre, affordability is also a challenge recognised in the NZTS and RLTS. When modelling future traffic flows in Nelson, Peet *et al.* (Peet *et al.* 2010b) found that overall, the number of trips is expected to increase by 26%-28% over Nelson's entire network between 2006 and 2036 (Peet *et al.* 2010b). This projection, however, was done without considering future oil prices. In a later report, Peet *et al.* included in their model a 50% and 100% rise in fuel costs[7], as was also done by the Ministry of Transport in their 2007 report, *Implementing New Zealand Transport Strategy*. The models found that, by 2036, a reduction in the total number of trips of 6-9% and 12-16% below 2006 levels could be expected given a 50% and 100% rise in fuel costs respectively (Peet *et al.* 2010a). The number of vehicles owned by Nelson residents, and the duration of trips taken is also expected to drop by 2036, with people being expected to walk and cycle more (Peet *et al.* 2010a). This modelling is also supported by a report prepared for the New Zealand Land Transport Authority in 2008. The models for this report found that oil prices were likely to continue to increase and with this increase, the total kilometres travelled per year would decrease by four

[7] The base year for these projections is 2006 with a petrol price of $1.53 per litre.

billion km between 2008 and 2016 and then increase, however the increase will be at a much lower rate than the historical average (Donovan *et al.* 2008).

Examples of some of the consequences of this sustainability challenge on the four sustainability principles are shown in Table 19.

Table 19. Examples of positive and negative impacts on the sustainability principles resulting from the transport challenge.

<table>
<tr><th colspan="2">Principle</th><th>Positive Impact</th><th>Negative Impact</th></tr>
<tr><td>1</td><td>Increasing concentrations of extracted chemicals from the Earth's crust</td><td rowspan="4">• Non-motorised commuters
• Commuting by bicycle one of the highest in New Zealand
• Public transport network</td><td>• Use of fossil fuels</td></tr>
<tr><td>2</td><td>Increasing concentrations of synthetic material</td><td>• Greenhouse gas emissions from fuel use
• PM_{10} and other air pollution</td></tr>
<tr><td>3</td><td>Degradation by physical means</td><td>• Contaminant runoff into waterways and land
• Road network "paving of nature"</td></tr>
<tr><td>4</td><td>Undermine the capacity of others to meet their needs</td><td>• Noise pollution
• Impacts on people's health
• Dependence on other regions for fuel</td></tr>
</table>

6.3. Hitting the walls of the funnel

The challenges raised in the preceding pages are summarised and presented in Table 20. For each challenge, we have provided examples of some of the potential impacts and the consequences of Nelson "hitting the wall" of the funnel.

Table 20. Nelson's demand side challenges, examples of potential impacts and consequences of "hitting the wall" of the funnel.

Sustainability challenges	Potential impacts	Hitting the wall of the Funnel
Category A challenges		
Consumption	• Lifestyle adjustments • Decline in current expectations	• Diminished resilience • Dependence elsewhere for wellbeing
Energy security	• Undermine key economic sectors • Increased cost of energy	• Diminished resilience • Economic decline • Food shortages • Fuel shortages
Population	• Pressure on infrastructure • Demographic change	• Housing shortages - unaffordable housing • Infrastructure unable to cope • Social tensions • Increased pressure on natural resources
Category B challenges		
Food security	• Increasing costs of food • Increasing poverty and social decline	• Diminished resilience • Food shortages • Social unrest
Social Vulnerability	• Reduction of living standard relative to the rest of NZ • Insecure imports and exports • Increasing poverty and social decline	• Potential social unrest • Import commodity shortages (*e.g.* oil, food) • Diminishing resilience • Economic decline • Social unrest
Transport	• Undermine key economic sectors – exports suffer • Lifestyle adjustments	• Diminished resilience • Food shortages • Fuel shortages • Economic decline

7. NELSON AND THE FUNNEL

Having identified the sustainable challenges facing Nelson, can we ascertain Nelson's position in terms of the sustainability funnel? This is not straight forward because the community's current response to each challenge is different. However, it is possible to locate Nelson within one of three broad areas of the funnel.

As shown in Figure 9, area A is within the entrance to the funnel, where activities are unsustainable and the community runs the risk of "hitting the wall". Area B is in the neck of the funnel, where the community has eradicated unsustainable activities and is no longer putting pressure on the natural or social systems. Area C is on the right of the funnel, where the community's activities are restorative, enhancing the natural and social systems.

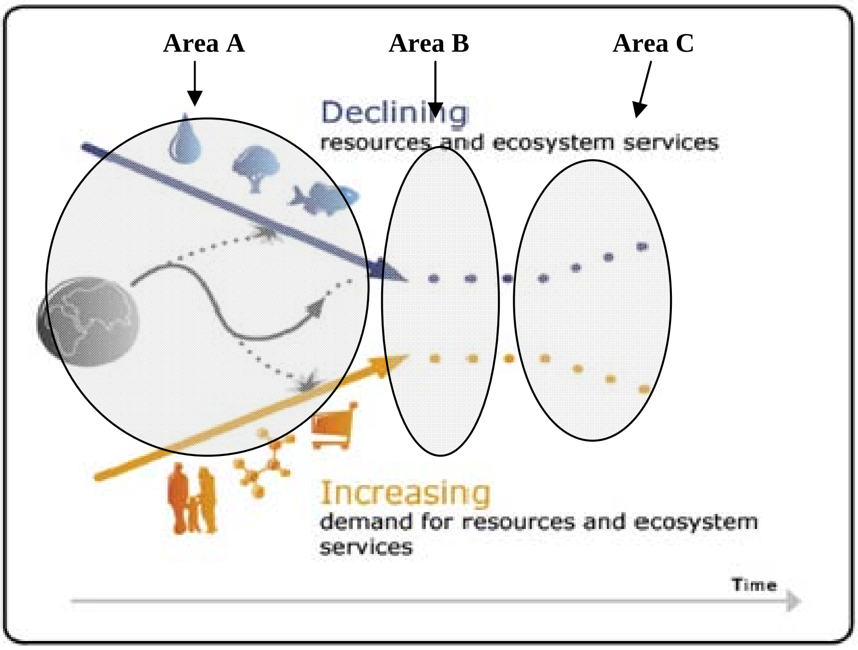

Figure 9. Nelson and the sustainability funnel.

It is the view of the authors that while the risks posed by some challenges has reduced (*e.g.* air quality), others remain as challenges that continue to place Nelson at odds with a sustainable and resilient lifestyle (*e.g.* energy security) and as a result we place Nelson somewhere in Area A, of Figure 9.

8. SUMMARY

This report is an initial discussion of the sustainability challenges pertinent to Nelson City, and is the first stage in a three-stage research programme to inform the development of Nelson's sustainability strategy, *"Framing Our Future"*. It is important to note that the challenges identified, and the discussion of their implications, are exploratory in nature rather than exhaustive. During the consultation and discussions with members of the community to develop *"Framing Our Future"* these challenges can be explored further to identify any missing challenges.

To conduct our research, the Cawthron research team combined TNS's *funnel* and *sustainability principles* with the analytical model DPSIR. This process resulted in the identification of 14 sustainability challenges that could potentially cause Nelson to "hit the wall" of the funnel. These are as follows: air quality, atmosphere (greenhouse gas and ozone), biodiversity, coasts, consumption, energy security, externalisation of environmental issues, food security, freshwater, land cover and land use, population, societal impacts, transport and waste disposal.

Each of these sustainability challenges has been discussed in detail in Sections 5 and 6 of the report, along with a discussion of their impacts against the four sustainability principles. In broad terms the findings of the research indicate that there are many aspects of the lifestyles of Nelson City that are positively contributing to sustainability. These include improvements to the atmosphere and air quality resulting from Port Nelson's better standards in its treatment of methyl bromide, and NCC's success with reducing particulate matter from residential home heating. However, to increase Nelson's sustainability, many challenges remain. Examples include: increasing energy security by reducing Nelson's dependence on foreign oil and imported electricity; and reducing the social vulnerability of the community.

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10. APPENDICES

Appendix 1. Definition of Manfred Max-Neef's Fundamental Human Needs

Table 21. Definitions of Manfred Max-Neef's Fundamental Human Needs.

Fundamental Human Need	Being (Qualities)	Having (Things)	Doing (Actions)	Interacting (Settings)
Subsistence	physical and mental health	food, shelter, work	feed, clothe, rest, work	living environment, social setting
Protection	care, adaptability, autonomy	social security, health systems, work	co-operate, plan, take care of, help	social environment, dwelling
Affection	respect, sense of humour, generosity, sensuality	friendships, family, relationships with nature	share, take care of, make love, express emotions	privacy, intimate spaces of togetherness
Understanding	critical capacity, curiosity, intuition	literature, teachers, policies, educational	analyse, study, meditate, investigate,	schools, families, universities, communities,
Participation	receptiveness, dedication, sense of humour	responsibilities, duties, work, rights	cooperate, dissent, express opinions	associations, parties, churches, neighbourhoods
Idleness (Leisure)	imagination, tranquillity, spontaneity	games, parties, peace of mind	day-dream, remember, relax, have fun	landscapes, intimate spaces, places to be alone
Creation	imagination, boldness, inventiveness, curiosity	abilities, skills, work, techniques	invent, build, design, work, compose, interpret	spaces for expression, workshops, audiences
Identity	sense of belonging, self-esteem, consistency	language, religions, work, customs, values, norms	get to know oneself, grow, commit oneself	places one belongs to, everyday settings
Freedom	autonomy, passion, self-esteem, open-mindedness	equal rights	dissent, choose, run risks, develop awareness	anywhere

Appendix 2. Life cycle analysis of an ordinary plastic bottle.

A brief summary of the life cycle of a plastic bottle is described here to give an indication of the complexities involved in the sustainability challenge. For the purposes of this section, the term “life-cycle” for a product describes all stages from resource extraction and processing/packaging, through to transportation, use and disposal. In Section 5, we described some of the environmental impacts of some of the activities occurring in Nelson. We acknowledge that the nature of these descriptions is superficial, and is deliberately so primarily for reasons of brevity. This discussion goes a little deeper to give an indication of what would be involved in a true analysis of the sustainability of an entire town, with the myriad activities undertaken, and products consumed, by the resident population.

Resource Extraction

The life cycle of a plastic bottle begins with the raw materials used to create it, and in the vast majority of cases, petroleum is the main ingredient. Petroleum is pumped from underground reservoirs of crude oil. The amount of global oil supplies diverted for the production of plastics is significant at around 4%, with another 3-4% expended to provide energy for its manufacture (Hopewell *et al.* 2009). Accessing the oil involves drilling down through sedimentary layers in the Earth’s crust, and then pumping the oil up to the surface. Extraction of oil occurs throughout the world, and, for the most part, is a relatively environmentally benign process.

When the extraction process goes wrong, however, the environmental costs can be significant. Oil spills periodically remind us of the high environmental risk posed by oil drilling and transportation. The most recent oil spill resulted from an explosion at British Petroleum’s Deepwater Horizon rig in the Gulf of Mexico in 2010. 800,000 litres of oil is estimated to have escaped into the Gulf every day (McKie 2010) during the course of the spill that lasted for three months. The resulting slick devastated wildlife and ecosystems both in the Gulf and on the coast (Gutman & Netter 2010; Tangley 2010) and has been described by a senior United States government official as “the United States’ worst environmental disaster” ever (BBC 2010).

Aside from the obvious and oft cited cases of oil spills, there are other environmental impacts associated with this stage of the life cycle, but these don’t typically feature in a life cycle analysis. Exploration and extraction, for example, requires vehicles in the form of aeroplanes, boats, cars and oil rigs – all of which use energy in the form of fossil fuels. The vehicles themselves have a life cycle and associated environmental impact of their own, as do the individual components that comprise the vehicles. It is outside the scope of this report to analyse each and every component associated with each stage of the bottle’s life cycle. However, we simply note that their requirement in the extraction process deserves mention in order to show the unbounded complexity of the life cycle of a plastic bottle.

Processing and packaging

The first stage of converting oil to plastic occurs in a “cracking process”. The cracking process involves heating and pressurising crude oil to break large hydrocarbons into small hydrocarbons (Cleveland & Szostak 2011). A catalyst may, or may not, be used in the process. From this process forms polyethylene terephthalate (PET) pellets that resemble rice. Energy required to produce these pellets derives from oil and natural gas, and electricity from the grid and ranges between 19–23 KWH per kg of PET resin produced (Gleick & Cooley 2009; Franklin Associates 2010). These small pellets are then melted down into preforms. The preforms are miniature plastic bottles which, when heated, stretched and blown expand into conventional plastic bottles. Heating the preforms into bottles also requires energy in the order of around 6 KWH per kg (Gleick & Cooley 2009).

The next stage of the life cycle of a plastic bottle involves sterilising, capping, labeling, and packing into cases to prepare for shipping. Bottling factories can clean, fill, and cap an average of 15,000 bottles an hour and use 0.001 KWH per bottle. Labelling machines can process around 36,000-40,000 bottles per hour at an average of 0.002 KWH per bottle. The total energy required to clean, cap, fill, label and pack a plastic bottle, therefore, is 0.003 KWH (Gleick & Cooley 2009) or around 0.3% of the total energy required in its production.

The Pacific Institute (2008) has researched some of the environmental effects during the processing stage of plastic bottles. They found that the creation of one tonne of PET plastic (the most common form of plastic used in plastic bottles) produces three tonnes of CO_2. According to their statistics, this amounts to 2.5 million tonnes of CO_2 for the manufacture of plastic bottles for water, alone, in the United States in 2006. Also, the production of one plastic water bottle requires three litres of water (Pacific Institute 2008).

As well as the energy required for the processing of bottles, mention should also be given to the life cycle of the machinery used for this processing. Each and every piece of machinery in every bottle processing factory around the world has its own life cycle story, with its unique environmental impacts and energy requirements.

Transportation

The transportation of plastic bottles can contribute significantly to the environmental footprint of a plastic bottle. As can be seen in Figure 10, there are five stages of transportation involved in the life cycle of a plastic bottle. Bottles may travel short or long distances before reaching the end user with greatly varying, with longer distances requiring significantly more energy. A bottle produced within 200 km of its end market may require 0.38 KWH of energy, compared to 1.6 KWH per litre of bottled water produced and filled in France and transported to California (Gleick & Cooley 2009). When adding the energy needed for transportation, then, the total amount of energy required for the processing and transportation per litre of bottle water filled with water requires between 1.6 and 2.83 KWH (Gleick & Cooley 2009).

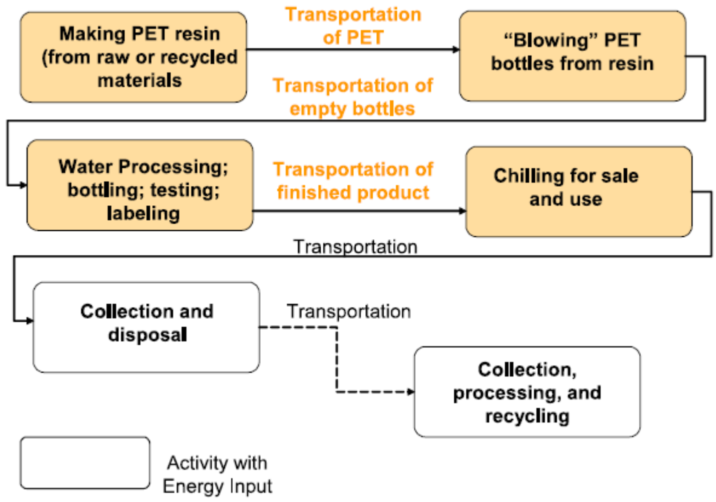

Figure 10. **Flow diagramme showing the stages of the life cycle of a plastic bottle where energy is required. Energy is required for each stage within a box, and also for each of the transportation links between boxes (Source: Gleick & Cooley 2009; 2).**

Again, the energy used in the transportation of plastic bottles is but one consideration of the life cycle. When including other factors necessary during transportation, the life cycle of a plastic bottle becomes greatly more complex. Infrastructure, for example, included in the transportation network includes roads, airports, ports and railways. Further, vehicles used for transport include aeroplanes, ships, trucks, cars and trains. These vehicles and structures also required raw materials and energy for their construction, as well as ongoing maintenance. While it is outside the convention of life cycle analysis to include these factors, because of their integral role in the life of a plastic bottle, their mention is made here to highlight the enormous breadth of factors contributing to the life cycle of the plastic bottle.

Use

The volumes at which plastic bottles are used is large. The bottled water[8] market is expected to have a global trading volume of 174,286,600,000 litres in 2011, up 51% since 2006 (King 2008). The use of most plastic bottles ends when its content has been emptied. In some cases, bottles can be reused *e.g.* as water bottles.

Again, the products that fill these bottles also have their own life cycle stories. Plastic bottles are used ubiquitously throughout the world to contain products such as water, soft drinks, motor oil, cooking oil, medicine, shampoo and milk.

Disposal

Plastic is a very durable product that can take hundreds of years to decay in nature (American Chemistry Council 2010). Effects on the environment associated with plastic decay include the release of toxic pollutants and litter. Recent attention has focused on the environmental

[8] "Bottled water" consists of sparkling flavoured water, sparkling unflavoured water, still flavoured water and still unflavoured water.

effects of the floating garbage patch in the North Pacific Ocean gyre containing plastic bottles and other products (Hoare 2009). An estimated 1 million sea birds and 100,000 marine mammals are killed each year through ingesting, or becoming entangled in, plastic products (United Nations Environment Programme 2011).

It is difficult to say how many plastic bottles are recycled globally, but estimates and measurements between countries suggest the amount is between 15-35% (NAPCOR 2009; Wisegeek 2011) – the remainder being either disposed of to landfills or discarded as litter. An estimated 2 million tonnes of plastic bottles are sent to landfills each year in the United States alone (Worldwatch Institute 2011). The bottles that are recycled are first sorted, and then shredded, washed, rinsed, melted and extruded into plastic flakes to be used for the manufacture of other products, such as t-shirts, shoes, carpet, sweaters, jackets, upholstery for luggage, car parts, sleeping bag fill, and water bottles. The recycling process entails significant energy use. A lifecycle assessment study by Arena *et al.* (2003) found that to make 1kg of recycled plastic flakes requires between 12 and 15 KWH of energy.

If transportation is involved before recycling can take place, the amount of energy required climbs higher. In New Zealand, recycled plastic is collected by local Councils and sent to a sorting facility. After this, plastic recycling is either processed in New Zealand, Australia or China depending on the type of plastic (Ministry for the Environment 2009). International shipping relies on fossil fuels to power the ships, and this releases greenhouse gases - but even transporting recycling to China emits less greenhouse gases than sending bottles to landfill at home (Crosse n.d.).

Not all recyclable plastics make it to recycling facilities in China, however. The recycling industry in China ebbs and flows with fluctuating prices for recycled materials. Those plastics that are uneconomic to recycle are often incinerated. Burning plastics releases toxic chemicals, such as dioxin and mercury to the atmosphere, and these can travel long distances affecting the whole planet. An article in the New York Times provides a first-hand account of two privately owned incinerators in Shenzhen, China; "[t]hey can be smelled a mile away and pour out so much dark smoke and hazardous chemicals that hundreds of local residents recently staged an all-day sit-in, demanding that the incinerators be cleaner and that a planned third incinerator not be built nearby" (Bradsher 2009).

Conclusion

This discussion has briefly evaluated the life cycle of a plastic bottle. From its beginnings as crude oil beneath the Earth's surface, the life of a plastic bottle takes many forms and can travel large distances. This cycle can involve environmental impacts at every stage. During extraction, oil spills can cause great environmental damage, while the technology and fuel used also carry their own environmental footprints. The processing of raw materials into a capped, labeled and filled plastic bottle requires energy, and, combined with the energy used in transportation, results in a total energy bill of between 1.6 and 2.8 KWH per bottle. Finally, three possibilities exist for the disposal of plastic bottles: landfill, litter or recycling. Plastic takes a very long time to decompose in the environment and in landfills, and so can impact on nature long into the future. Recycling entails significant energy use to turn the bottles into useful products.

For reasons of brevity, this discussion has omitted including the environmental impacts of the many mechanical components, vehicles, infrastructure, personnel and other factors involved in the production, processing and transportation of a plastic bottle.

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