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Title of Paper: **Engineering Best Practice Where are we at? Climate Change in Context**

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Abstract

The paper considers the context of the current legislative setting and drivers that require Local Government Engineers to incorporate climate change predictions into their asset management practices, their engineering design Codes of Practice and their planning for long term sustainability of basic infrastructure. The position of key agencies who have been tracking Central Government intervention strategies, in relation to climate change impacts on New Zealand society and sustainable infrastructure planning is discussed.

A review of some typical Territorial Local Authority Code of Practices has been undertaken to establish the extent to which climate change factors are built into activity management plans and current Codes of Practices with some suggestions on how impacts of climate change predictions can be incorporated into "Engineering Best Practice" for basic infrastructure services.

Case study examples of where and how climate change is likely to impact on engineering design and the context of these impacts in relation to other factors and variables such as population growth, levels of services, planning horizons, current design practices and other sustainability issues are discussed.

The importance of a sound supporting framework and organization strategy to ensure consistency of approach to incorporating aspects of climate change predictions into any overall organizational risk strategy is stressed. Adaptation methods and options for innovative actions to integrate climate change impacts into overall asset management planning and engineering design practices are put forward.

Introduction

While scientists continue to grapple with the complexities of climate change, we as engineers must act now. We believe there is sufficient evidence to be proactive in offering strategies and solutions for implementation to local bodies to provide for an immediate and sustainable future.

The solutions to deal with the impact of climate change on our infrastructure need to be fully integrated with other demands, such as infrastructure planning and management, population growth, asset renewal policies, civil defence and emergency management, insurance matters, long term strategic planning and other critical social changes. This paper considers the likely impact of climate change on infrastructure and attempts to put it in context with these other demands on infrastructure planning and design. In addition the aspects of engineering best practice that take into account climate change predictions and impacts are discussed.

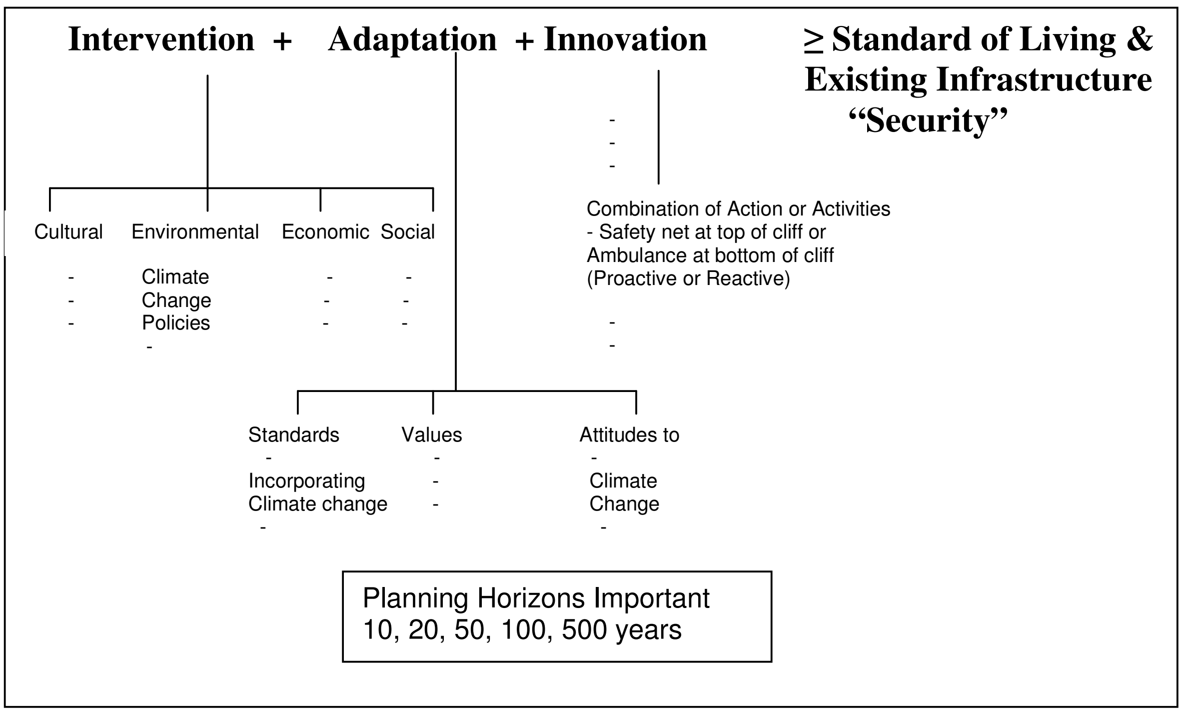
The importance of a sound supporting framework and organization strategy to ensure consistency of approach to incorporating aspects of climate change predictions into any overall organizational risk strategy is seen to be an important driver for development of engineering best practice. Adaptation methods and options for innovative actions to integrate climate change impacts into overall asset management planning and engineering design practices are put forward.

Infrastructure Planning and Design

Historically infrastructure planning and design is based on what could be described as the traditional model which incorporates growth and 'tried and proven' design philosophies. The primary objective of this model has been to maintain and where possible improve on existing levels of service, according to new codes and standards.

More recently, there has been a trend to consider a new dimension called *sustainability*. Codes and standards have tried to incorporate a sustainability concept with varying degrees of success. From left field comes yet another factor for engineers to grapple with – namely *climate change*. Both terms are now impacting on traditional engineering best practice.

I believe the traditional philosophy of the global economy can be summarized as :



It can be seen from this diagram that climate change is only one of many contributing factors to the conundrum facing the infrastructure planners and designers. Apart from issues of definition in terminology, engineers are faced with the immediate need to implement long term (20 years plus) infrastructure development capital work programmes as well as ongoing asset maintenance of renewal activity management plans.

These relatively new concepts of sustainability and climate change impact, not only threaten traditional engineering solutions, but engender a whole new range of options which often do not fit easily with standard engineering practice in terms of selecting the preferred solution. In fact the New Zealand climate change guidance manual strongly advocates a risk based approach to incorporating climate change predictions into engineering infrastructure design.

We are at a critical point in time in needing to rethink our approach to infrastructure planning and design, triggered by impacts of climate change predictions. This is especially so with the current 10 year reviews with the local government Long Term Community Consultation Plans currently underway. Traditional levels of service, standards and codes all need to be revised in the light of the uncertainty created by climate change predictions and associated impacts on design solutions and options.

What is required is a radical rethink of our original premise contained in the equation set out in Box 1. We are forced to consider an alternative approach that may go some way to ensure long term sustainability of our country.

Climate Change Impact on Engineering Infrastructure

The impact of climate change across all aspects of engineering infrastructure, water supply, wastewater, storm water and flood protection is being increasingly recognized all around the world. A key reference on climate change adaptation "Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change" (1) identifies these impacts and outlines a number of case studies where proactive steps in terms of physical construction to adapt to climate change have already been undertaken.

Examples of these around the world are:

- Confederation Bridge in Canada 13km bridge constructed 1m higher than current design standards provided for to allow for climate change.
- Deer Island sewage treatment plant in Boston constructed at a higher level to allow for climate change.
- Thames Barrier design UK provides for sea level rise
- Changes in temperature, precipitation, sea level rise and extreme events have been identified as climate change impact parameters for water supply masterplanning in the New York region.

In each of these cases a conscious decision has been made to incorporate climate change factors into the long term planning and design of major new infrastructure. The IPCC adaptation book (1) highlights the varying impacts between countries and between regions and cities within a country, depending on specific climate parameters and contour.

The urgent question we need to address currently in New Zealand is – *Which climate change factors should we adopt to incorporate into our current standards?* We are relatively advanced in New Zealand with the MfE guidelines on climate change; Preparing for Climate Change – A Guide for Local Government in New Zealand, July 2008 (2); Climate Change Effects and Impacts Assessment - A Guidance Manual for Local Government in New Zealand, 2nd Edition, May 2008 (3) and Coastal Hazards and Climate Change – A Guidance Manual for Local Government in New Zealand, 2nd Edition, July 2008 (4). These guidelines do not provide definitive answers but provide excellent material for a risk based approach. This approach introduces a new dimension into engineering practice. Options need to be tested for different scenarios and confidence limits and sensitivity analysis need to be applied, plus affordability considerations. This context of options and scenarios is nothing new. However, it does demand agreement on definitive action amongst our profession to allay uncertainty and establish **consistent** application of the guidelines.

Intervention

Intervention in terms of incorporating climate change impacts into engineering best practice can be described as the overriding policies and strategies within business, central government or local government, which direct, support and empower changes in direction thereby determining radical rethinking of engineering best practice. In some cases it is the reverse – advances in engineering research and development can drive policy or strategy changes which in turn will determine engineering best practice. In the case of climate change predictions, we have a combination of policies and strategies driving best practice and alternative engineering approaches that are risk based, as opposed to standards based, that will need to be incorporated into best practice design processes.

Top down intervention will need to be a key driver in the development of engineering best practice to enable climate change to be incorporated formally into engineering best practice design process. Intervention in society comes in all forms across all four well beings (Local Government Act 2002 (5)). Intervention strategies are wide ranging and complex. Intervention from a high level, to accommodate climate change, is necessary to drive nation wide best practice. At present we have fragmented approaches across all engineering design areas.

Climate change impacts are relatively new and need positive intervention strategies for our country to maintain/develop sustainable communities in the future. It is important to note that in this paper intervention considerations have been confined to specific areas of climate change adaptation and associated engineering design best practice. The other aspects of climate change which include greenhouse gas emissions, carbon foot printing, climate change mitigation policies and carbon trading have not been considered. It is acknowledged that some aspects of these components of climate change could well impact on engineering best practice.

The adaptation strategies discussed here tend to focus on the environmental components of the four well beings with some potential serious flow effects which overlap into the economic component and social effects. Intervention includes aspects of the following:

- Central government legislation
- Central government policies
- Central government guidelines
- Regional council strategies
- Regional council plans
- CDEM plans
- TLA policies and District plans
- IPCC Guidelines
- Business development strategies

Legislation:

The key statutes in New Zealand at present that give some lead on how climate change should be approached are as follows:

- Resource Management Act 1991
- Local Government Act 2002
- Building Act 2004
- Civil Defence and Emergency Management Act 2002
- Land Transport Act 2004
- National Policy Statement on Flood Risk 2008

Each one of these pieces of legislation identifies climate change as a factor to consider in infrastructure planning. It is important to note, however, that in New Zealand central government so far does *not* have any specific climate change adaptation legislation or regulations to drive policies or plans at the regional or local level. As a result we have a vast range of approaches within, across and between regions. From an international review carried out for the IPCC Climate Change Committee in 2007 Fourth Assessment (1), it appears New Zealand is at the fore front of developed nations with its series of guidance manuals for regional and local councils on climate change effects and impacts. As much as these are an excellent base to work from as practicing engineers and planners, it has been found from a sample of regional councils and TLAs there is a major issue with the integration of the development of these guidance documents into best practice or engineering standards.

There is no clear direction from central government on climate change adaptation apart from general indications such as:

- Limit risk
- Adapt to changes
- Consider alternatives
- Think of future generation and their needs

The actual intervention means and adaptation policies are devolved to regional and local councils and businesses themselves. As a result we have an extremely wide range of strategies and policies and adaptation methods in place or being developed around the country.

I believe this is becoming a major headache for planners and engineers in terms of sensible long term planning and design of infrastructure in New Zealand. The different approaches are likely to cause some interesting Environmental Court cases and decisions. Because of uncertainties surrounding climate change, quantum of effects and timing of effects, the guidance manuals advise/promote a risk based approach rather than a standards based approach. This is fine in theory, however it highlights major issues in terms of:

- Consistency of adaptation strategies and implementation measures across New Zealand
- Implementation of risk based strategies and policies in regional and district plans
- Preparation of appropriate NZ engineering standards and codes of practice which incorporate climate change predictions

The Risk Based Approach is based on the New Zealand Standard for Risk Management AS/NZ4360 (6). This approach incorporates the following steps in the decision making processes to take into account climate change impacts:

- Two stage approach for climate change effects
    - Screening studies/assessments
    - Detailed study of climate change effects likely to be material
- Establish the context, i.e. service or function and community expectation of performance
- Identify the hazards and describe the risks
- Analyse the risk, i.e. look at scenarios over investment lifetime to identify key risks
- Evaluate the risk – likelihood/level/consequences
- Identify and assess responses, i.e avoid or mitigate, how much and at what cost?
- Communicate, consult, monitor and evaluate

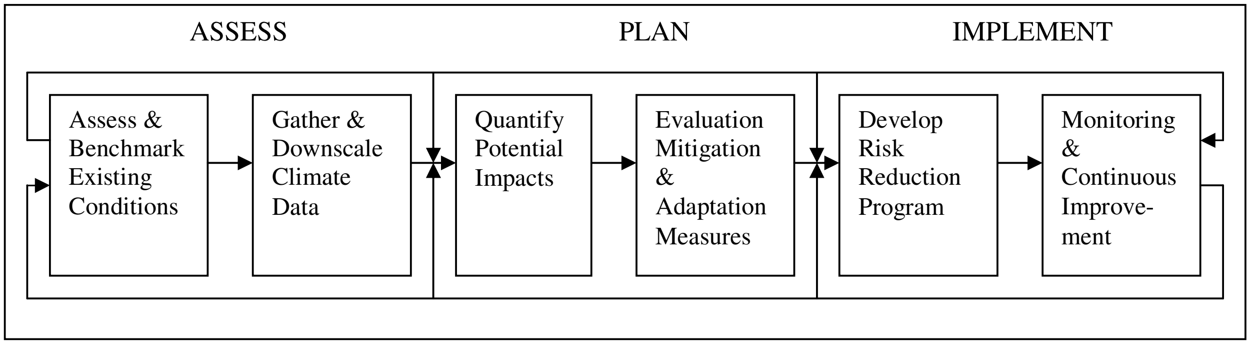
It has become very evident that in order to facilitate engineering best practice incorporating climate change parameters, overarching policies and strategies need to be in place initially by central government, followed by regional and local councils. A case study example involving strategising climate change impacts, where MWH acted as a facilitator, involved Chicago City which embarked on a programme of "Integration of Climate Change Adaptation into their Decision making; Strategic and Tactical" (7). This was a year long process incorporating all aspects of climate change adaptation and impacts on the city's living function and involved all departments in the city.

The primary objectives of the project were:

- A process for choosing high priority adaptations to the changing climate
- Develop a plan as to how to integrate consideration of potential climate change impacts & adaptation into the city's planning process

As part of the outcome from the project, the figure below outlines an overall process the Chicago City is considering for their climate change risk reduction programme. The key message here is that the City needs to implement an iterative process of continuous learning, monitoring, and improvements to effectively respond to the dynamics of climate change.

Chicago City Climate Risk Reduction Program



These type of outcomes give support and direction to engineering best practice. In this era of social change, climate change and sustainability issues, policies and strategies need to be strengthened by a national and collaborative approach between agencies in order to provide more consistent outcomes and direction with respect to specific climate change adaptation methodologies and design guidance throughout New Zealand.

Some excellent work and initiatives have already been done or are underway and continue to be developed by a number of Councils. Examples are:

- Environment Canterbury "Climate Change – An analysis of the policy considerations for climate change for the Review of the Canterbury Regional Policy Statement" (8)
- Auckland Regional Council "Auckland Sustainability Framework" (9)
- Horizons Regional Council "Rivers and Drainage Schemes Draft Global Warming Policy" (10)
- Environment Waikato "Draft River Flood Risk Management Strategy" (11)

These policies and strategies are typically being developed in isolation and the jury is still out as to which is the "best" approach. Much of the work combines mitigation and adaptations aspects of climate change. I consider we need a stronger lead from central government with some funding support to SOLGM and LGNZ to develop some coherent and consistent policy and strategic direction through, perhaps, a National Policy Statement.

Adaptation

New Zealand maybe leading the developed world with our guidance manuals, but we are definitely lagging behind the developed world in adaptation approaches, methodologies and standards. A review of key adaptation agencies in NZ did not come up with favourable results in terms of the NZ situation. Sustainability and climate change are definitely on the agenda of most regional councils and local authorities and many businesses. The issues are on the table. The questions and the road blocks are saying – *Where to from here?* Many decisions related to climate change adaptation will have intergenerational impacts and some visionary planning strategies and tactics are urgently required. Many organisations are focused by necessity on the here and now and not many are taking time out like Chicago City to consider the new era issues of climate change and sustainability and the need to incorporate these aspects into their overall planning strategies.

For example Local Government NZ has identified the following risk areas:

- Transportation – road, rail, sea and air
- Water Resources – salination, scarcity yields
- Stormwater – capacity and discharge constraints
- Wastewater – capacity, discharge, treatment methodologies
- Flood Mitigation – rivers, protection schemes, catchment management
- Waste Disposal – location, containment
- Building – design, weather tightness
- Planning – land use

Ingenium members have recognized the need to build in sustainability and climate change into their programmes. A significant rise in awareness has been noted over the past year. The burning questions being asked however are – '*How do we adapt to the climate change?'* and '*When do we adapt to the climate change?* Members are looking for leadership and direction on the matter as well as some practical tools that will help incorporate climate change into their codes of practice and engineering standards. A risk based approach is not necessary or appropriate for all aspects of climate change issues.

As dangerous and difficult as it might be to embody climate change predictions into engineering standards, we in New Zealand need to consider a review of all our standards which involve climate based parameters and revise them to incorporate the climate change effects. The revised standard needs to be based on current scientific knowledge, combined with the necessary pragmatism associated with setting engineering design standards. An example is from the UK where DEFRA under the UK Planning and Policy Statement No.25: Development and Flood Risk Annex B (12) have set standards for sea level rise, rainfall adjustment factors and river flow design factors.

DEFRA – Planning Policy Statement 25
Development & Flood Risk (2006)
Annex B (12)

Table B.1 Recommended contingency allowances for net sea level rise

Administrative Region	Net Sea Level rise (mm/yr) Relative to 1990			
	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
East of England	4.0	8.5	12.0	15.0
South West	3.5	8.0	11.5	14.5
NW England	2.5	7.0	10.0	13.0

Table B.2 Recommended national precautionary sensitivity ranges for peak rainfall intensities,
peak river flows, offshore wind speeds and wave heights

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak rainfall intensity	+5%	+10%	+20%	+30%
Peak river flow	+10%	+20%		
Offshore wind speed	+5%		+10%	
Extreme wave height	+5%		+10%	

A review of NZ engineering codes of practice has revealed an interesting mix of climate change considerations from 'being silent' to quite 'detailed prescriptive approaches' eg. Tasman District has flood level determination procedures that incorporate sea level rise.

Climate base parameters are the fundamental drivers in the setting of many engineering standards required for the planning, design, maintenance and operation of all infrastructure systems such as:

- Water supply
- Wastewater
- Stormwater
- Flood control
- Coastal protection systems
- Buildings
- Land use planning

Standards today have typically been derived from engineering theory, research on material properties and climate based parameters using a "stable" stochastic data base. This infers the "climate" per se has been stable and static for at least the past one hundred years. The problem the engineering profession faces now is that from here on this is not going to be the case. Every year on average the climate based parameters are changing to a greater or lesser extent over and above the current known climate driver events like the IPO and ENSO according to the "Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change". This annual change throws into chaos the concept of levels of service and KPI's for infrastructure performance that are explicitly stated in any LTCCP or Activity Management Plan because every year the LoS will be typically be reduced.

A standards based approach can provide for specific planning horizons for climate change predictions based on the preferred climate change model and works well for new infrastructure. A risk based approach is probably more robust and is able to incorporate other issues such as sustainability and social change into the analyses. However, with the lifecycle analysis there is a major issue in regard to existing infrastructure in that every year in theory the LoS will reduce and KPI will not be able to be met.

Under existing legislation, in theory, the lack of performance can be challenged by the community and potentially investigated by the audit department. The issue is further compounded by engineering standards not explicitly and specifically addressing climate change. NZ 4404: 2004 Subdivision Code of Practice (13) is an example. This is a widely used standard. As stated earlier, many TLA codes of practice do not address climate change. The developers through other Council documents or legislation are directed to these standards and codes of practice. Without overriding policy and specific guidance the designers or the developers will technically not need to consider climate factors.

One of the few positive examples where climate change considerations are explicitly incorporated into the design process in the Transit Bridge Manual July 2005 (14) and amendment where it states:

"*Section 1*
Design Statement

Section 1.3 Design Statement Content

a) ………..
b) -
- Climate change in terms of the influence on the intensity and frequency of precipitation and sea level for bridges and culverts serving at waterways, sea-coast and estuarine sites.

Comment:

> *Climate Change – In future extreme weather events may increase in frequency and intensity anywhere in New Zealand with increased mean annual precipitation in western zones compared with possible decreases for eastern zones. Climate change may also result in future increases in mean sea level. The statistics available at present are uncertain and designers should seek expert advice when assessing the significance of climate change for design at specific sites."*

Set out below are some typical impacts of climate change which need to be taken into consideration from now on along with the usual design factors such as growth and technology advances, social changes and sustainability issues. Climate change factors are just some of the many factors that feed into the planning and design phases of new infrastructure:

Water supply:

- increases in demand through higher temperatures
- reduction in sources of supply (higher residual flows due to increased flow requirements for aquatic ecology due to temperature rise and reduced yields due to rainfall patterns)
- increased demand for domestic and garden watering

Wastewater:

- increases in inflows and infiltration
- increased environmental flows (less flow for mixing)
- increases in overflows
- sea level rise

Stormwater:

- sea level rise
- rainfall intensity frequency

Flood control:

- sea level rise
- rainfall parameters
- increased flood hazard zones

Coastal protection:

- reduced level of protection
- sea level rise

Some examples of impacts of these effects developed from a series of case studies for the IPENZ Seminar Series August-September 2008 "Incorporating Climate Change Predictions into Engineering Design", MWH Case Study Presentation (15) are set out below:

Water supply:

- A hypothetical study at a water supply system with 10% increase in demand due to climate change indicated approximately 12% increase in non compliance of minimum pressure LoS.
- Another study on reservoir yield indicated a 20% increase in reservoir volume would be required to maintain current LoS for supply reliability under 1 in 5 year drought conditions.

Wastewater:

- A planning study in the Auckland region wastewater trunk mains indicated minimum impact on sizing of conveyance sections but significant impact, up to 50% increase in diameter on the storage section.

- A study by North Shore City Council on possible climate change effects on wet weather flows indicated significant impacts of LoS associated with wet weather overflows KPIs.

Stormwater:

- Case studies in Wellington and Taranaki areas indicate sea level rise scenarios of 0.5m has a significant impact of performance of stormwater systems. The studies indicate that stormwater pumping will be necessary/inevitable to maintain current levels of service.
- A stormwater options study in Taranaki involving a detention structure indicated that a 250% increase in flood volume for the 1 in 5 year event resulting in an increase of 100% in the flood detention storage volume to maintain the same level of service.
- Case studies indicate that pipe systems have a certain amount of 'elasticity' and the dominant design factors are not related to climate change but other factors such as growth and sustainability philosophies. On the other hand the areas of infrastructure involving sea level rise, stormwater volumes and storage are significantly impacted by climate change predictions.

Flood Protection:

- Preliminary design for stop-banks upgrade in the Motueka River indicated a 11% increase in design flow which translated into a 300mm 'climate change allowance' on the 100 year design flood level.
- Typically the 2% rise in temperature climate change scenario results in a 16% increase in the 1 in 5 year design rainfall.
- It appears that for most of New Zealand, levels of service will be typically halved for the 50-100 year projection of rainfall in the face of increased rainfall intensity (typically 16%).
- For open channel systems, rivers and streams, current free board allowances will be significantly reduced for current design flows. As a result flood protection systems will need to be upgraded to maintain current levels of service and current freeboard design allowances.

Coastal Protection:

- Case studies indicate coastal protection review and analyses will need to involve joint probability assessment of sea level rise, storm surge and minor climate changes. Review of initial studies indicate that any current developments and certainly any future or present planned developments or land use changes to residential or industrial zoning under RL 4.0m will need very close scrutiny and analysis to ensure long term sustainability.
- Coastal protection adaptation for all future planning around the New Zealand coast needs to incorporate the processes set out in the box below:

Evolution of planned coastal adaptation practices (from Figure 6.11 Ref. 16)

Coastal adaptation (IPCC CZMS, 1990)	Adaptation objectives (Klein and Tol, 1997)	Adaptation responses (after Cooper et al., 2002; Defra, 2001	Example
		Advance the line →	Land claim; empoldering Estuary closure
Protect →	Increased robustness →	Hold the line →	Dyke; beach nourishment
Accommodate →	Increased flexibility →	→	'Flood proof' buildings Floating agricultural system
		Retreat the line →	Managed realignment
Retreat →	Enhanced adaptability →	Limited intervention →	Ad hoc seawall
		No intervention →	Monitoring only
	Reversing maladaptive trends →	Sustainable adaptation →	Wetland restoration
	Improved awareness and preparedness →	Community-focussed adaptation →	Flood hazard mapping; flood warnings

It can be seen from these examples that the future impacts of climate change are significant in the planning and design of infrastructure. Typically if we do not positively address these impacts our designs will fall short of the stated target performance parameters. Future generations of engineers will then be reviewing and questioning our assumptions about climate change.

Adaptation is relatively straight forward either through a standards based approach or a risk based approach. However the engineer today is also faced with the other issues and factors which influence the design solution, many of which outweigh and have greater influences on final design outcomes than climate change.

These factors and issues include:

- Growth
- Social change
- LoS
- Sustainability issues
- Contingency planning

Climate change factors need to be incorporated into the overall design process as a matter of course from here on. Maybe that the connecting sign from Box 1 reproduced below needs to be changed. Do we lower our expectations, standards and levels of service or do we adapt and conceptually adjust our infrastructure planning and design processes to incorporate climate change to ensure a sustainable future?

Intervention + Adaptation + Innovation ≠ ? ≠ Standard of Living & Existing Infrastructure "Security" Social adaptation Environmental adaptation

Innovation

There are many innovative ways to incorporate climate change factors into the review and development of engineering design processes and practices. These include such things as:

- Reduction in levels of service
- Innovative planning rules eg: houses on stilts
- Indemnity provisions
- Civil Defence and Emergency Planning
- Insurance
- Business as usual (wait for social adaptation)
- Shorten planning horizons (Defer the climate change issue for now)
- Creative and flexible designs to allow for climate change adaptation in the future
- Relocatable housing
- Essential service location review
- Creative solutions

The question needs to be asked whether these approaches will be sustainable in the long term. They typically veer away from the traditional long term (100 year planning horizons) and robust engineering solutions associated with traditional infrastructure planning and design. More than likely these alternative approaches will leave future generations to pick up the true costs of the effects of climate change.

Our forefather engineers planned and designed infrastructure which has typically lasted for 100 years. We are looking at the next generation of infrastructure solutions which desirably will take us through another four generations. We have traditional and robust solutions through optioneering processes which lead to preferred solutions – the jury is still out as to how we will incorporate climate change factors into this infrastructure planning in a consistent and coherent manner across New Zealand. Inevitably any solutions from here on are going to involve trade offs and social adaptation.

Conclusions

1. Climate change is happening now and needs to be addressed.
2. National leadership from central government and the profession is urgently required to provide the direction and mandatory inclusion of climate change factors into planning and design of infrastructure and land use planning.
3. Climate parameters are factors incorporated in many engineering standards and have been based on a "stable" climate and a stochastic data base.
4. Traditional engineering standards and codes of practice incorporating climate parameters are now changing every year (on average).
5. Urgent attention is required from the engineering profession as to how to address the problem of the changing standards attributed to the climate change factors.
6. Risk based approach as promoted in the MfE guidance manuals is a very sound basis on which to proceed and needs to be mandatory for major infrastructure, taking into account the wider factors associated with sustainability.
7. There is also need for a standards base approach like the UK example.
8. Innovation provides some interesting non traditional solutions which have not yet had the sustainability test.

9. The traditional concept of levels of service and KPI is under challenge.

10. The vital question: *Climate change in context, Engineering Best Practice - where are we at?*
The answer: Currently we do not have a nationally promoted mandatory best practice and as for "where are we at? " I suggest we are at a MAJOR cross roads which potentially will turn traditional design practices and processes on their head.

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Glossary of Terms

Adaptation
Adjustment in natural or *human systems* in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation.

Climate Change
Climate change refers to any change in *climate* over time, whether due to natural variability or as a result of human activity. This usage differs from that in the *United Nations Framework Convention on Climate Change (UNFCCC)*, which defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition

of the global *atmosphere* and which is in addition to natural climate variability observed over comparable time periods'.

Climate variability
Climate variability refers to variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the *climate* on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the *climate system* (internal variability), or to variations in natural or *anthropogenic* external forcing (external variability).

Mitigation
An *anthropogenic* intervention to reduce the anthropogenic forcing of the *climate system*; it includes strategies to reduce *greenhouse gas sources* and emissions and enhancing *greenhouse gas sinks.*

Planning horizon
The time frame on which planning and lifecycle of new infrastructure based

Sea-level rise
An increase in the mean level of the ocean. *Eustatic sea-level rise* is a change in global average sea level brought about by an increase in the volume of the world ocean. *Relative sea-level rise* occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence. In areas subject to rapid land-level uplift, relative sea level can fall.

Sustainable development
Development that meets the cultural, social, political and economic needs of the present generation without compromising the ability of future generations to meet their own needs.

Acronyms

ENSO
El Nino Southern Oscillation Influence

DEFRA
Department of Environment, Food & Rural Affairs

Ingenium
Brand name for the Association of Local Government engineering New Zealand Incorporated

IPENZ
Institution of Professional Engineers of New Zealand

IPO
Interdecadal Pacific Oscillation Influence

KPIs
Key performance indicators

LGA (2002)
Local Government Act 2002

LGNZ
Local Government New Zealand

LoS
Level of Service

LTCCP
Long Term Council Community Plan

MfE
Ministry for the Environment

RL
Reduced level above mean sea level.

SOLGM
Society of Local Government Managers

TLA
Territorial Local Authority