Climate Change Adjustments for Detailed Engineering Design

A Step-by-Step Manual Using Worked Examples from Viet Nam

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The Problem of Design under Climate Change, Uncertainty

The importance of design standards:

“Infrastructure is expected to remain functional, durable and safe for long service lives, typically 50 to more than 100 years. They are exposed to, and potentially vulnerable to, the effects and extremes of climate and weather, such as droughts, floods, heat waves, high winds, (and) storm surges. Engineering practices and standards are intended to provide acceptably low risks of failures regarding functionality, durability and safety over the service lives of infrastructure systems and facilities.” *(ASCE (2014): Adapting Infrastructure and Civil Engineering Practice to a Changing Climate)*

The challenge posed by climate change:

“The climate science community now faces a major new challenge of providing society with reliable regional climate predictions. Adapting to climate change while pursuing sustainable development will require accurate and reliable predictions of changes in regional weather systems, especially extremes . . . Yet, current climate models have serious limitations in simulating regional weather variations and therefore in generating the requisite information about regional changes with a level of confidence required by society.” *(Weaver et al. (2013) Improving the Contribution of Climate Model to Decision Making)*

Road Design in Viet Nam: Hazards from Extreme Rainfall and Sea Level Rise

ADB PPTA 8957-VIE*:

- On the basis of an ADB road transport project in Viet Nam, we have developed a technical guidance document to illustrate the development of reference climate change scenarios for extreme rainfall and sea level rise to inform the design of road transport projects.
- It builds upon existing design standards.

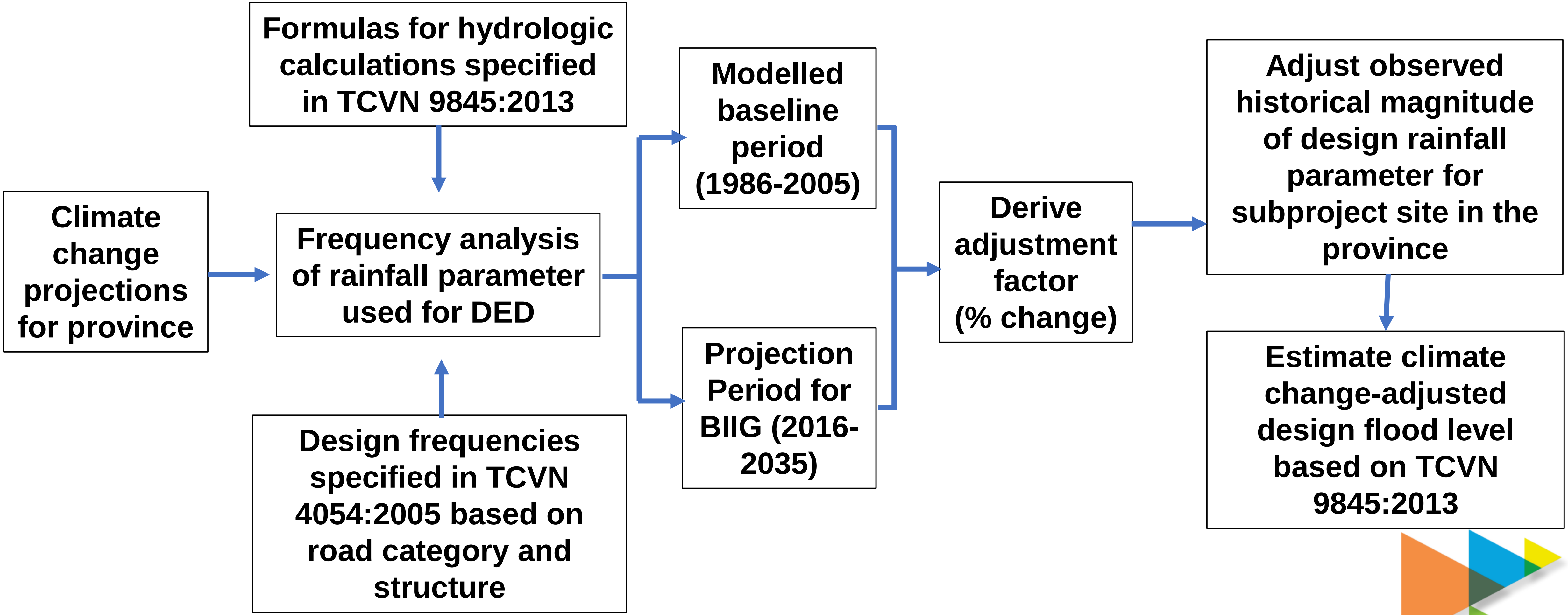
**Adjusting Hydrological Inputs to Road Design for Climate Change Risk Based on Extreme Value Analysis*

Case Study: Fluvial Flooding and Road Drainage

Climate Risks to Roads:

Bao Ninh to Hai Ninh coastal road, Quang Bing Province. The expected life-time of the culverts is 10 years and the standard of protection for a rural road in Viet Nam is for a 25-year flood (TCVN 4054:2005). The key design variable used for flood estimation is Rx1day.

Viet Nam Road Drainage Design Process with Adjustment for Climate Change



Climate change projections for province

Formulas for hydrologic calculations specified in TCVN 9845:2013

Frequency analysis of rainfall parameter used for DED

Design frequencies specified in TCVN 4054:2005 based on road category and structure

Modelled baseline period (1986-2005)

Projection Period for BIIG (2016-2035)

Derive adjustment factor (% change)

Adjust observed historical magnitude of design rainfall parameter for subproject site in the province

Estimate climate change-adjusted design flood level based on TCVN 9845:2013

Flow Chart for Calculation of Extreme Precipitation

Step	Activities	Illustration
R1	Specify project ***objectives***	Upgrade culverts beneath a coastal road with expected operating life of 10 years
R2	Check for ***contextual climate risks*** at the project concept stage and adjust the site selection and/or design accordingly	The most significant threat to the coastal road may not be from fluvial flooding but from storm surge and extreme waves
R3	Obtain the ***design value(s)*** from historic rainfall data	Use precipitation data for the nearest available station
R4	Download ***climate change scenarios*** for the design variable(s)	Refer to latest national climate change scenarios (if available) or most recent IPCC scenarios
R5	Calculate the ***design values*** for specified baseline and future periods	Fit an extreme value distribution to the Rx1day series for both baseline, projection periods
R6	Derive the ***change factor*** for the specified design variable(s) and return period(s)	The change factor is the percentage change in Rx1day between the baseline and future period
R7	Calculate the ***new design value*** for the future period at the specified return period and confidence level	Multiply the observed baseline value for Rx1day by the change factor for the 25-year event

National Design Rainfall Adjustment Factors for Various Time Periods, Event Recurrence Intervals

Look-up Table for Heavy Rainfall

National **adjustment factors** (%) for 1-day maximum rainfall amounts in Viet Nam based on CMIP5 RCP8.5. All changes are with respect to 1986-2005, based on the 95th percentile of the ensemble, rounded to the nearest 5%. Return period estimates assume the Gumbel distribution.

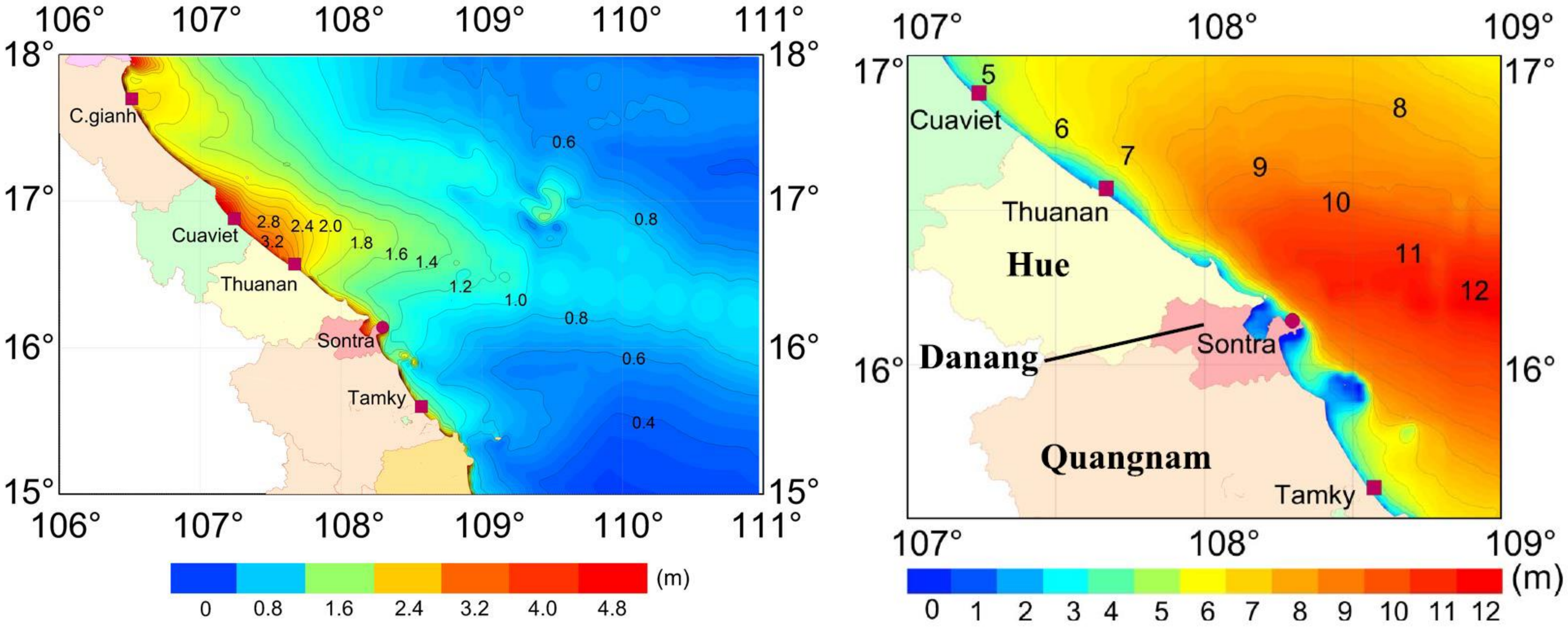
Future period	**Return period (years)**				
	2	5	10	20	25
2016-2035	15	20	25	25	25
2036-2055	35	25	30	30	35
2056-2075	50	45	45	45	45
2076-2095	80	75	75	70	70

Case Study: Mean Sea Level Rise and High-End Water Levels

Sea Level Rise and Related Factors:

Sections of the existing Bao Ninh to Hai Ninh coastal road, Quang Bing Province. When finished the road-top elevation would range between 4.1 to 9.9 m above mean seal level. Is this enough or should a more inland route be considered?

Other Climate Risks – Surge and Wave



Simulated maximum surge level (left) and significant wave height (right) on the coast from Quang Binh to Quan Gnam during Typhoon Xangsane. Source: Thuy et al. (2017)

Flow Chart for Calculation of Extreme Precipitation

Step	Activities	Illustration
S1	Specify project ***objectives***	Assess risk of coastal flooding and erosion up to 2100 to support land-use planning and asset management along a rapidly eroding section of the north Viet Nam coast
S2	Check for ***contextual climate risks***	Climate change may disrupt the operation of impoundments and/or alter downstream sediment sources/transport mechanisms
S3	Derive a ***LOWER bound*** mean sea level change estimate from the trend in historic tide records	Obtain the historic annual mean sea level series, fit a linear regression line to obtain the gradient term (mm/year), extrapolate to the end of the analysis period (e.g., 2100)
S4	Derive a ***CENTRAL estimate*** of SL including local factors but excluding component uncertainty	Refer to most recent global mean sea level change components issued by the IPCC (by RCP); adjust for gravity effects, local vertical land movements; add median estimates of local components (e.g. high tide, nearshore wave and surge heights)
S5	Derive a ***HIGH estimate*** of SL including local factors with component uncertainty	Follow the same procedure as in S4 but add half the combined component uncertainty estimated by quadrature
S6	Derive ***EXTREME estimate*** of SL including local factors with component uncertainty	Follow the same procedure as in S5 but use the most extreme values for all components with attendant uncertainty ranges

Provisional Table for Credible Maximum High Water Level Components (all units cm)

Example from Viet Nam

Upper SLR is from the uncertainty range of RCP8.5 from MoNRE (2016). *Surge* is the highest storm that might occur for Quang Binh – Thua Thien Hue from MonRE (2016). *Wave* is the maximum wave height observed at Da Nang during Typhoon Kaemi by Tran et al. (2004). *High Tide* is half the maximum amplitude given for Da Nang in MoNRE (2016). *Tidal Regime* adds 20% of *Mean SLR* (rounded up to next cm) to reflect modelled changes in long wave resonance for deeper water from Thuc and Son (2012).

Scenario	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Upper SLR	18	26	35	46	57	71	86	102
Surge	420	420	420	420	420	420	420	420
Wave	800	800	800	800	800	800	800	800
High Tide	90	90	90	90	90	90	90	90
Tidal Regime	4	5	7	9	11	14	17	20
Total	**1332**	**1341**	**1352**	**1365**	**1378**	**1395**	**1413**	**1432**

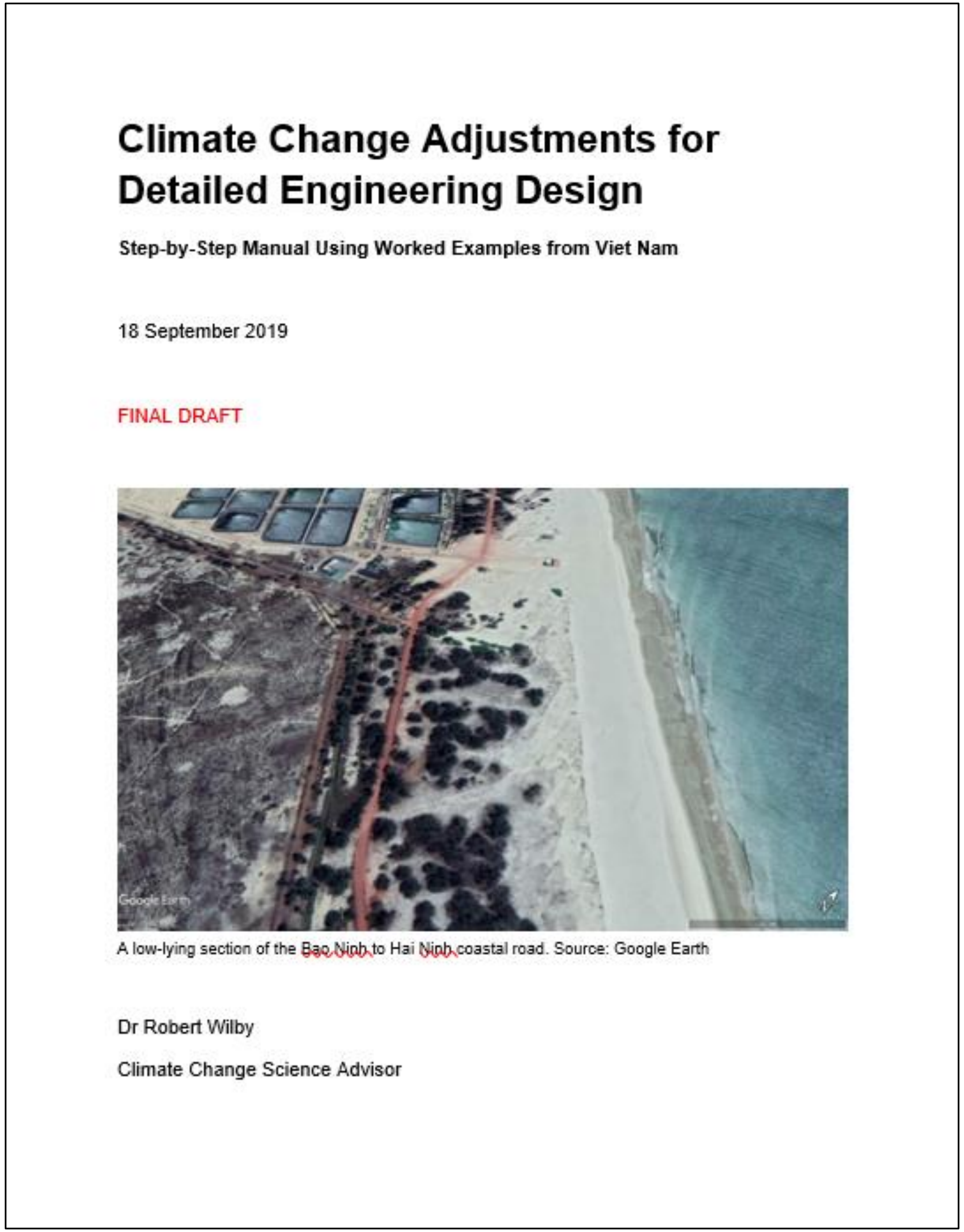
Key Messages

- Extreme weather *already* present significant threats to coastal infrastructure even without climate change
- An approach is proposed based on look-up tables
- The approach rests on transparency of data, methods
- The approach embodies precautionary principles
- The approach is transferrable to other sectors and regions
- The approach is cost-effective (reduce *ad-hoc* CRA)
- Supporting frameworks require periodic review and update of look-up tables
- All stages of the asset life-cycle should be considered – the most significant climate vulnerability may not be at the design stage.

Guidance in Designing for Climate Change

The guidance documents referred to in this presentation are under preparation and are scheduled for publication in Q4 2019. The research was conducted initially by Charles David Salter under PPTA 8957-VIE, and methodology and coverage extended by Prof. Rob Wilby.

Please see the ADB Adaptation Team in SDCD if you would like more information



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FINAL DRAFT

A low-lying section of the Bao Ninh to Hai Ninh coastal road. Source: Google Earth

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