COLLABORATIVE RISK INFORMED DECISION ANALYSIS (CRIDA):

AN APPROACH FOR PLANNING AND ADAPTATION INTERVENTIONS FOR WATER MANAGEMENT

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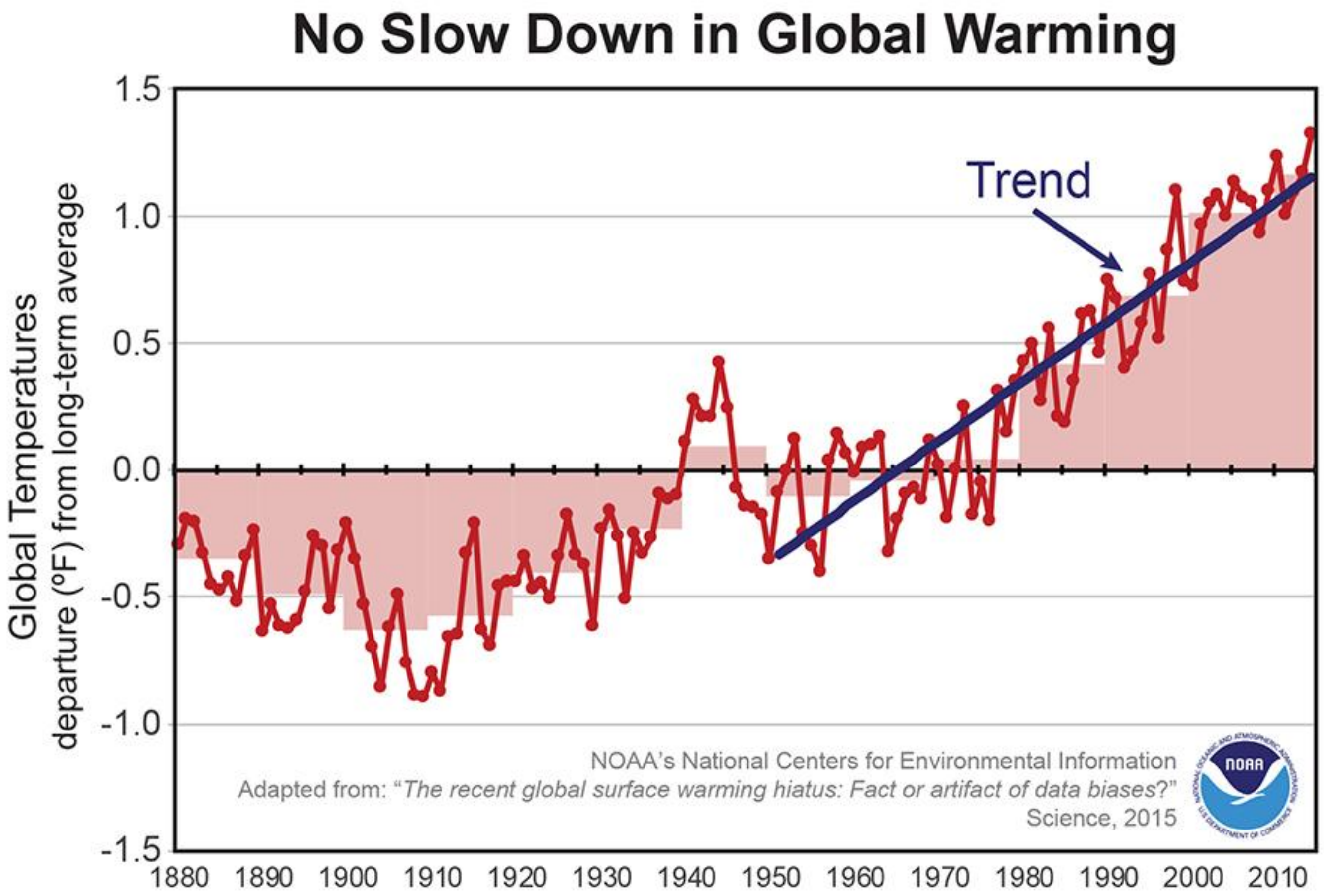
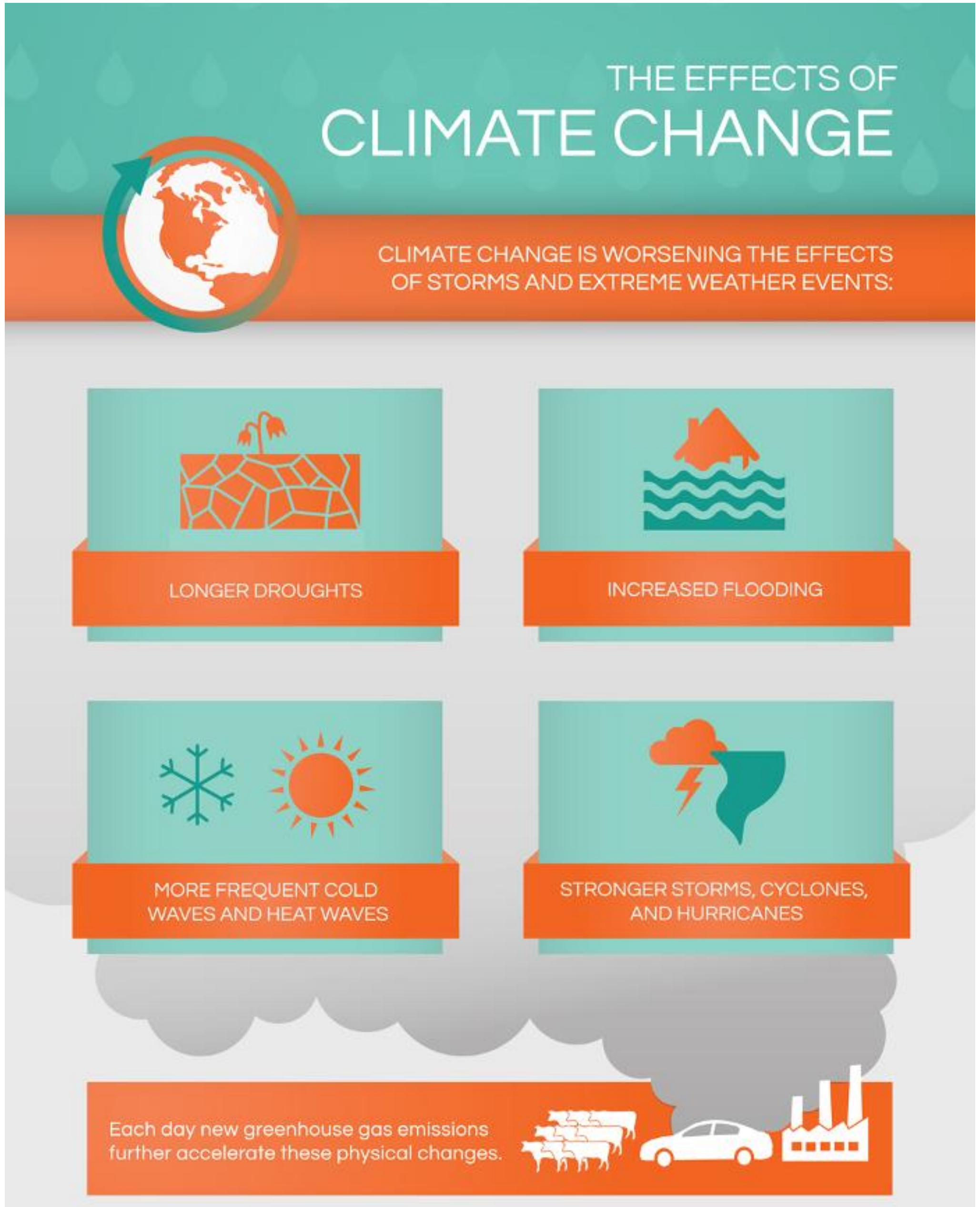
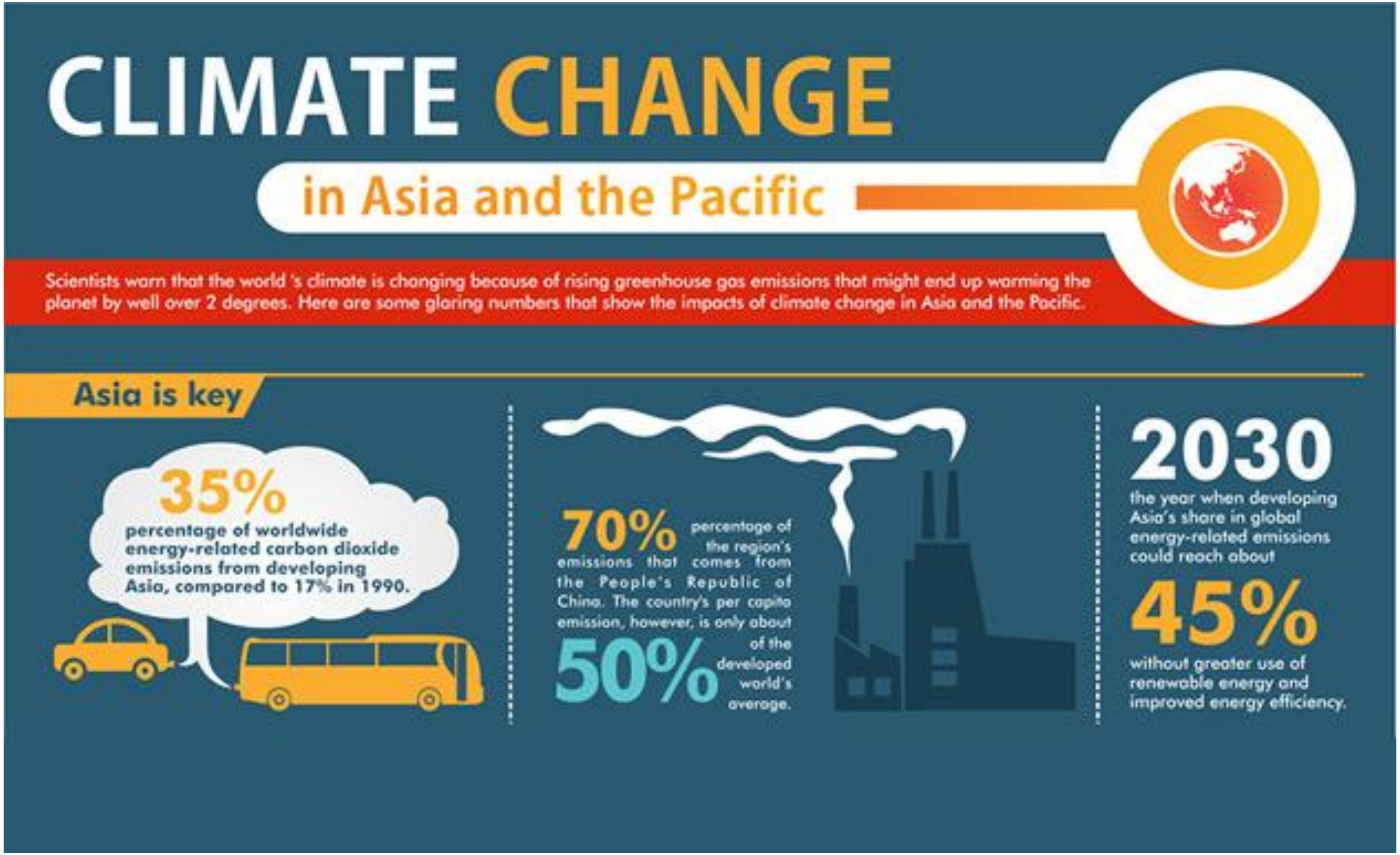
Climate change is real



Contrary to much recent discussion, the latest corrected analysis shows that the rate of global warming has continued, and there has been no slow down.



Climate change is real



Asian Development Bank (2012)

India is at the forefront in the battle against climate change

FIRSTPOST.
Sunday, April 09, 2017 Latest E-book | Switch to हिन्दी

India is grossly unprepared for impending climate change and worsening monsoons

Rashme Sehgal Jan, 25 2017 15:42:46 IST

#Connectthedots #Goverdhan rathore #Imd #Kj ramesh #Mitigation of global warming #Sivananda pai

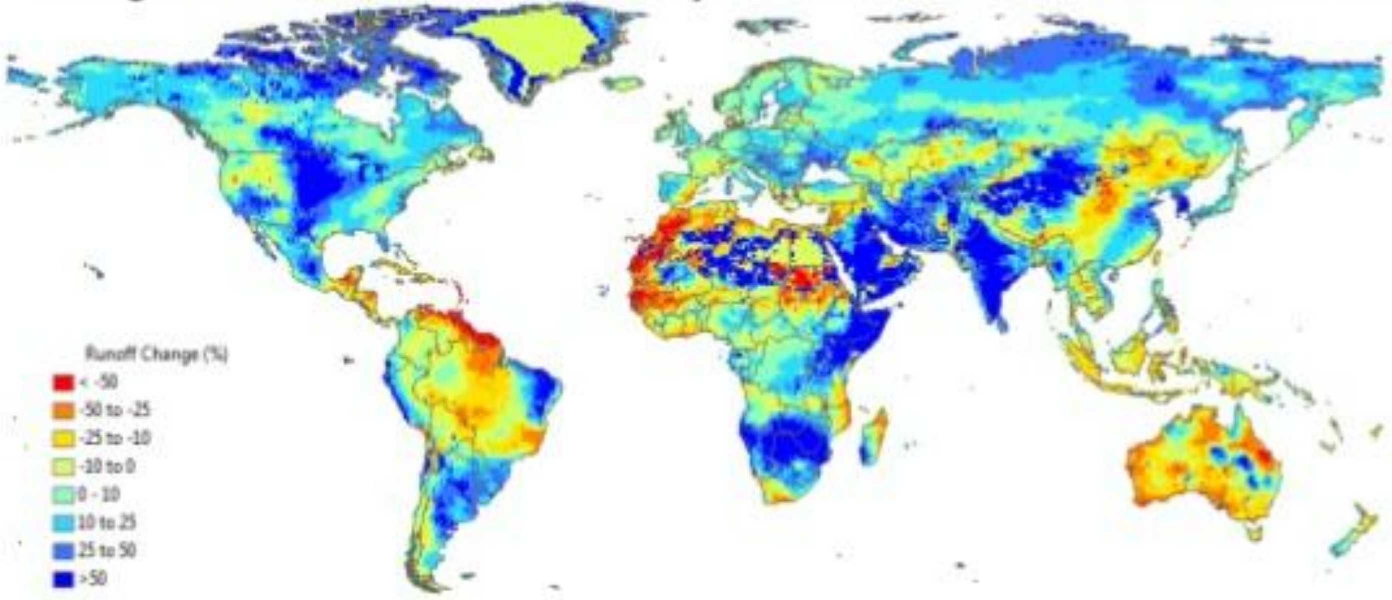
For the first time in its history, the Indian Meteorological Department (IMD) had given a winter forecast for 2016-17 warning that winter temperatures would be higher than usual.

Water is central to climate change response agenda

RESEARCH PROGRAM ON
Water, Land and Ecosystems
CGIAR

The impact of climate change on water resources

Change of Mean Annual Runoff by 2050 – HadGEM2-RCP6.0 Scenario



For every 1 degree of warming, another 7% of the pop experiences a 20% decline in water availability; today already 30-40% exposed to water shortages; also population exposed to 100-year flood triples from low to high emissions scenarios

Notes: 2040-2070 future period relative to the 1951-2000 historical period.

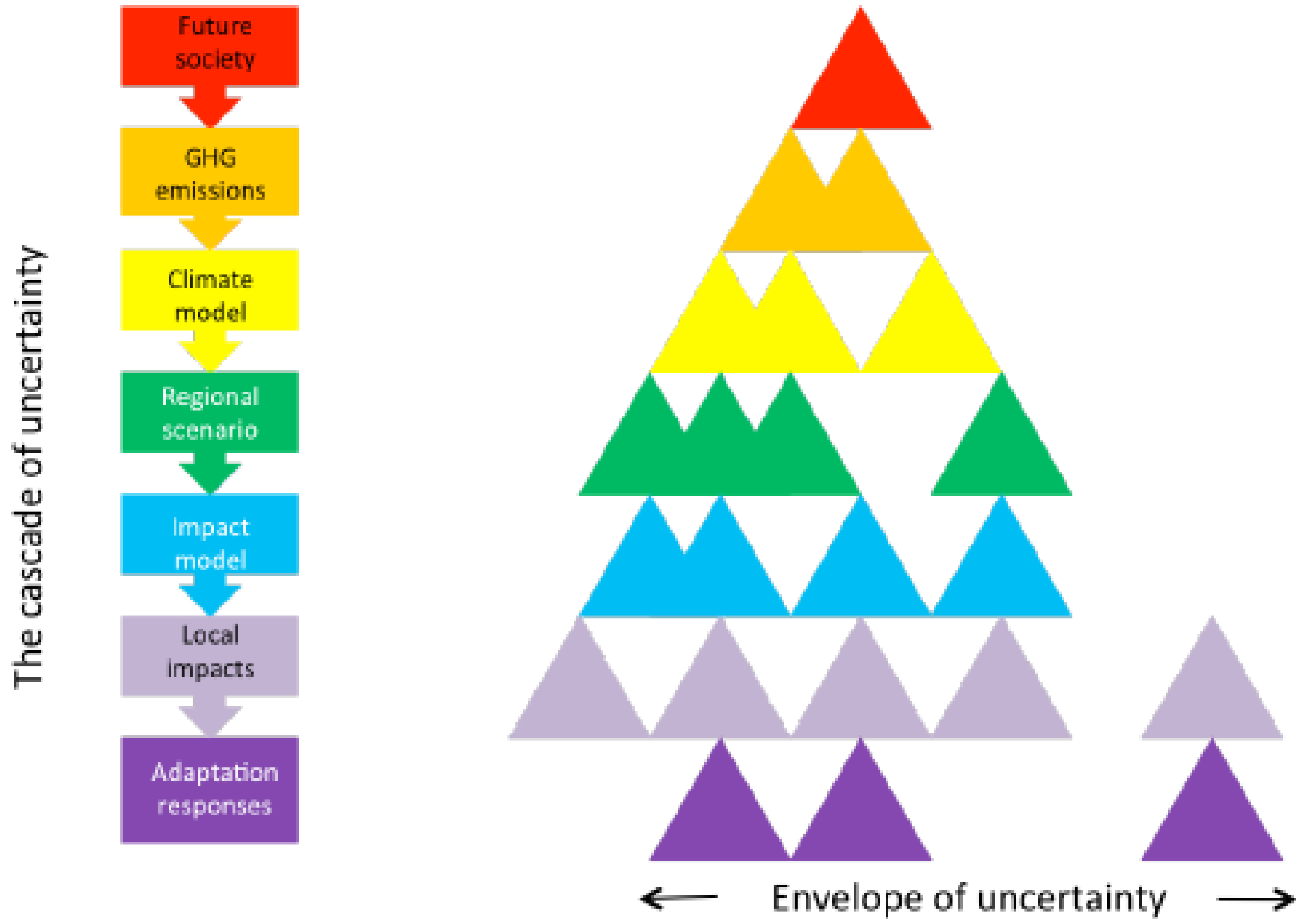
Source: IFPRI, IMPACT version 3.2, 8 September 2015

CGIAR(2015)

Adapting to climate change requires an estimate of future climate conditions

- A number of climate models have been developed to help forecast the future climate
- Unfortunately, projections regarding climate extremes remain highly uncertain, vary by region, and may be overshadowed by natural variability, at least in the short term
- Climate change poses significant challenges for investments in the water sector, particularly due to the long lifespan and large upfront costs associated with many water projects
- At the same time, adaptation to climate change must continue to build on conventional interventions while also addressing immediate challenges and needs, such as disaster management, ecological restoration, and poverty alleviation

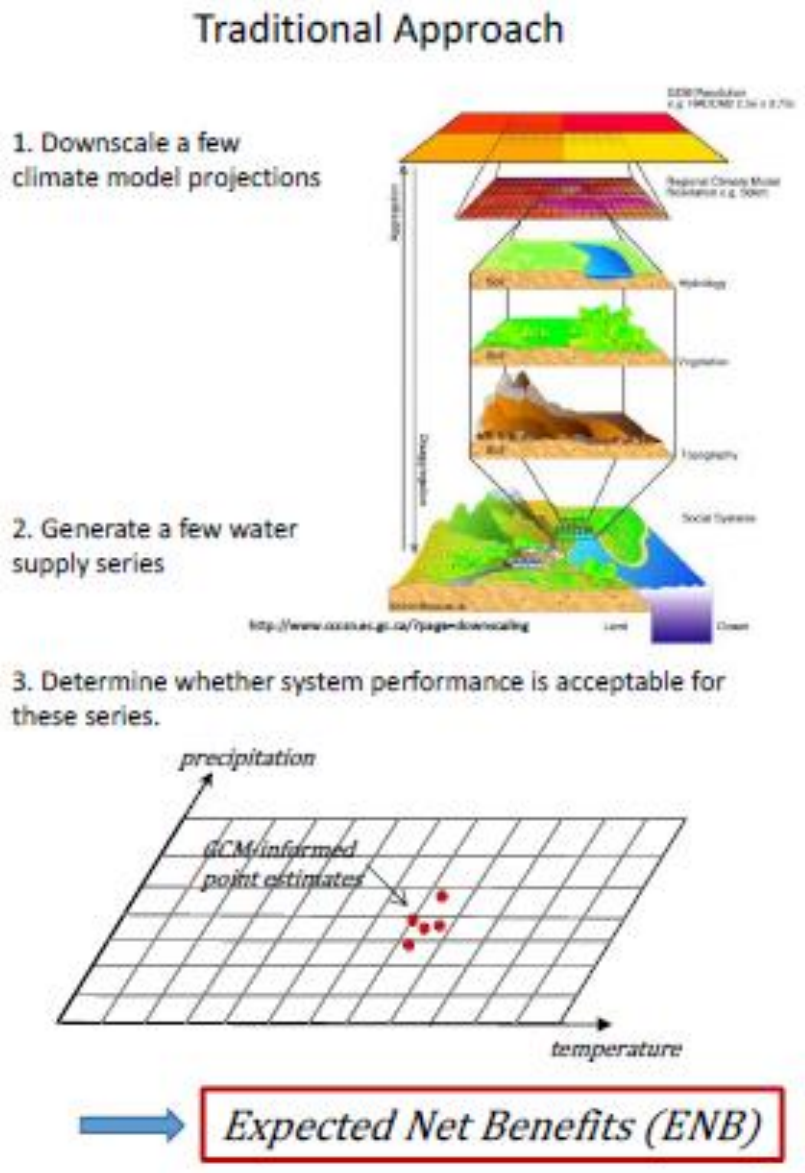
Global climate models have inherent uncertainty



Cascade of uncertainty of climate change

Wilby and Dessai (2010)

Traditional approaches for climate change adaptation in the water sector



Issues with traditional (top down) approaches

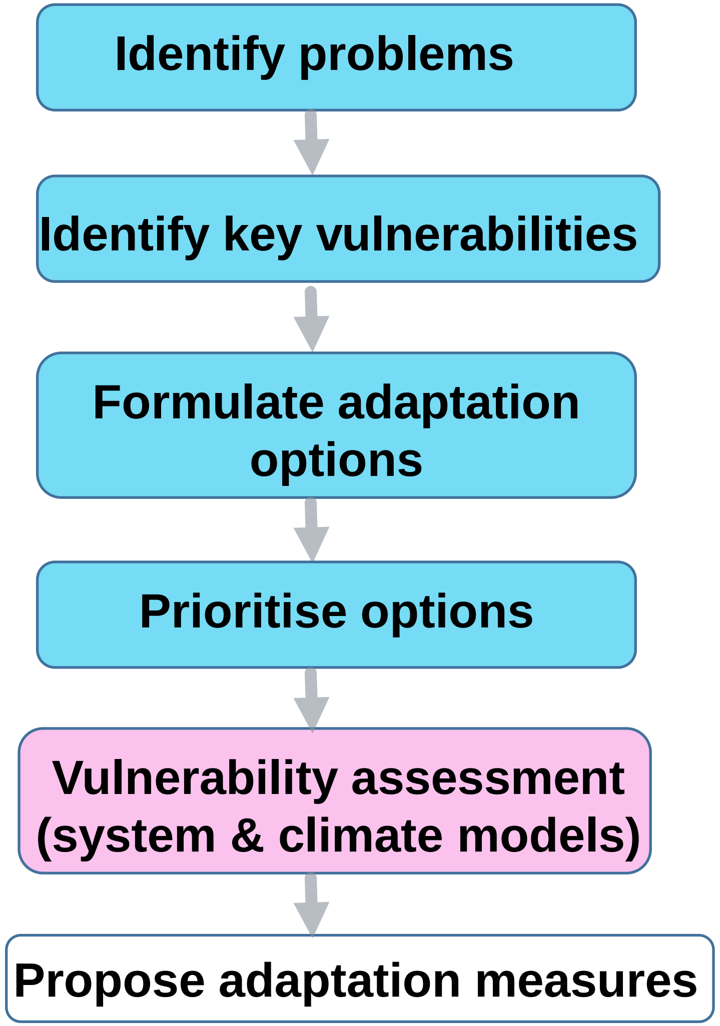
- When disasters occur, the impacts are felt at the local level → national → global scale
- The intensities and severity of impacts vary between places, locals possess better knowledge about historical conditions and methods to interact with environment Cutter et al. (2012)

To address risks involved in projections → uncertainty quantification

- Statistical approaches to estimate and propagate the uncertainty associated with various stages of future climate projection (Steinschneider et al., 2012)
- Residual risks (Brown et al., 2012)

Bottom-up approaches

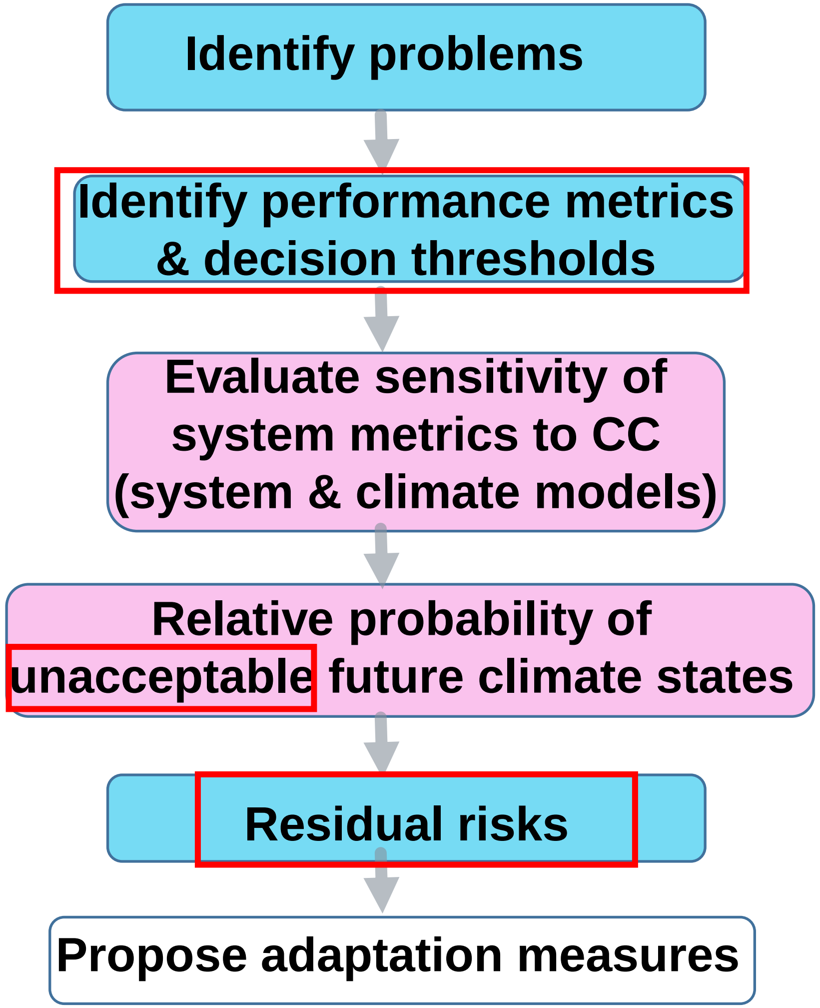
Combined bottom-up & top-down approach



Bhave et al. (2013); Wilby and Dessai (2010)

Bottom-up approaches

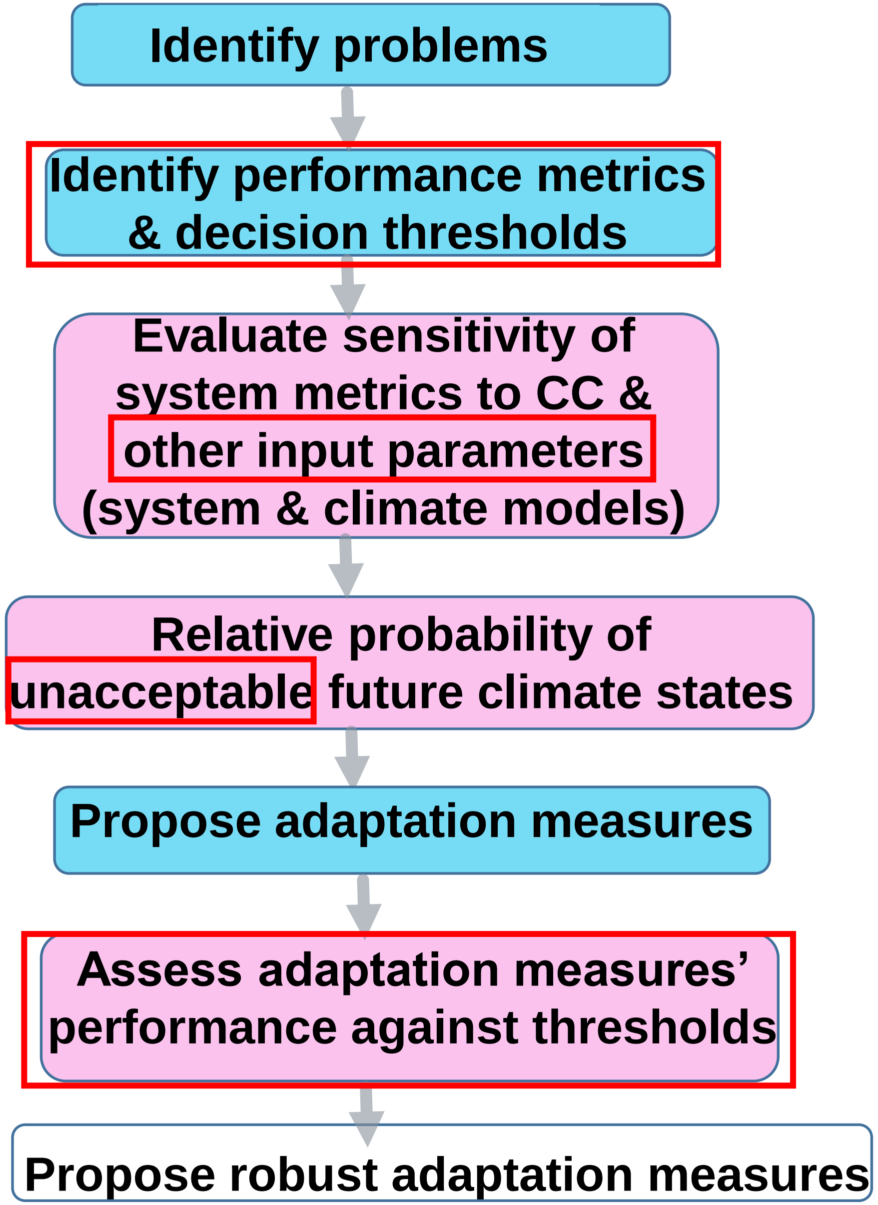
Decision scaling



Brown et al. (2012)

Bottom-up approaches

Eco-engineering decision scaling (EEDS)



Poff et al. (2016)

Collaborative Risk Informed Decision Analysis (CRIDA)*

CRIDA

- **Decision scaling** → Act of diagnosing and assessing the risk
- **Adaptation pathways** → Development of decision steps to compensate for uncertainty within the regulatory/ performance standards

WHAT? Adaptive planning, "decision-centric" approach

WHY? Uncertainty in investments and future planning

WHO? Decision makers, water managers, all stakeholders…

HOW? A series of steps for assessing, planning & decision making

WHERE? Any water resources project

WHEN? Any point during or before lifetime of WR project

* Developed by

AGWA Alliance for Global Water Adaptation alliance4water.org

WORLD BANK GROUP Water

WATER PARTNERSHIP PROGRAM

CONSERVATION INTERNATIONAL

US Army Corps of Engineers

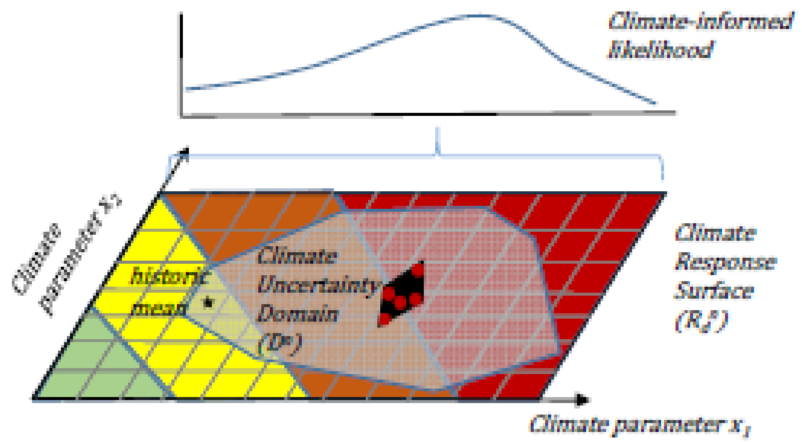
UMASS AMHERST

CRIDA Approach

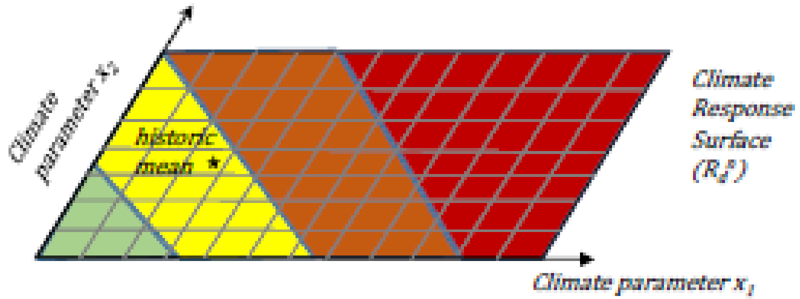
Decision Scaling

$$Risk\ to\ ENB = \sum_{s=1}^{\Omega} Impact \times Probability$$

3. Determine climate risks to project performance



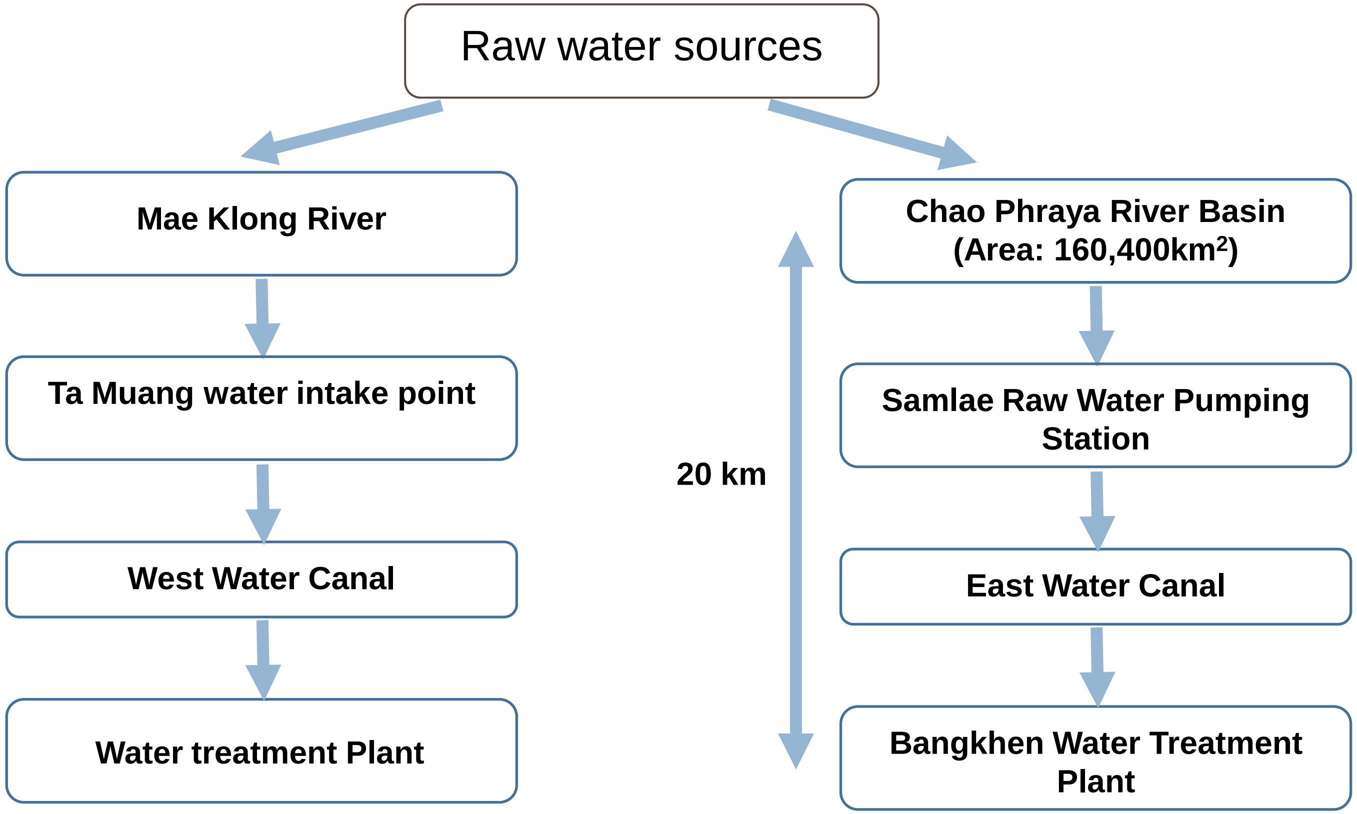
2. Map climate domain onto vulnerability domain



1. Determine the vulnerability domain

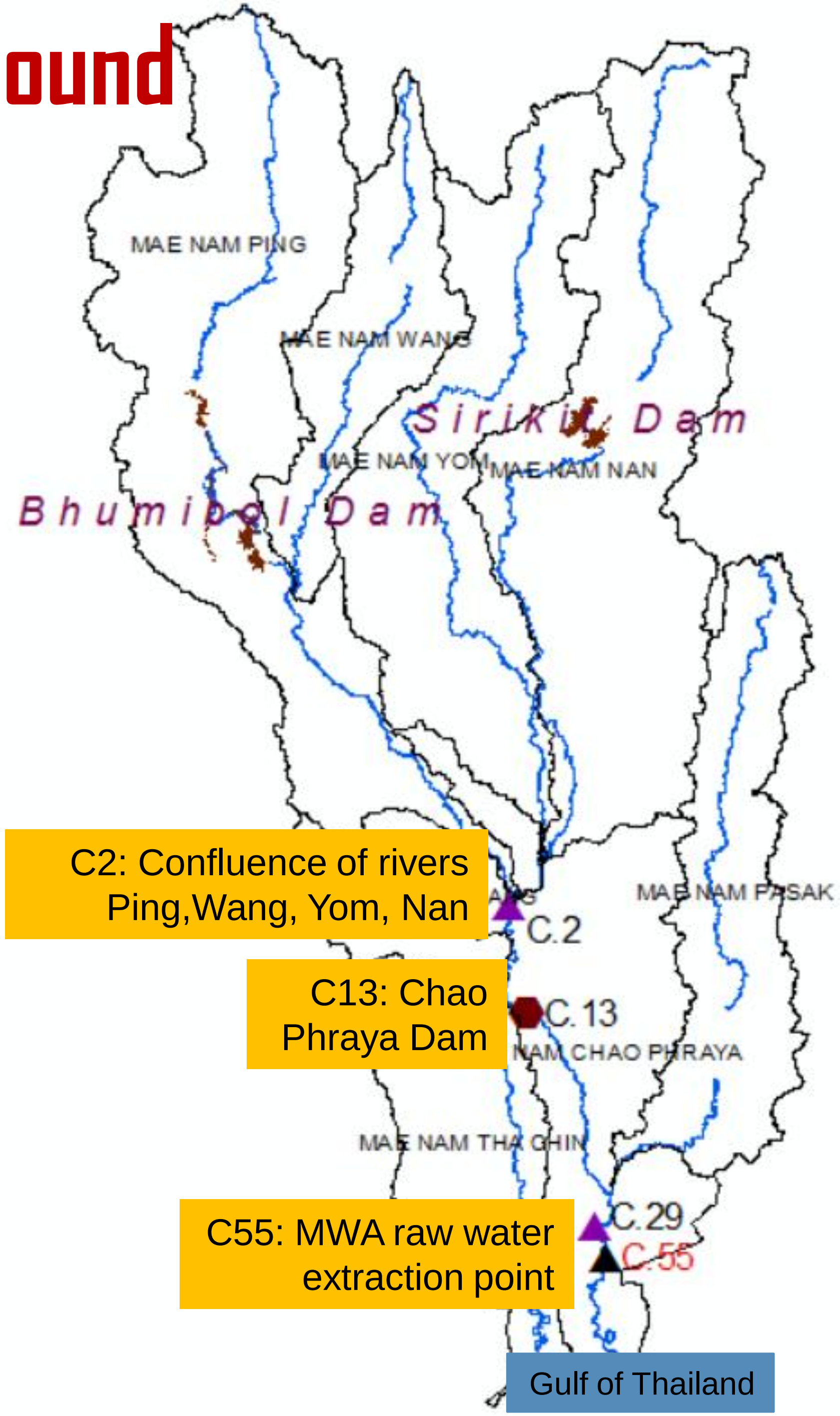
Applying CRIDA for water utility management in Bangkok

- Metropolitan Waterworks Authority (**MWA**)
- **Location:** About 10 km north of Bangkok Metropolis
- **First operation:** Year 1979
- **Service locations:** Most parts of Bangkok, Nonthaburi and Samut Prakan Provinces
- **Maximum capacity:** Approx. 4,000,000m^3/day

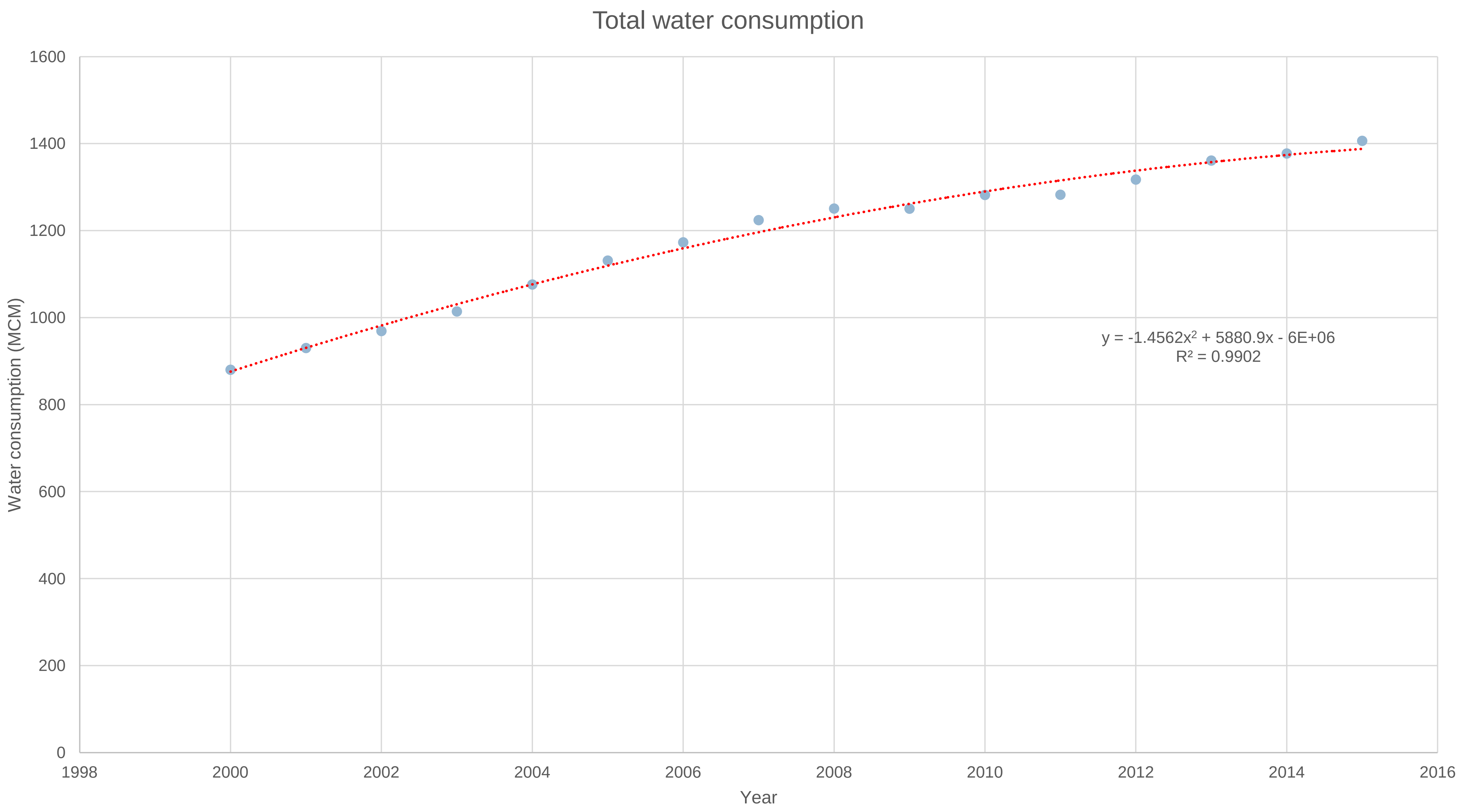


Study area background

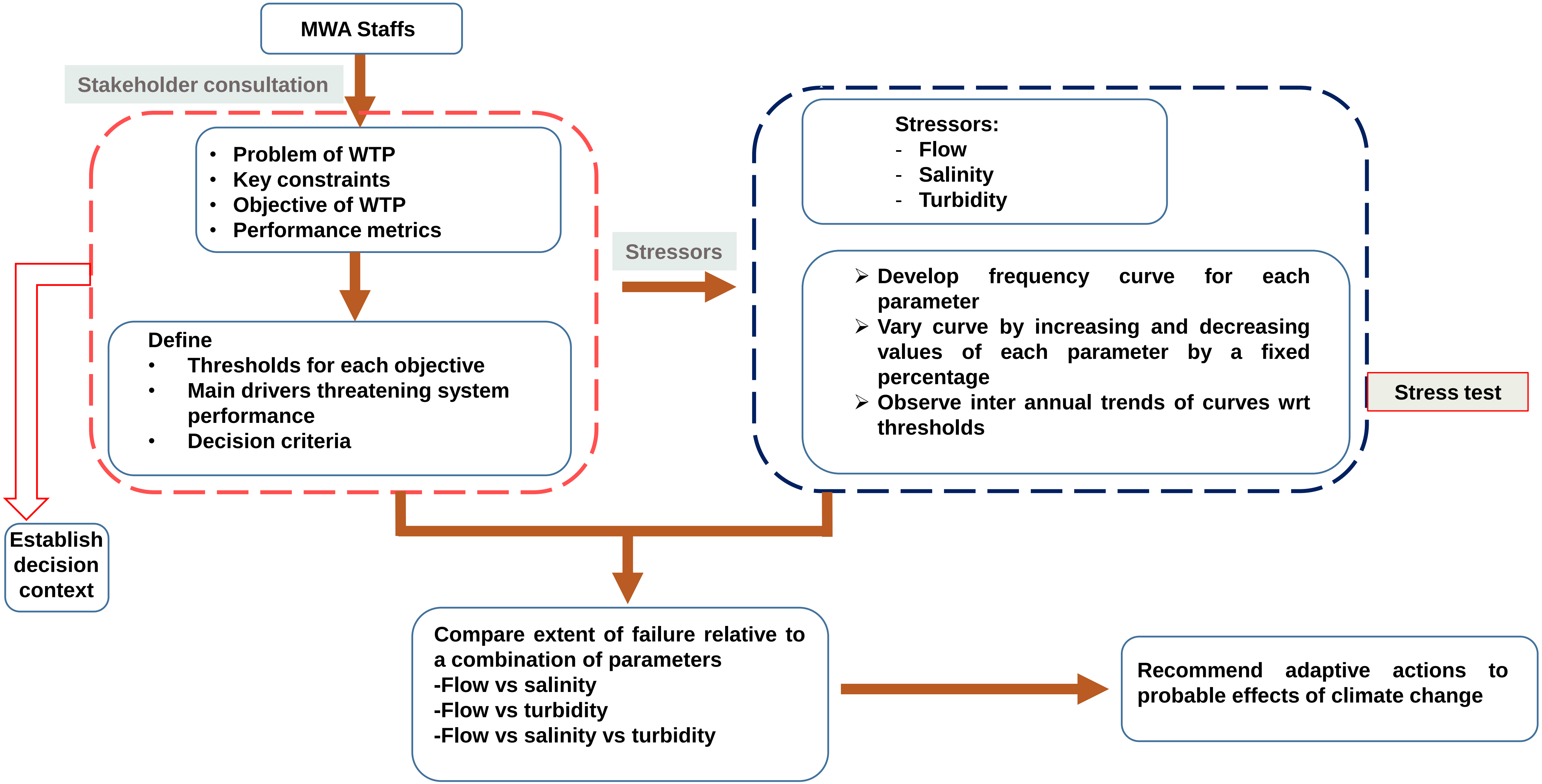
- Chao Phraya river basin
- Two main dams
  - Bhumibol dam on Ping River (Capacity: 13.5 billion m^3)
  - Sirikit dam on Nan River (Capacity: 9.5 billion m^3)
- During dry seasons, flows governed by upstream water release from dams more than rainfall
- C2: Confluence of four rivers
- C55: Location of water extraction by MWA (96.51km from Gulf of Thailand)
- C29: Location of threshold defined by MWA (approx. 30km upstream of C55)



Water demand trend for Bangkok



Study methodology



Study methodology: Establishing the decision context

Problem definition:

- In Bangkok (one of the service areas of Bangkhen WTP), there are many consumers of water. Intensive consumers come from the industry, whose demand cannot be easily altered. All user demand must be fulfilled, including industrial and domestic.
- There is problem of <u>salt water intrusion</u> from downstream (Gulf of Thailand) during periods of <u>low flow</u>.
- During periods of high flows, <u>water quality</u> may be affected due to <u>high turbidity</u>.
- During periods of low flows, if there is sufficient nutrients in water, there is a potential of <u>algae bloom</u> due to <u>low turbidity</u> hence higher sunshine penetration.

Study methodology: Establishing the decision context

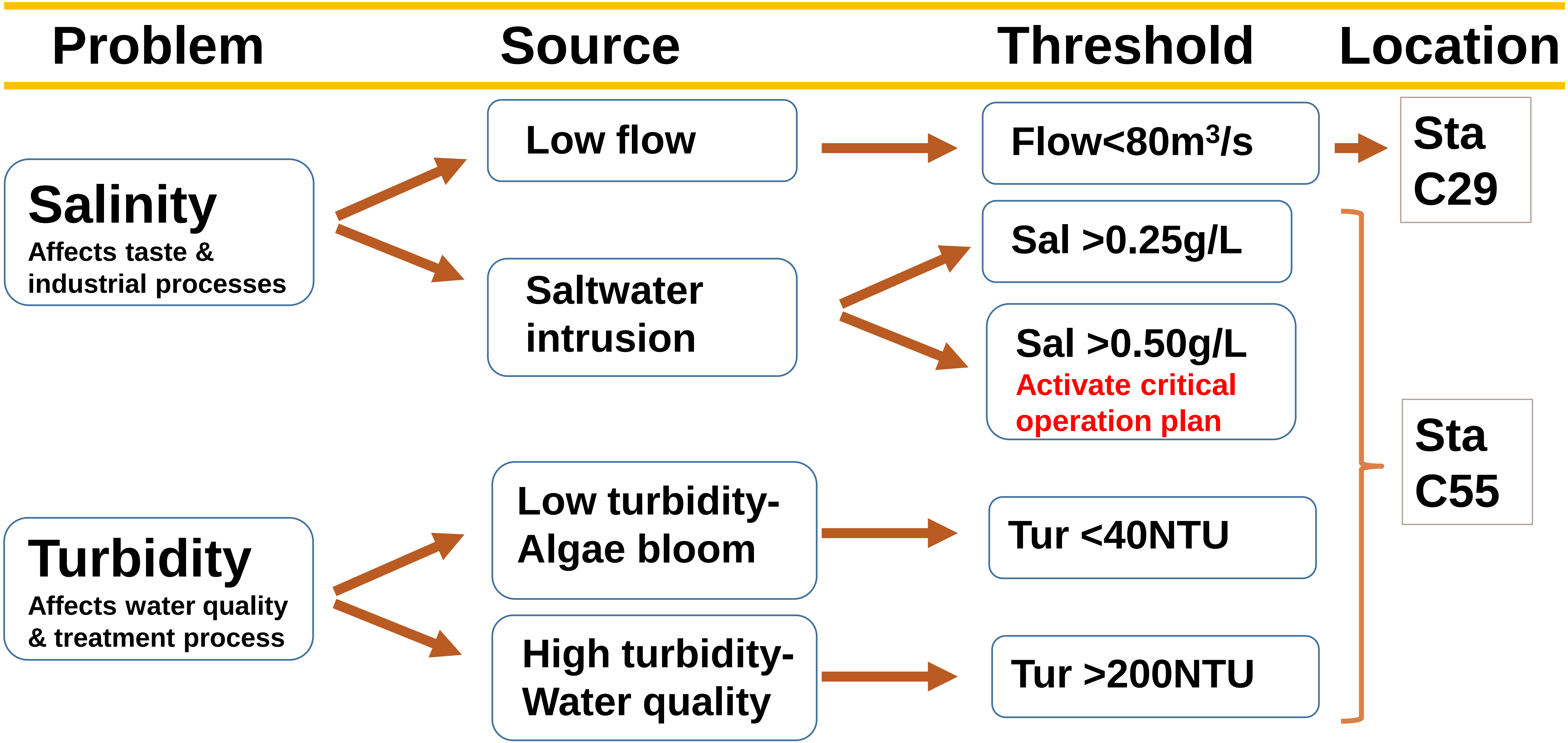
Objective:

- To fulfil water demand of service areas, including Bangkok, Nonthaburi and Samutprakan.
- To limit salinity levels of raw water at point of water extraction.
- To reduce turbidity in water and minimise the problems of algae bloom.

Performance metrics [Indicator of system performance]:

- Flow at Bangsai station
- Salinity at Samlae pumping station
- Turbidity at Samlae pumping station

Study methodology: Establishing the decision context



Study methodology: Establishing the decision context

Consequences of system failure:

- Bangkhen WTP is a conventional treatment system –not able to treat salinity
- RID releases water for dilution
- Salinity affects taste and industrial processes
- High turbidity affects water treatment process
- Low turbidity one of many factors that causes algal bloom
  - Amount of nutrient pollution in the water, mainly nitrogen and phosphorus levels caused by activities such as agricultural practices
  - Warming water temperature
  - Stable water conditions caused by low flows, resulting in low turbidity levels and higher sunshine penetration into the water
  - Higher carbon dioxide levels in the water and atmosphere
  - Rainfall changes causing an increase in nutrient runoff into water bodies

Applying CRIDA for water utility management in Bangkok

Bhumibol & Sirikit Dam

Chao Phraya Dam

Station C29: upstream of MWA water extraction point (Defined threshold: $80 m^3/s$ flow)

Station C55: MWA water extraction point (Approx. $40 m^3/s$ extracted)

Defined threshold:
Salinity>0.25g/L;
Salinity>0.50g/L;
Turbidity<40NTU;
Turbidity>200NTU

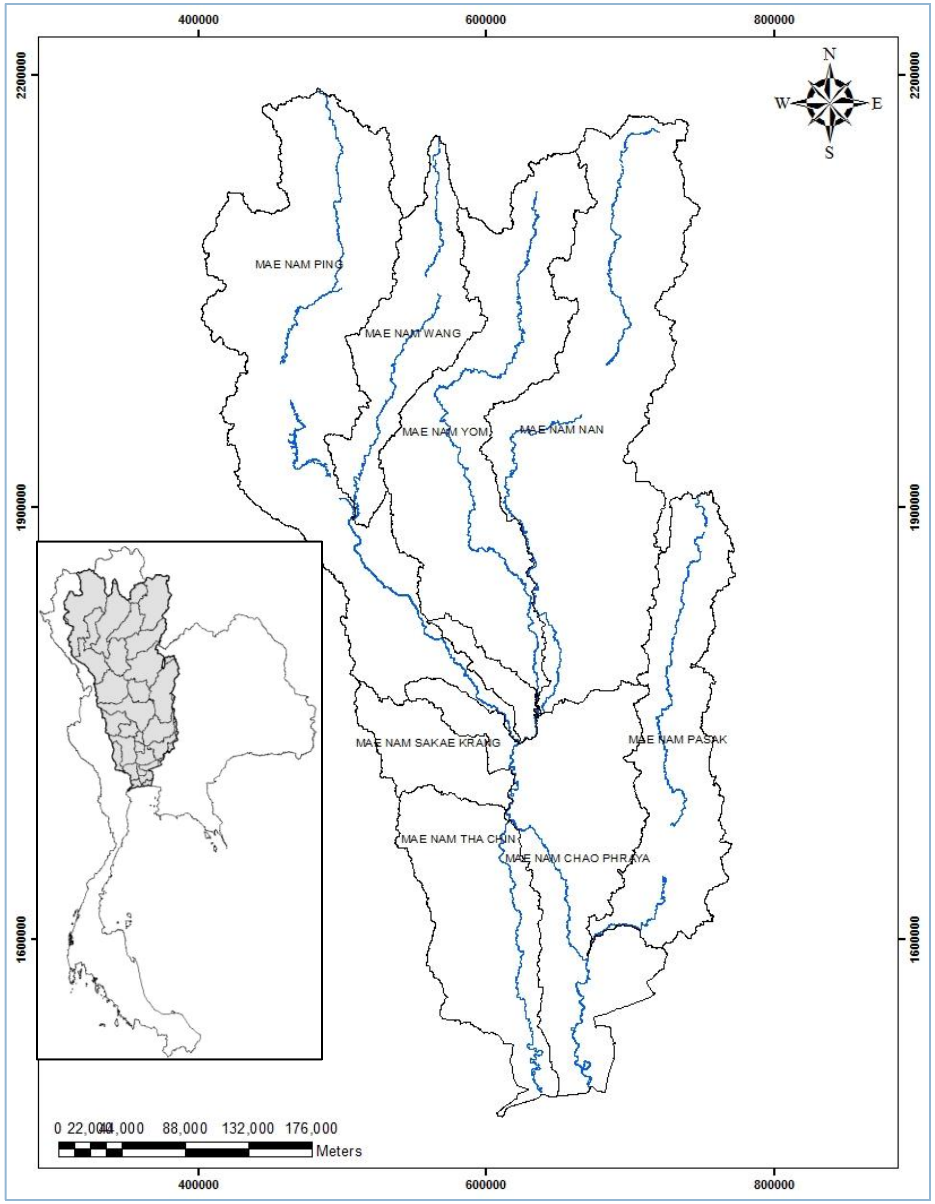
30km

97km

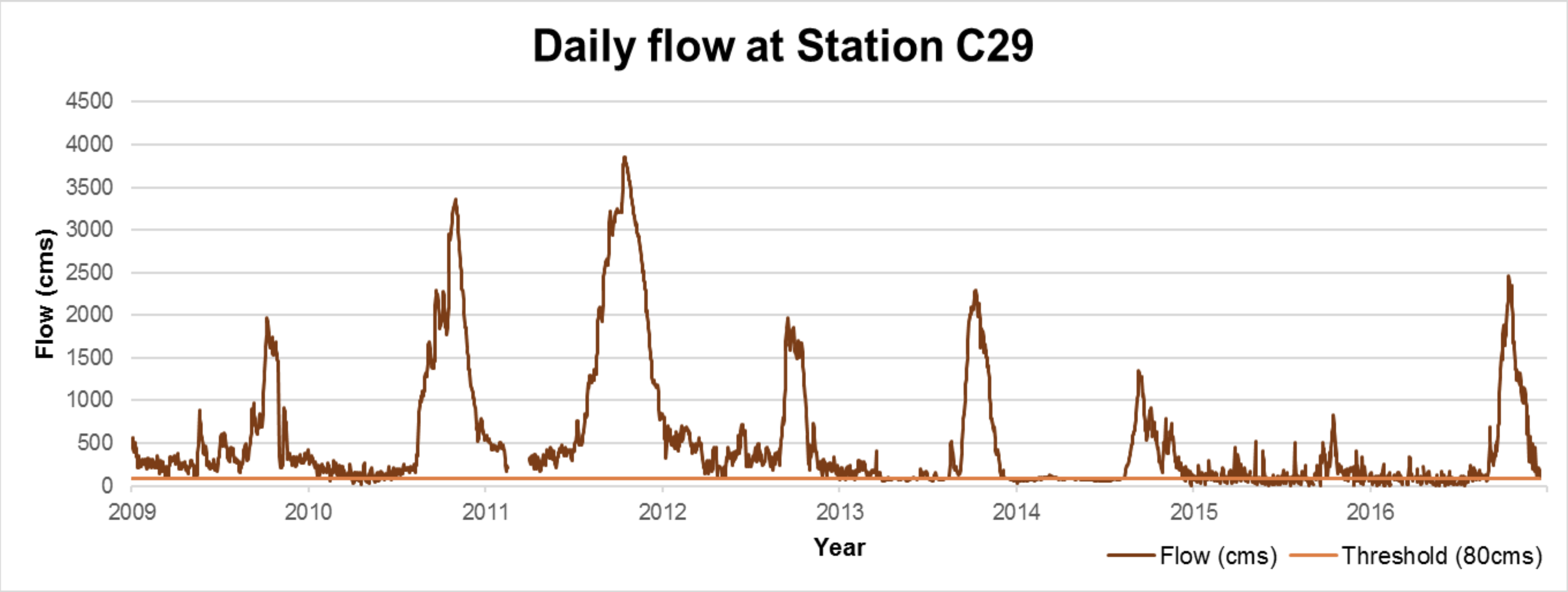
Gulf of Thailand

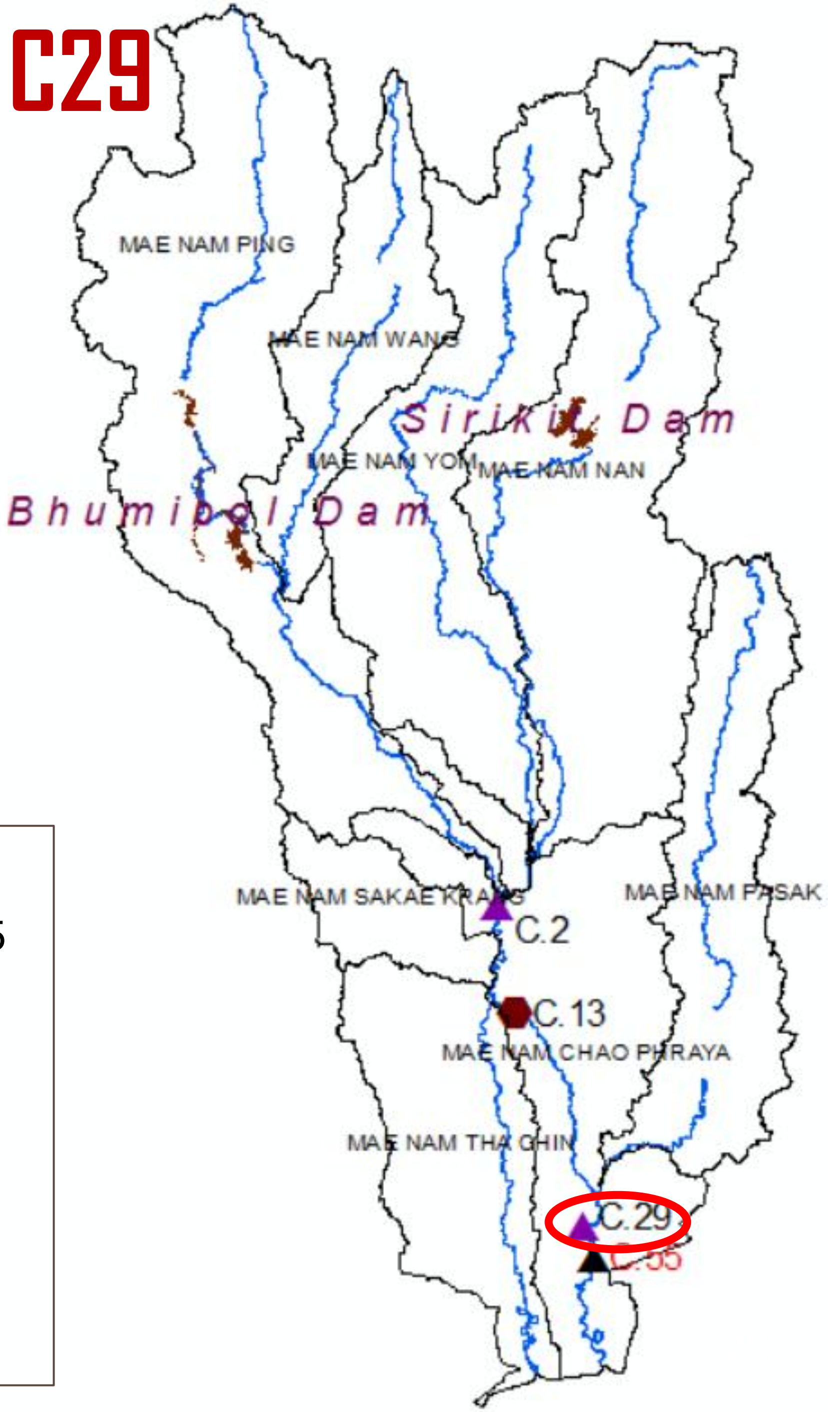
Usage for:
- Ping river
- Nan river
- Irrigation projects

Usage for:
- Irrigation projects
- Water utilities
- Salinity control
- Navigation



Streamflow analysis at station C29





Critical threshold:

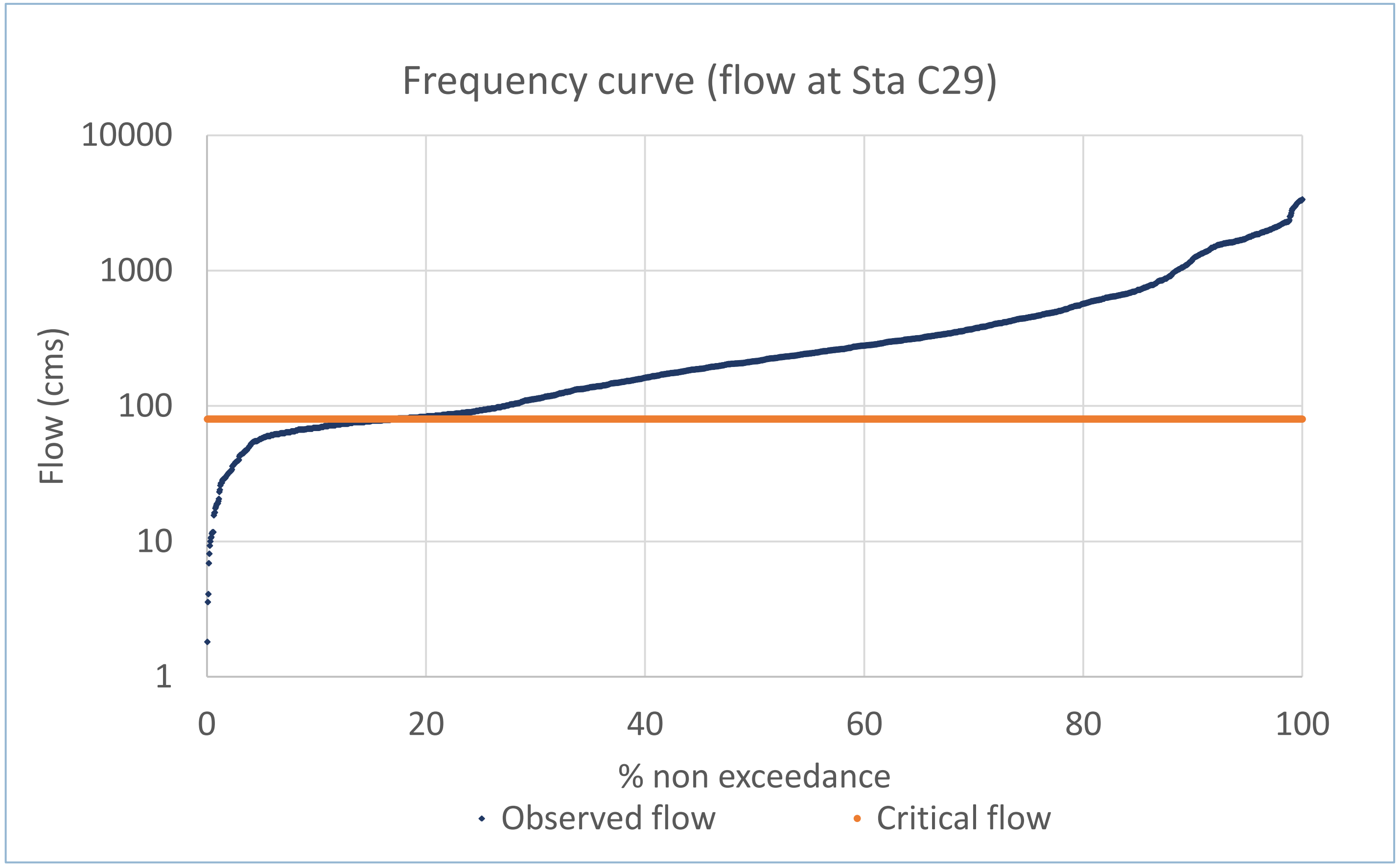
- **1. Upstream flow at Bangsai station (C29):**
- - Normal flow: 80-100cms
- **- Saltwater intrusion:**

  flow <80cms

Flow records at station C29:

- Years 2009, 2010, 2012, 2013, 2014, 2015
- 2191 data sets
- Data in years 2011 and 2016 not considered- missing & incomplete
- Flow range:
  - Min flow: 2 cms
  - Max flow: 3355cms

Streamflow frequency analysis at station C29

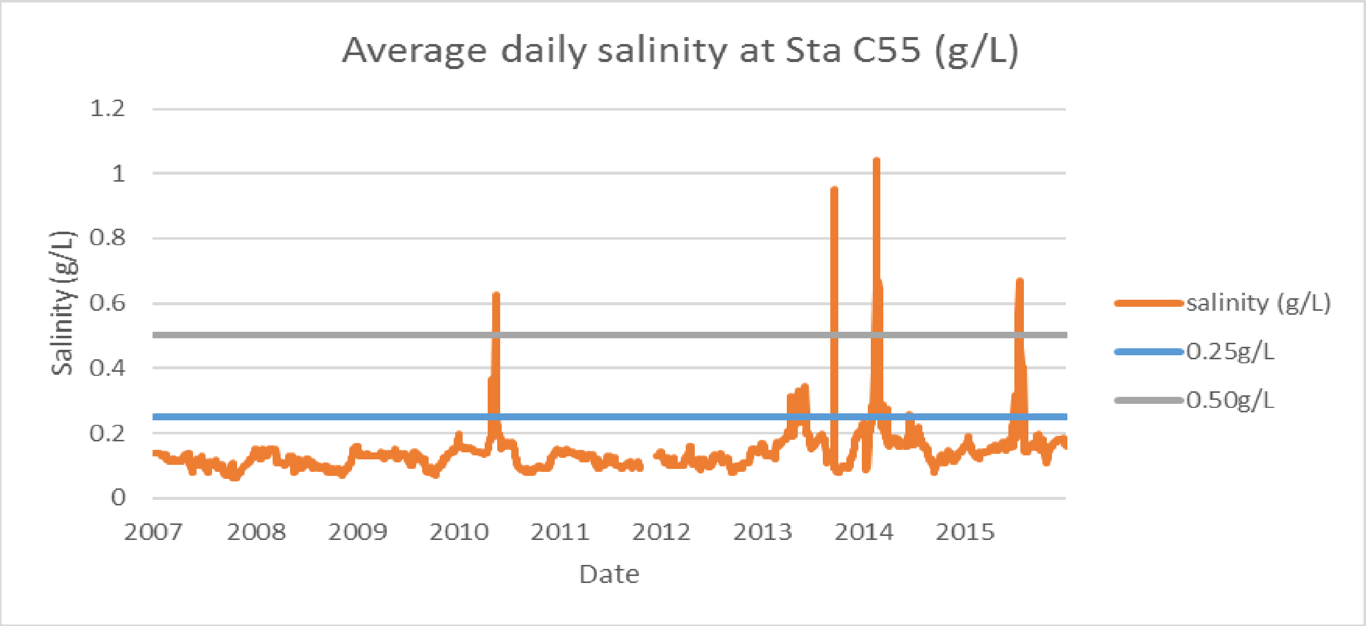


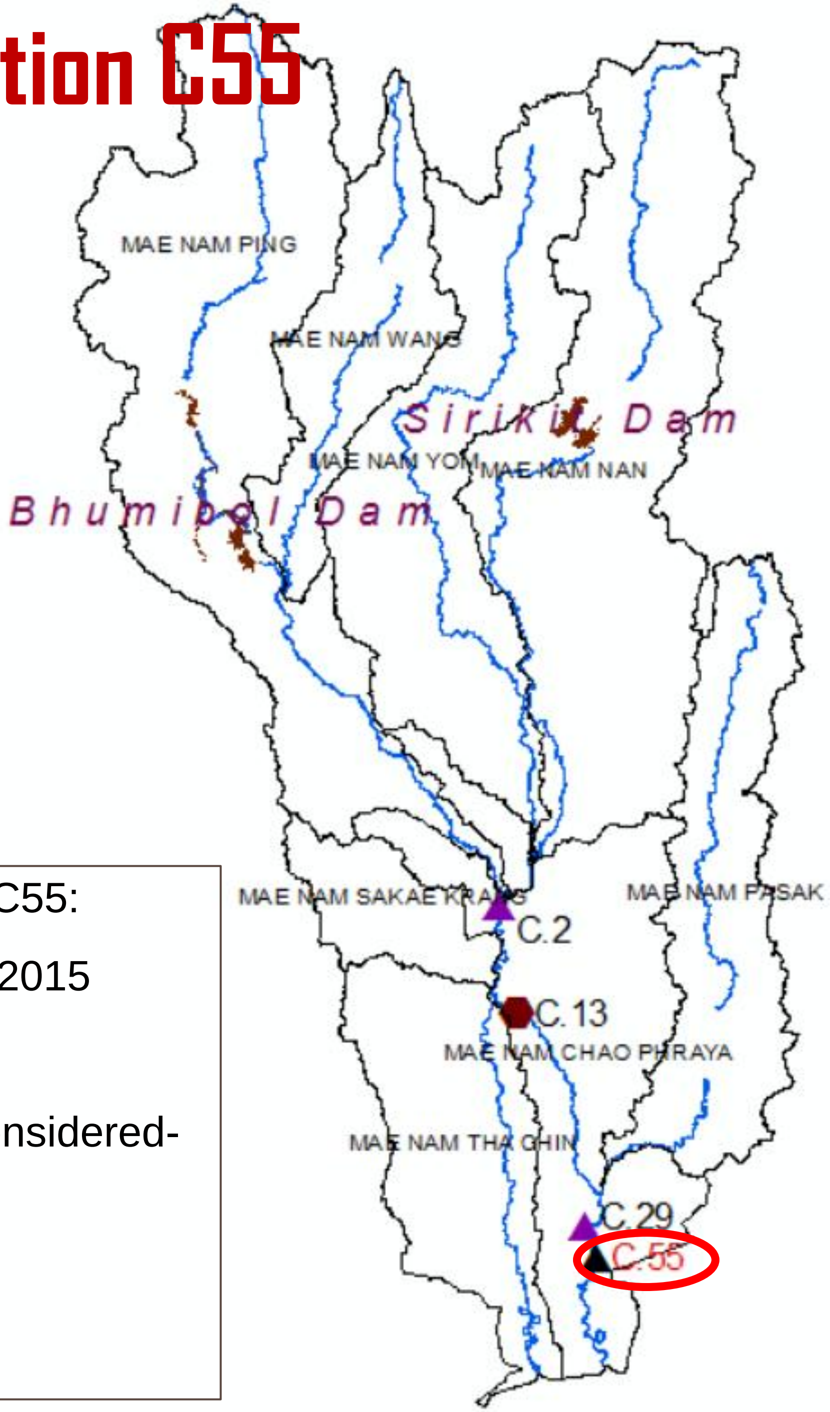
System failure states	No. of days failure
Flow<80cms	16.7% = 61 days

Streamflow frequency analysis at station C29

Flow (m^3/s)	<20	<30	<40	<50	<60	<70	<80	<90
2009	0	0	0	0	0	0	0	1
2010	1	3	6	9	14	18	24	26
2012	0	0	0	0	0	1	1	1
2013	0	0	0	0	8	21	74	136
2014	1	2	3	4	12	72	133	193
2015	19	28	48	79	99	121	135	157

Salinity analysis at station C55





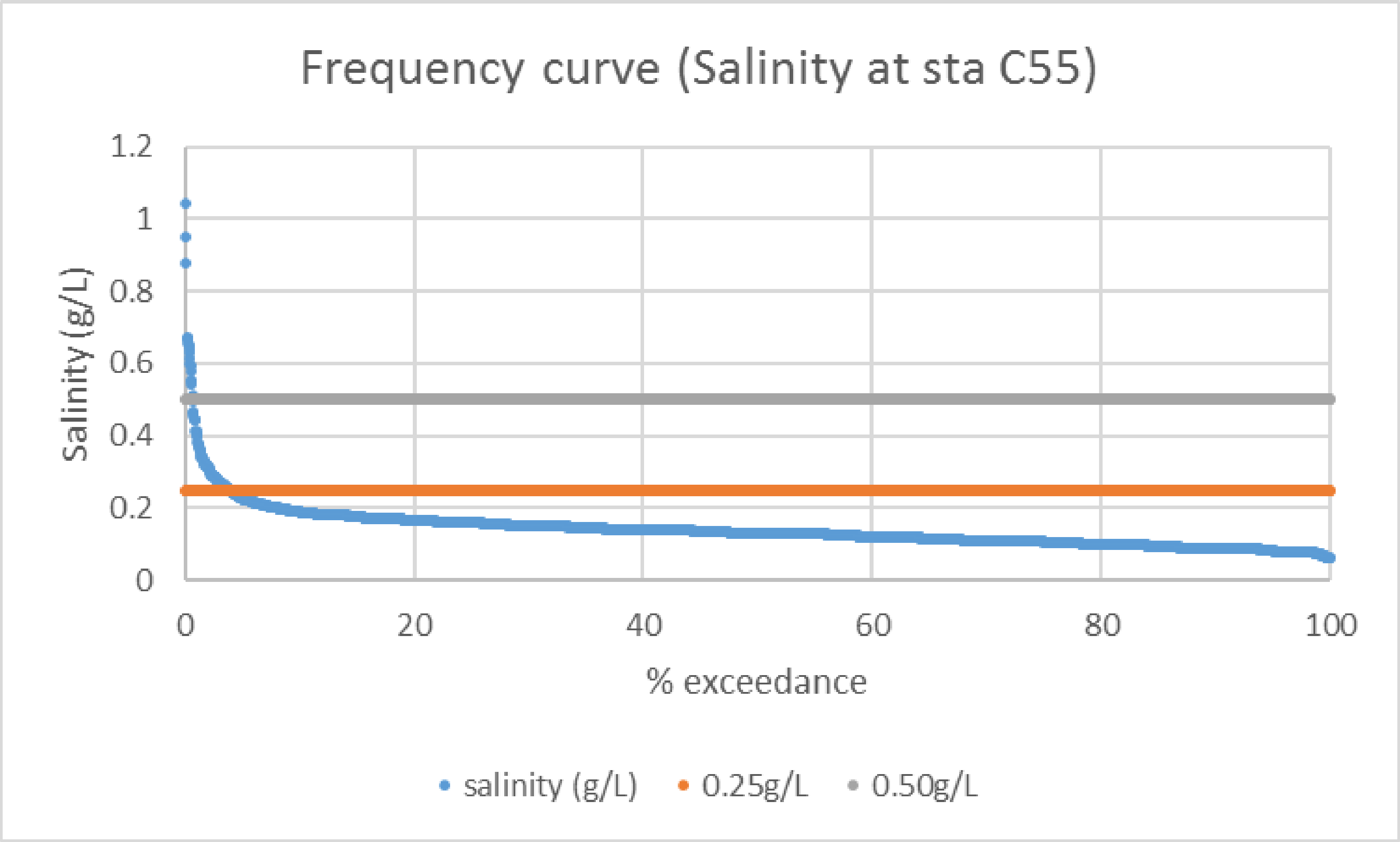
Critical threshold:

- For Bangkhen WTP:
- **<u>2. Salinity at Samlae station (C55):</u>**
- - Salinity >0.25g/L : slow down operations
- - Salinity >0.50g/L : stop operations

Salinity records at station C55:

- Years 2007-2010, 2012-2015
- 2557 data sets
- Data in year 2011 not considered-missing & incomplete
- Salinity range:
  - Min salinity: 0.06 g/L
  - Max salinity: 1.04 g/L

Salinity frequency analysis at station C55

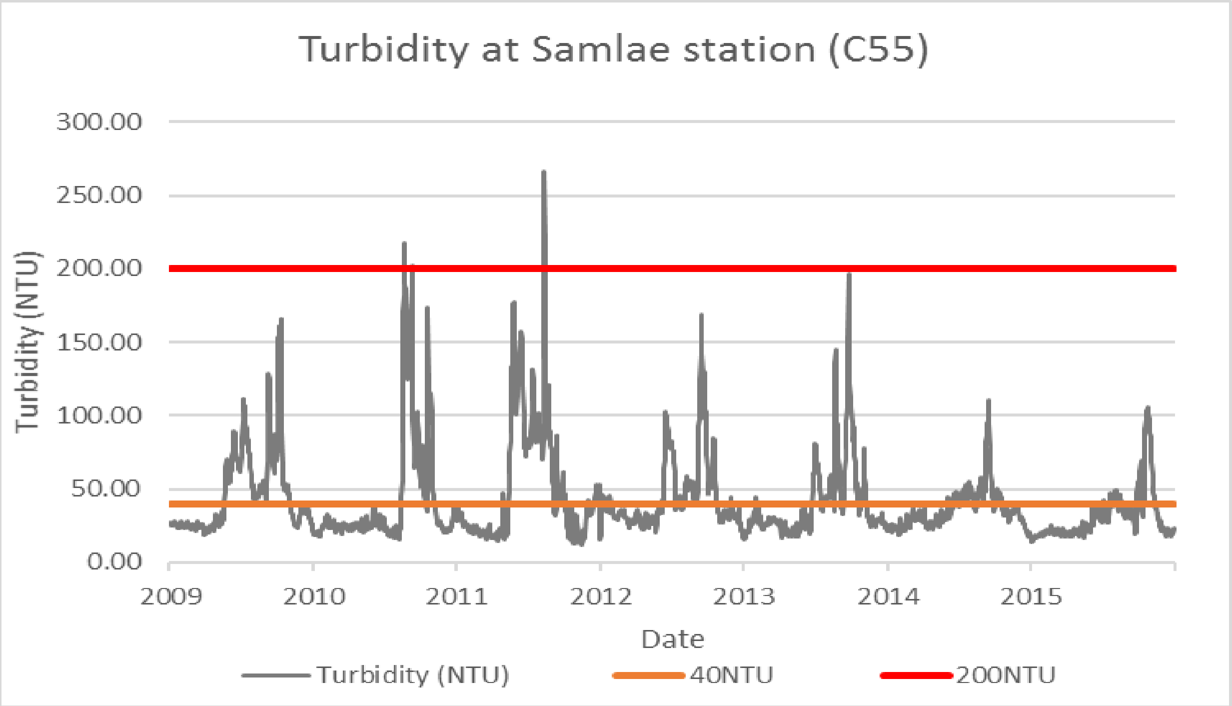


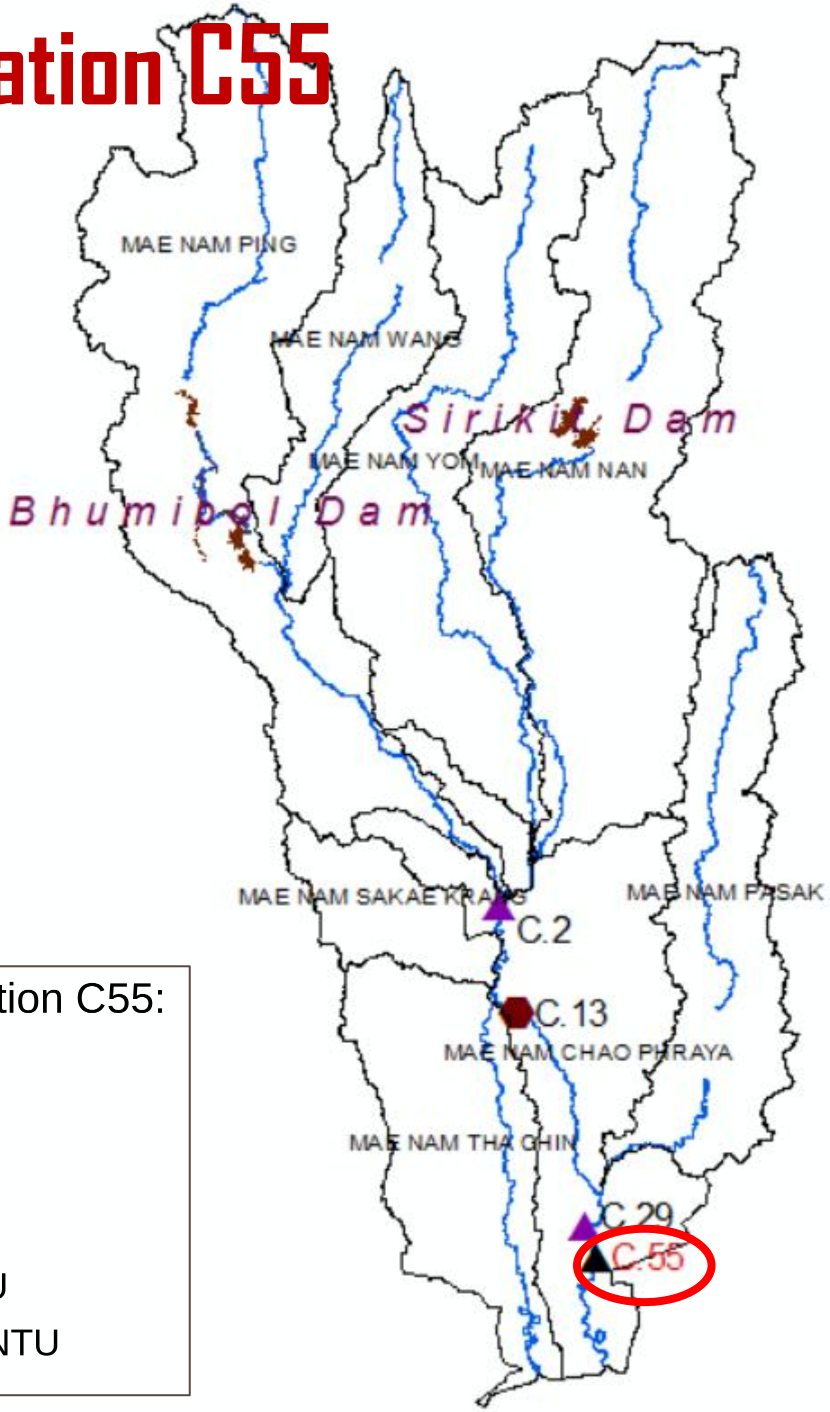
System failure states	No. of days failure
Salinity>0.25g/L	3.87% = 14 days
Salinity>0.50g/L	0.62% = 2 days

Salinity frequency analysis at station C55

Year \ Salinity	>0.05	>0.10	<0.15	>0.20	>0.25	>0.30	>0.35	>0.40	>0.45	>0.50	>0.55	>0.60	>0.65	>0.70	>0.75	>0.80	>0.85	>0.90	>0.95	>1
2007	365	365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	366	366	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	365	365	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	365	365	139	26	14	14	5	3	2	2	2	1	0	0	0	0	0	0	0	0
2011	304	304	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	366	366	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	365	365	223	73	39	39	1	1	1	1	1	1	1	1	1	1	1	1	0	0
2014	365	365	227	85	36	36	19	14	11	8	7	7	5	2	2	2	2	1	1	1
2015	365	365	259	38	24	24	14	11	8	7	6	2	1	0	0	0	0	0	0	0

Turbidity analysis at station C55





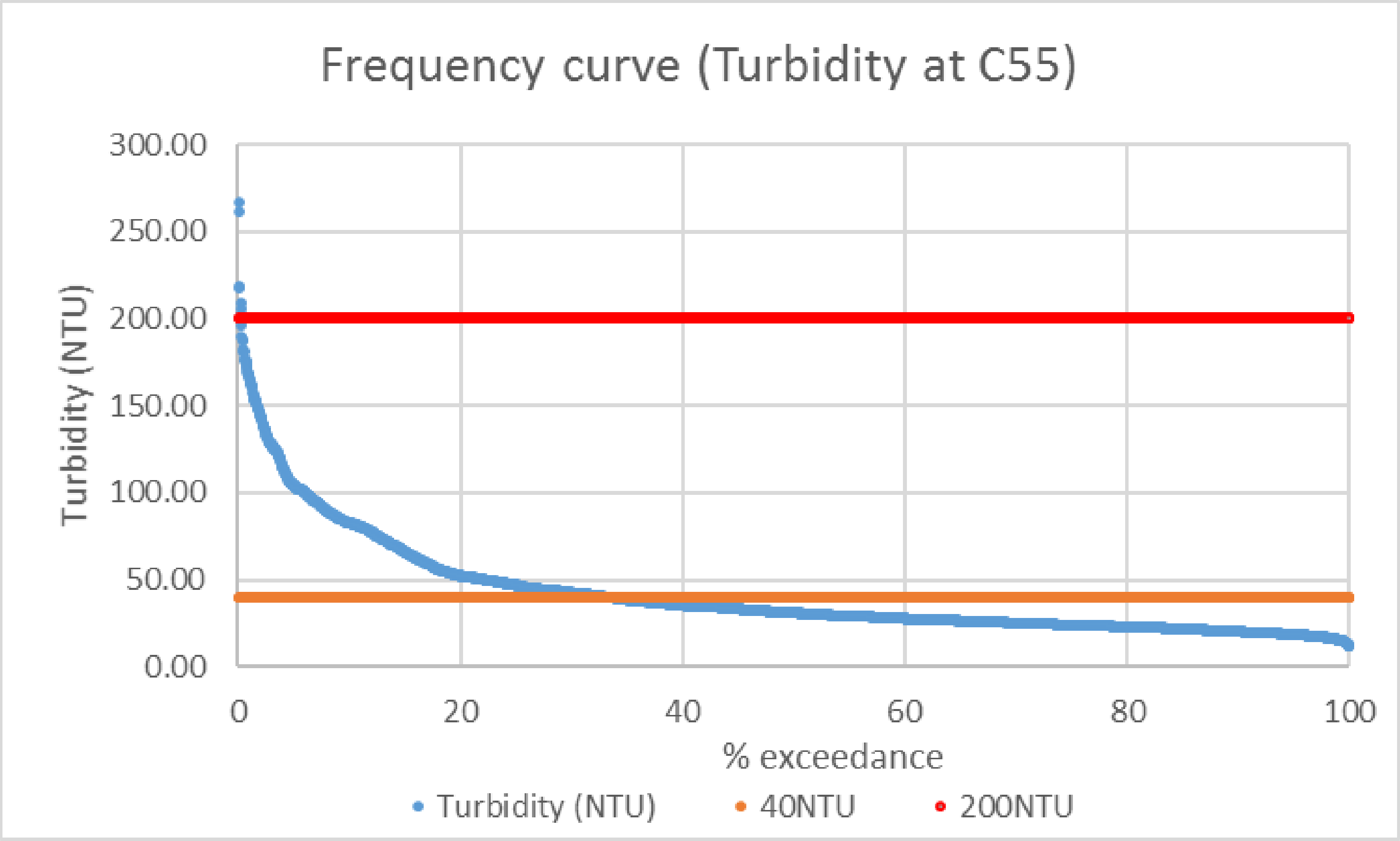
Critical threshold:

- For Bangkhen WTP:
- **<u>3. Turbidity at Samlae station (C55):</u>**
- - Turbidity >200 NTU : reduce operations
- - Turbidity <40 NTU : Algae problem

Turbidity records at station C55:

- 2009 - 2015
- 2556 data points
- Turbidity range:
  - Min turbidity: 12 NTU
  - Max turbidity : 267 NTU

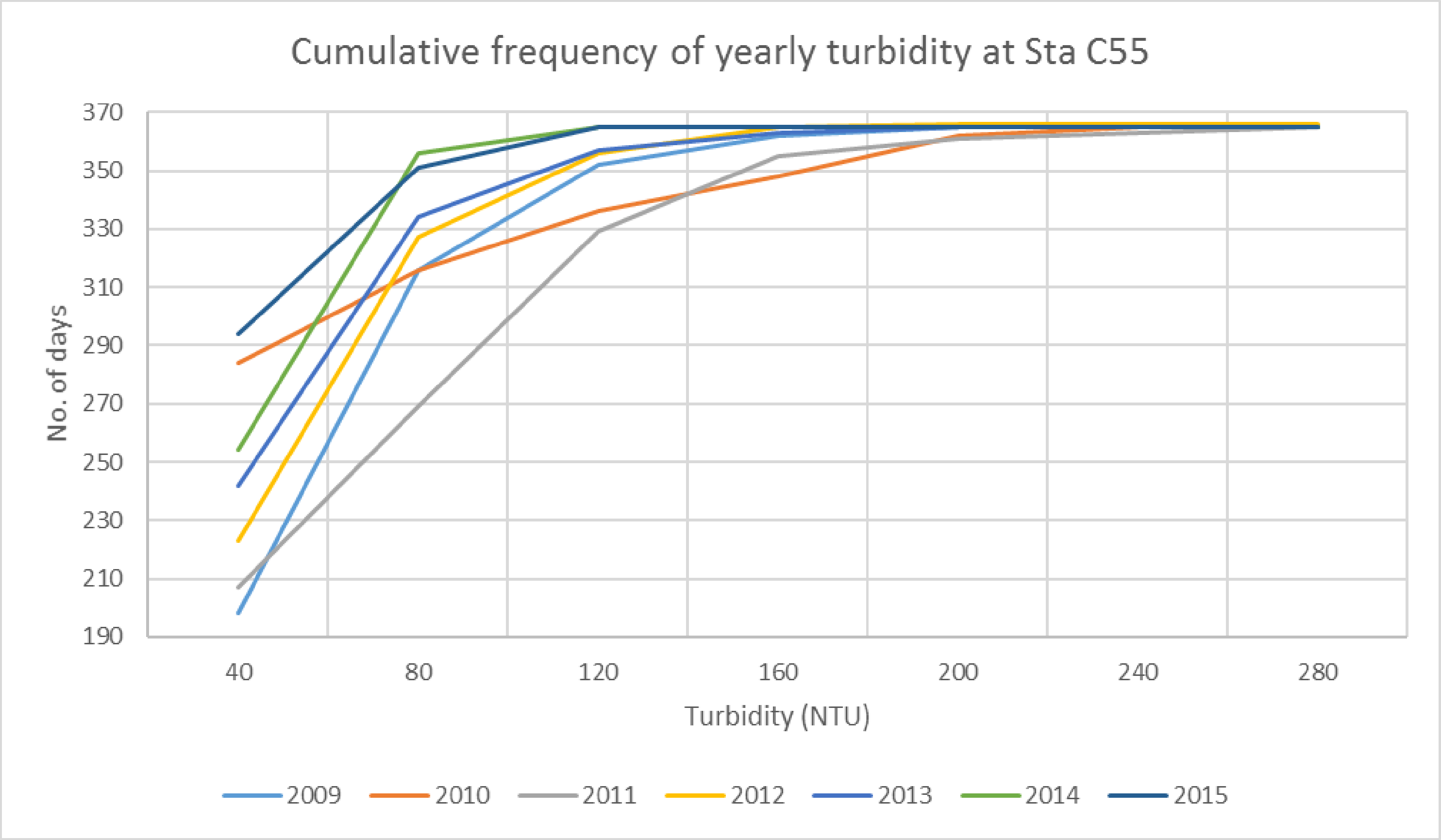
Turbidity frequency analysis at station C55



System failure states	No. of days failure
Turbidity <40NTU	66.55% = 243 days
Turbidity >200NTU	0.27% = 1 day

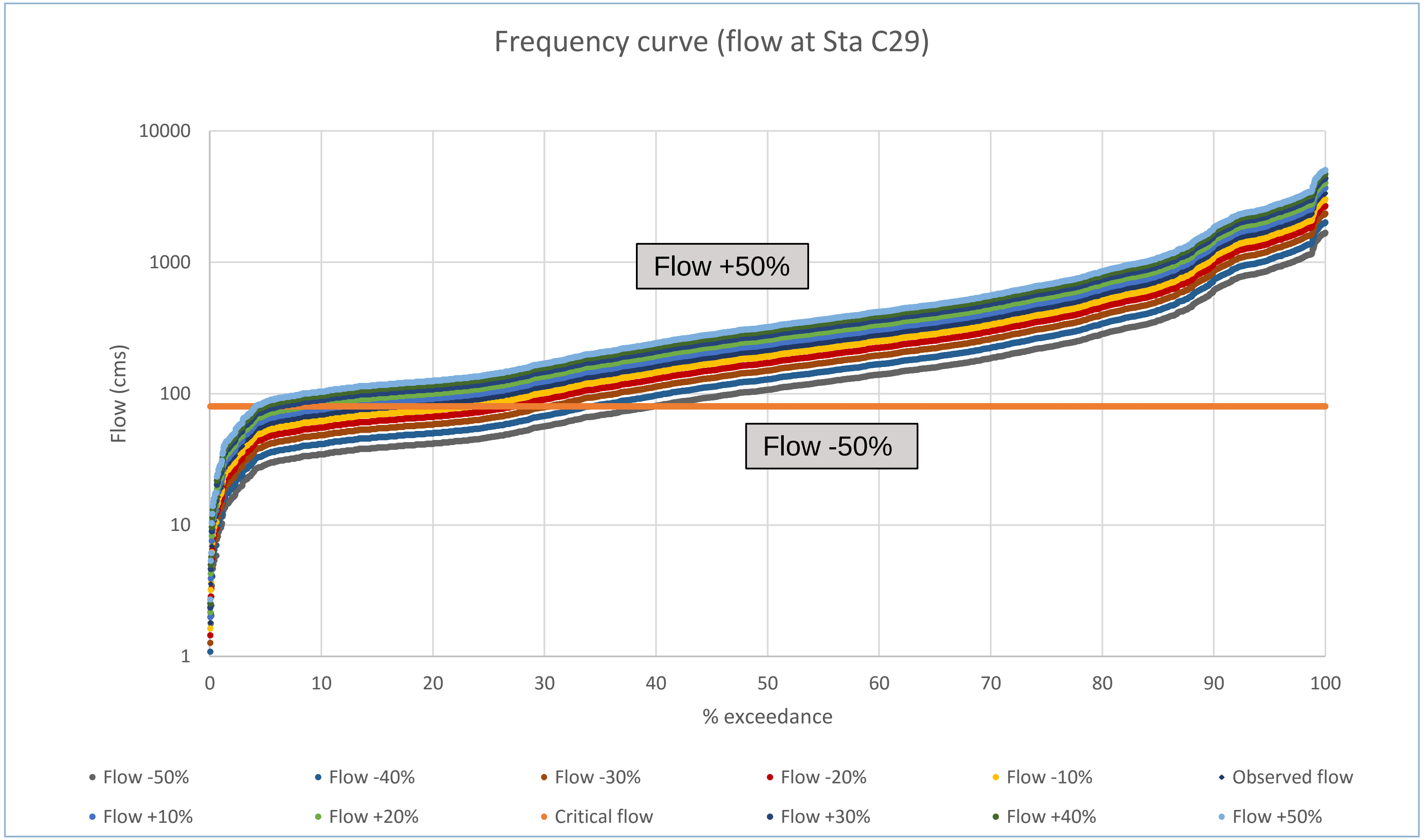
Turbidity frequency analysis at station C55

Yearly turbidity (NTU)	<40	<80	<120	<160	<200	<240	<280
2009	198	316	352	362	365	365	365
2010	284	316	336	348	362	365	365
2011	207	269	329	355	361	363	365
2012	223	327	356	365	366	366	366
2013	242	334	357	363	365	365	365
2014	254	356	365	365	365	365	365
2015	294	351	365	365	365	365	365

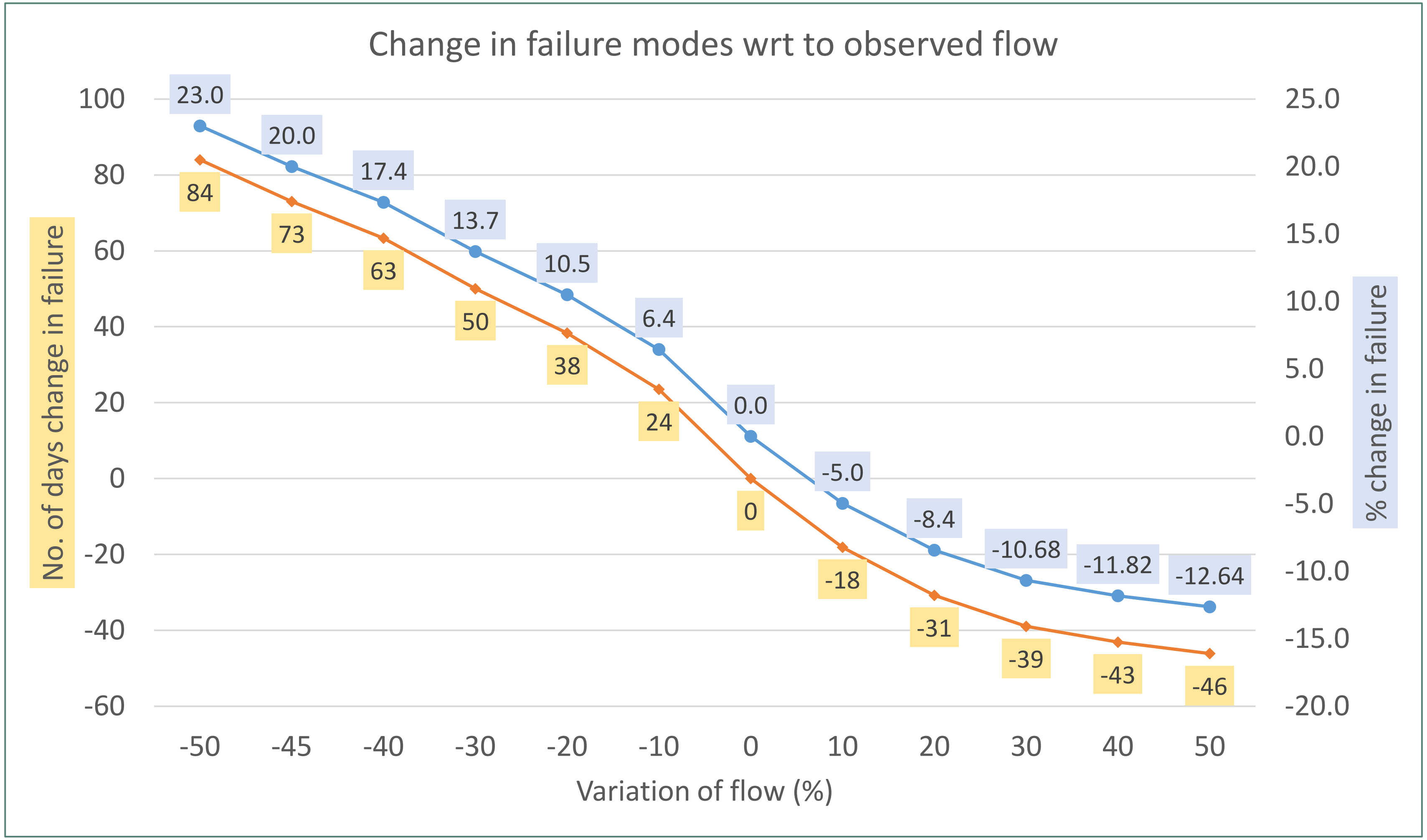


Study methodology: Conducing the stress test with flow parameter

Flow variation	%failure per year	No. days flow <80m³/s per year
Flow -50%	39.7	145
Flow -40%	34.1	124
Flow -30%	30.4	111
Flow -20%	27.2	99
Flow -10%	23.1	84
Flow	16.7	61
Flow +10%	11.7	43
Flow +20%	8.3	30
Flow +30%	6.0	22
Flow +40%	4.9	18
Flow +50%	4.1	15

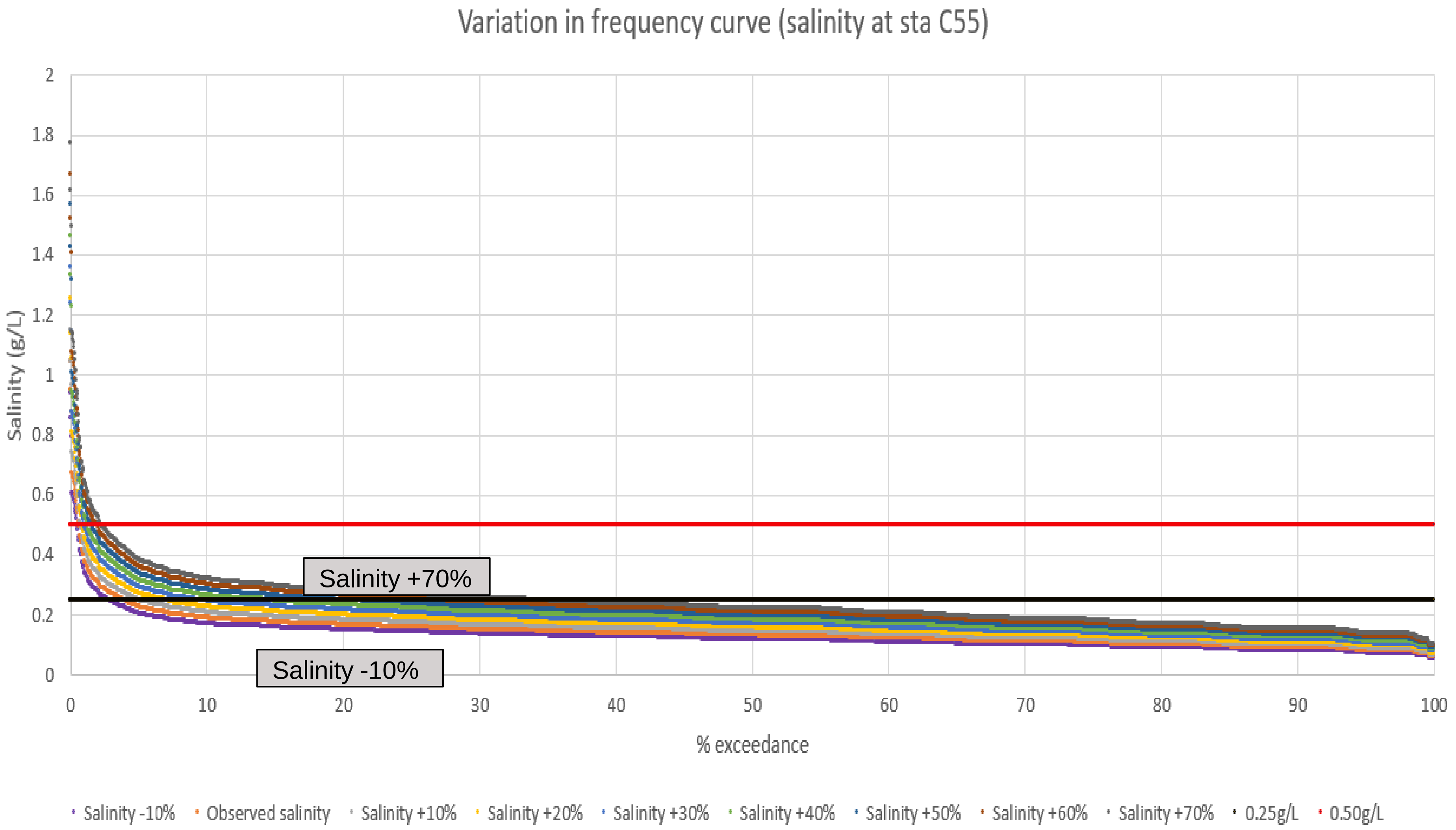


Study methodology: Conducing the stress test with flow parameter

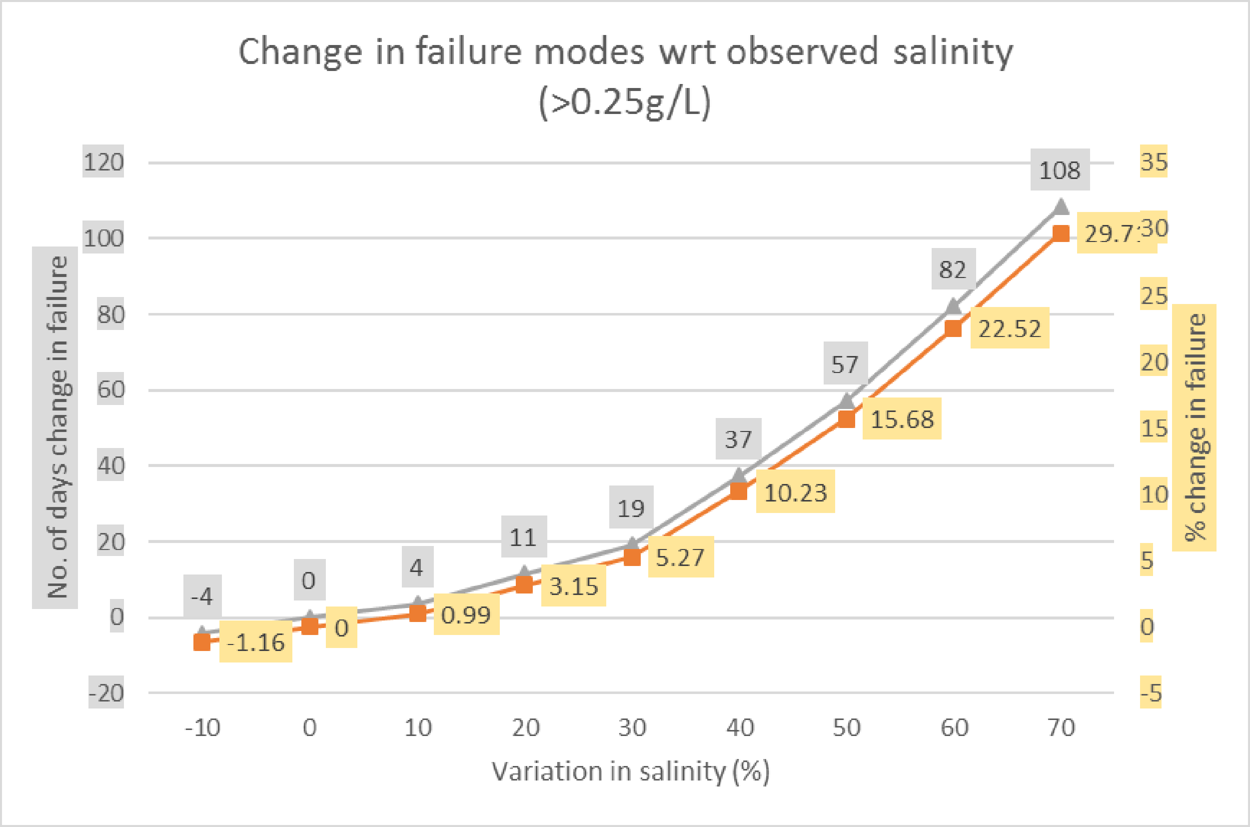


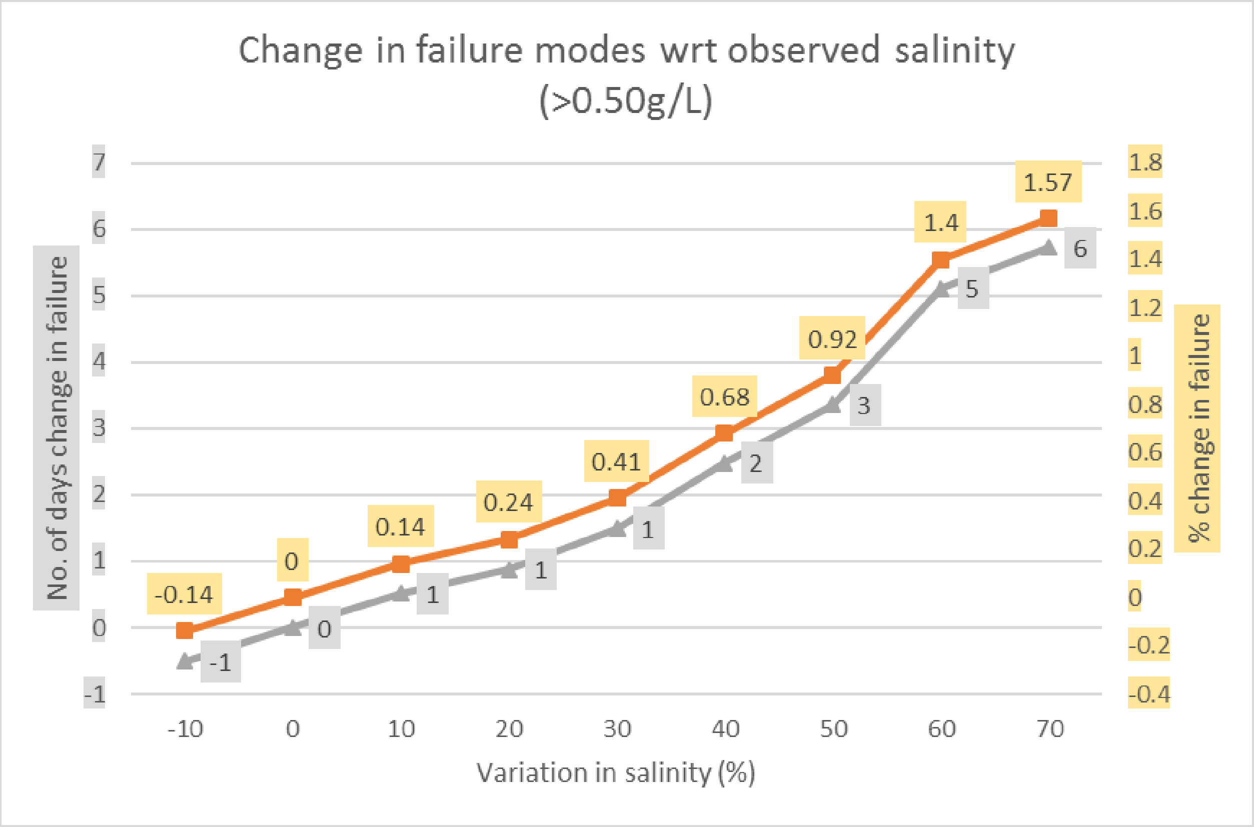
Study methodology: Conducing the stress test with salinity parameter

Overall Salinity variation	>0.25g/L	>0.50g/L
Salinity -10%	10	2
Salinity	14	2
Salinity +10%	18	3
Salinity +20%	26	3
Salinity +30%	33	4
Salinity +40%	52	5
Salinity +50%	71	6
Salinity +60%	96	7
Salinity +70%	123	8



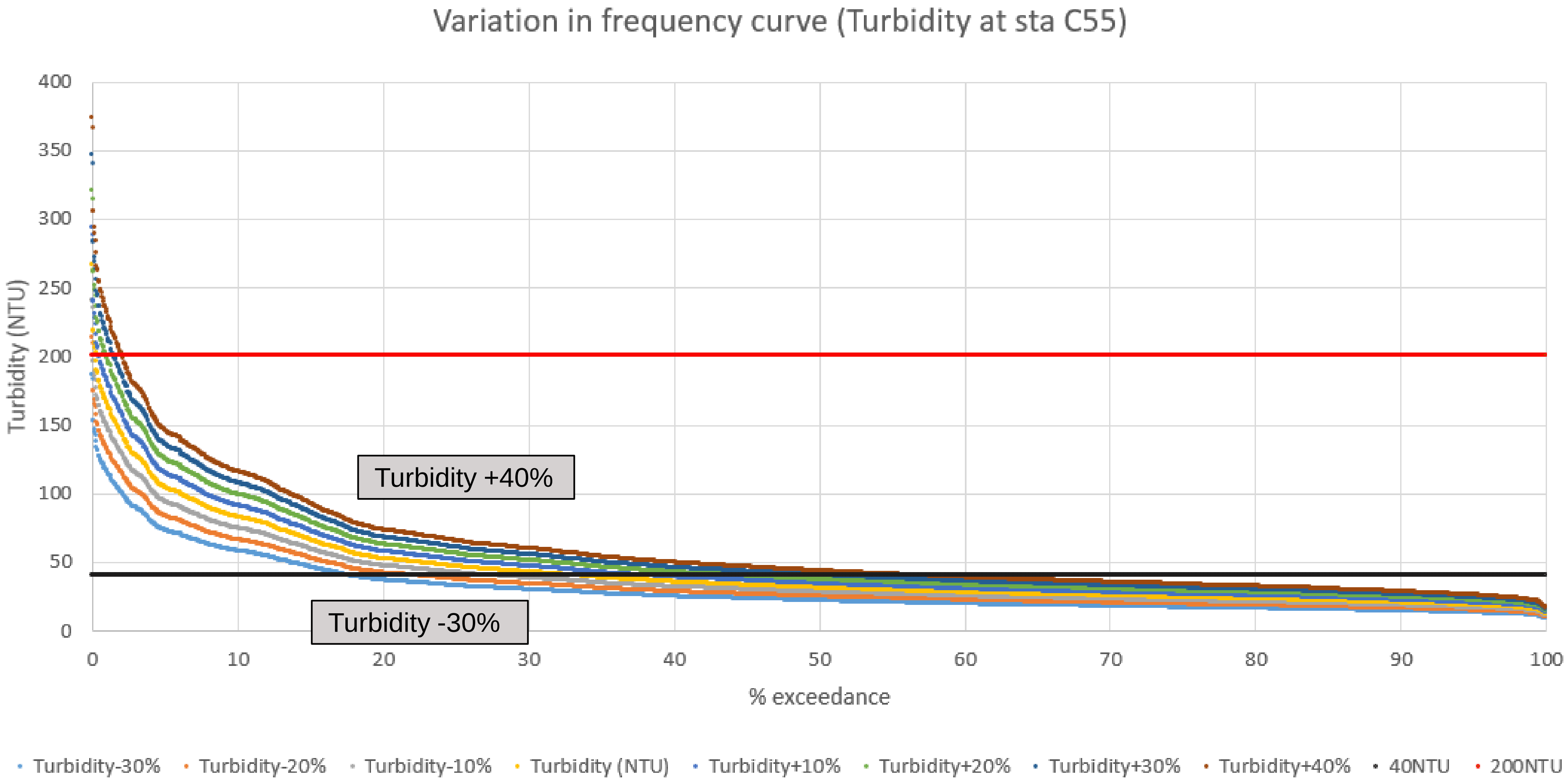
Study methodology: Conducing the stress test with salinity parameter



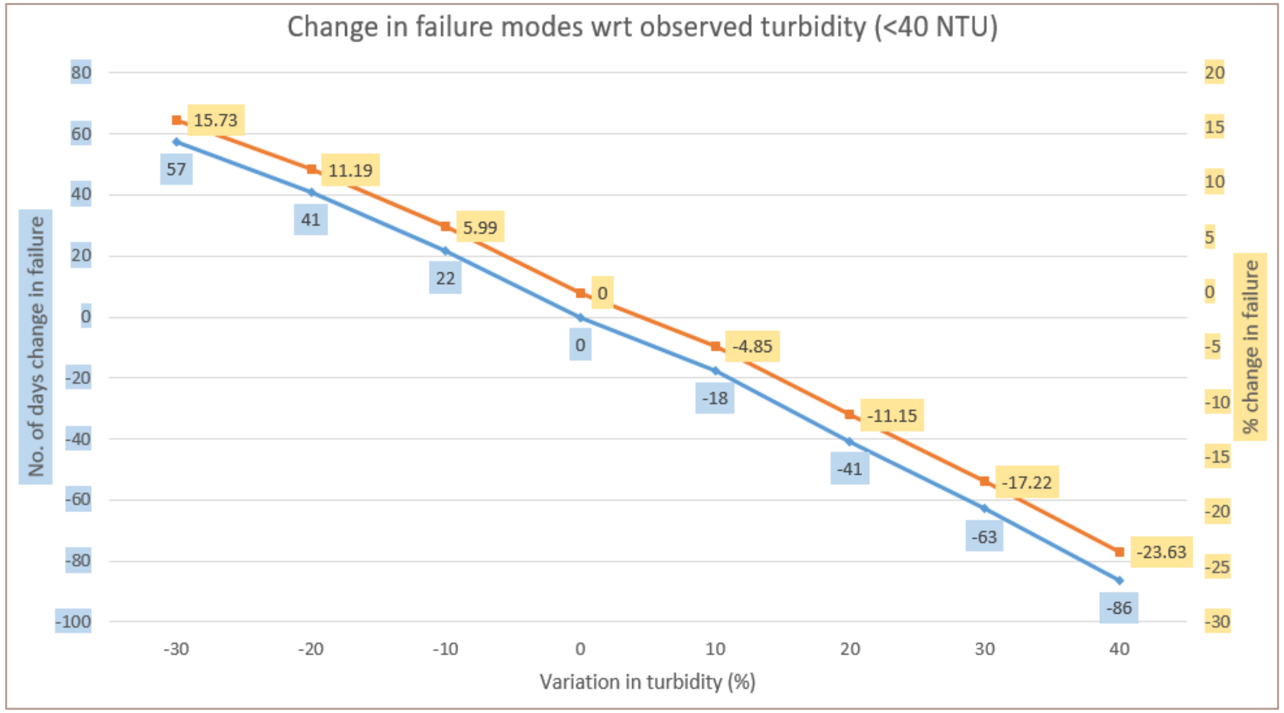


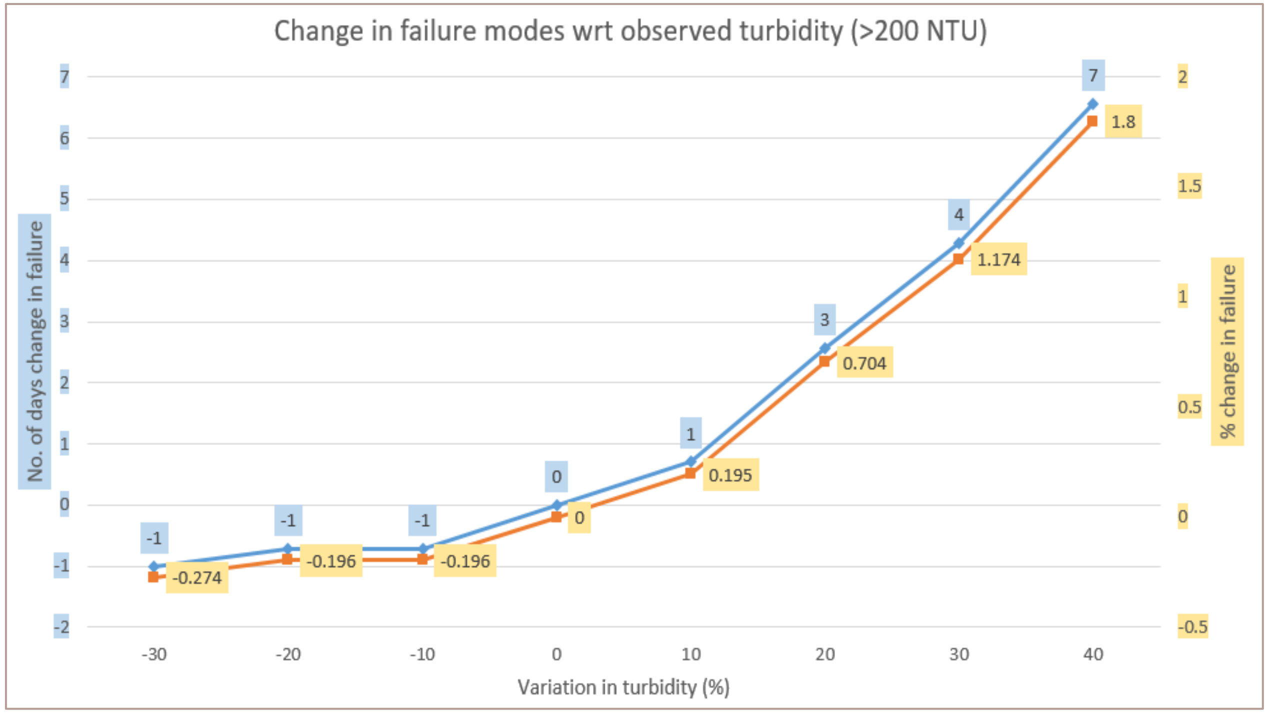
Study methodology: Conducing the stress test with turbidity parameter

Overall turbidity variation	<40NTU	>200NTU
Turbidity-30%	300	0
Turbidity-20%	284	0
Turbidity-10%	265	0
Turbidity (NTU)	243	1
Turbidity+10%	225	2
Turbidity+20%	202	4
Turbidity+30%	180	5
Turbidity+40%	157	8



Study methodology: Conducing the stress test with turbidity parameter

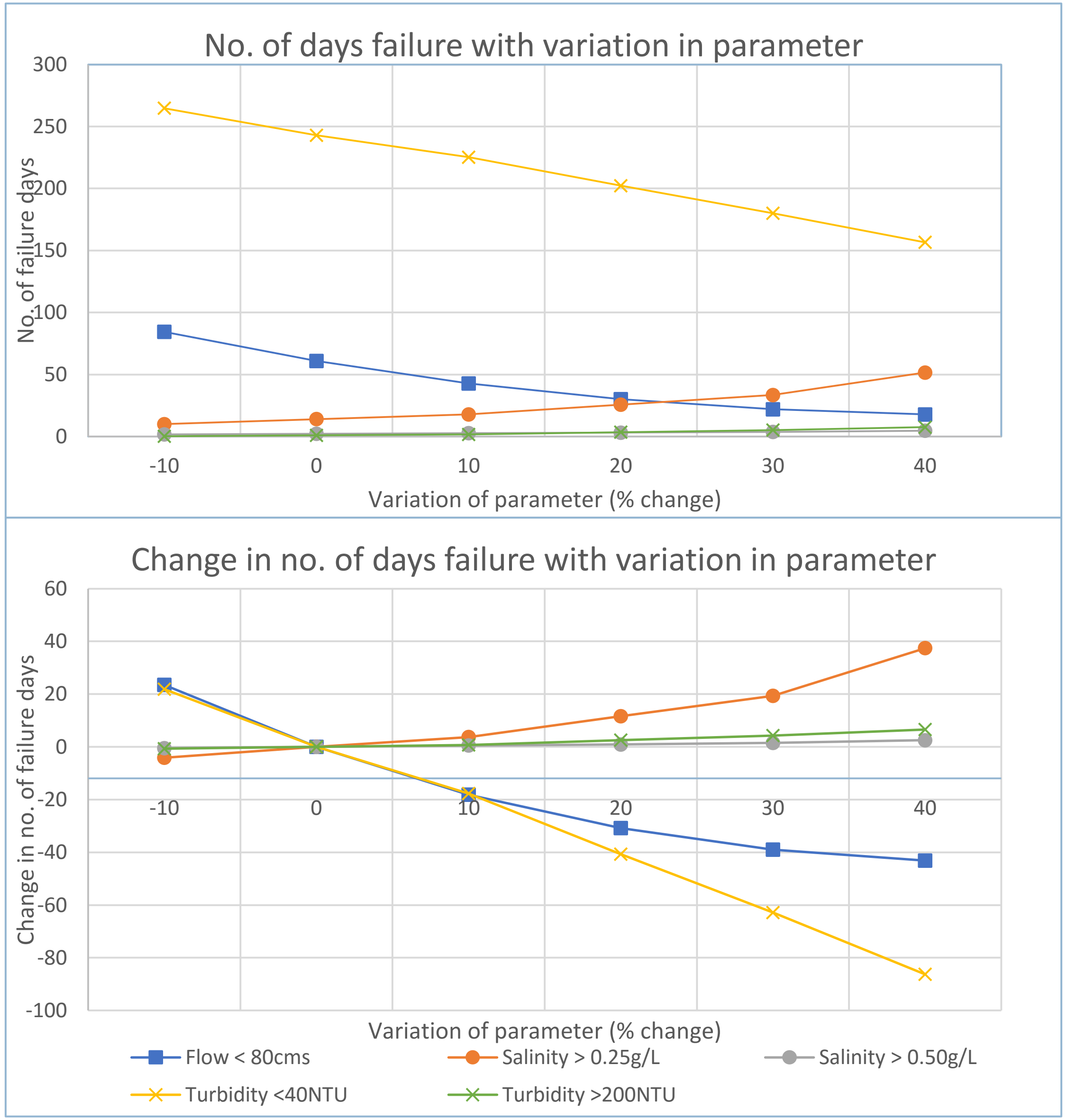




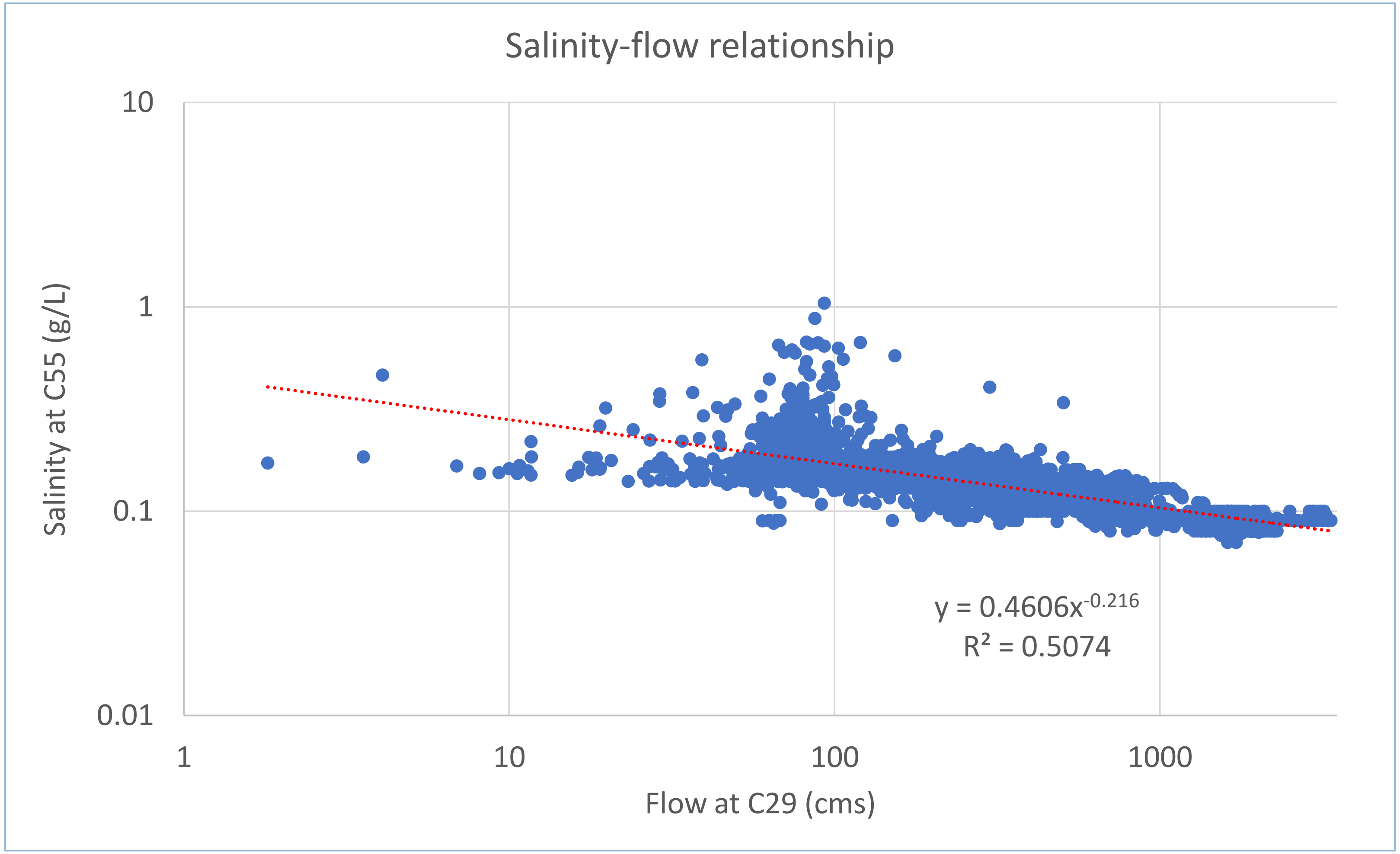
Study methodology: Summary of stress tests

Average no. of days of failure per year due to changes in flow, salinity and turbidity (years 2009-2010, 2012-2015)						
	Variation of parameter (% change)					
Critical thresholds	**-10**	**0**	**+10**	**+20**	**+30**	**+40**
Flow < 80cms	84	61	43	30	22	18
Salinity > 0.25g/L	10	14	18	26	33	52
Salinity > 0.50g/L	2	2	3	3	4	5
Turbidity <40NTU	265	243	225	202	180	157
Turbidity >200NTU	0	1	2	4	5	8

Change in average no. of days of failure per year due to changes in flow, salinity and turbidity (years 2009-2010, 2012-2015)						
	Variation of parameter (% change)					
Critical thresholds	**-10**	**0**	**+10**	**+20**	**+30**	**+40**
Flow < 80cms	24	0	-18	-31	-39	-43
Salinity > 0.25g/L	-4	0	4	12	19	37
Salinity > 0.50g/L	-1	0	1	1	1	2
Turbidity <40NTU	22	0	-18	-41	-63	-86
Turbidity >200NTU	-1	0	1	3	4	7



Relation between flow and salinity



Stress test: Number of failure days due to flow and salinity

Failure mode: Flow < 80cms OR Salinity >0.25g/L OR Both

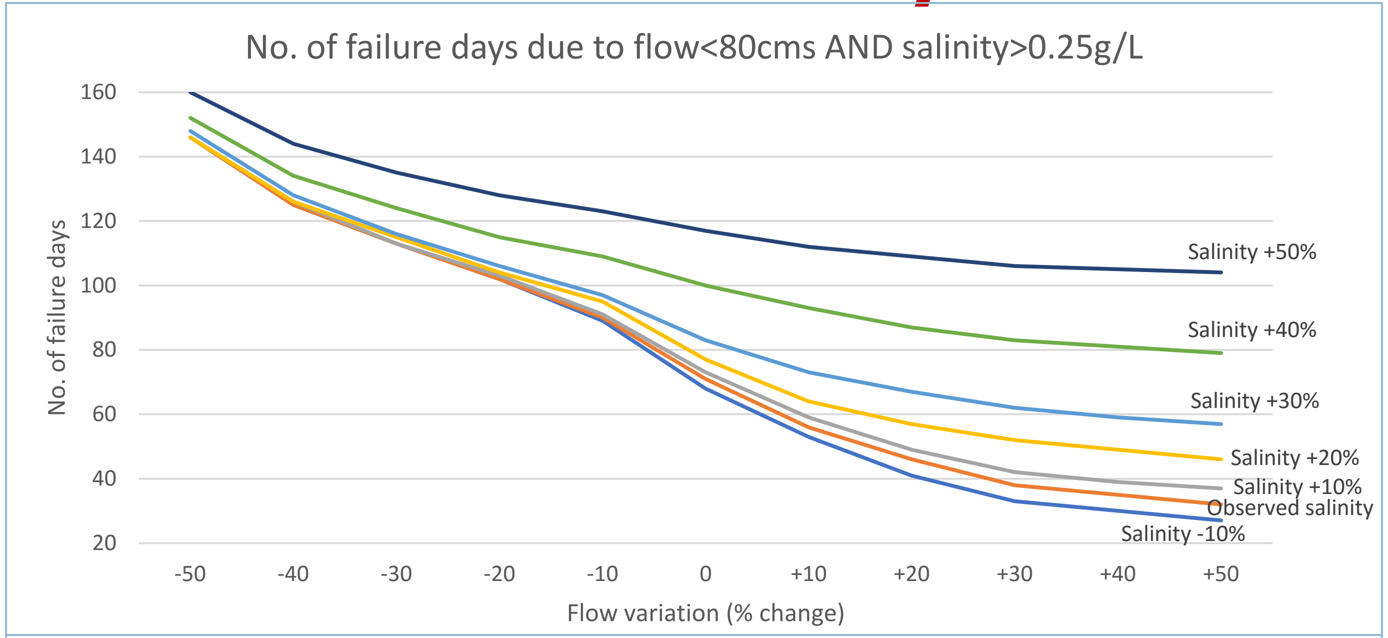
	Salinity -10%	**Observed salinity**	Salinity +10%	Salinity +20%	Salinity +30%	Salinity +40%	Salinity +50%
Flow -50%	146	146	146	146	148	152	160
Flow -40%	125	125	126	126	128	134	144
Flow -30%	113	113	113	115	116	124	135
Flow -20%	102	102	103	104	106	115	128
Flow -10%	89	90	91	95	97	109	123
Observed flow	68	71	73	77	83	100	117
Flow +10%	53	56	59	64	73	93	112
Flow +20%	41	46	49	57	67	87	109
Flow +30%	33	38	42	52	62	83	106
Flow +40%	30	35	39	49	59	81	105
Flow +50%	27	32	37	46	57	79	104

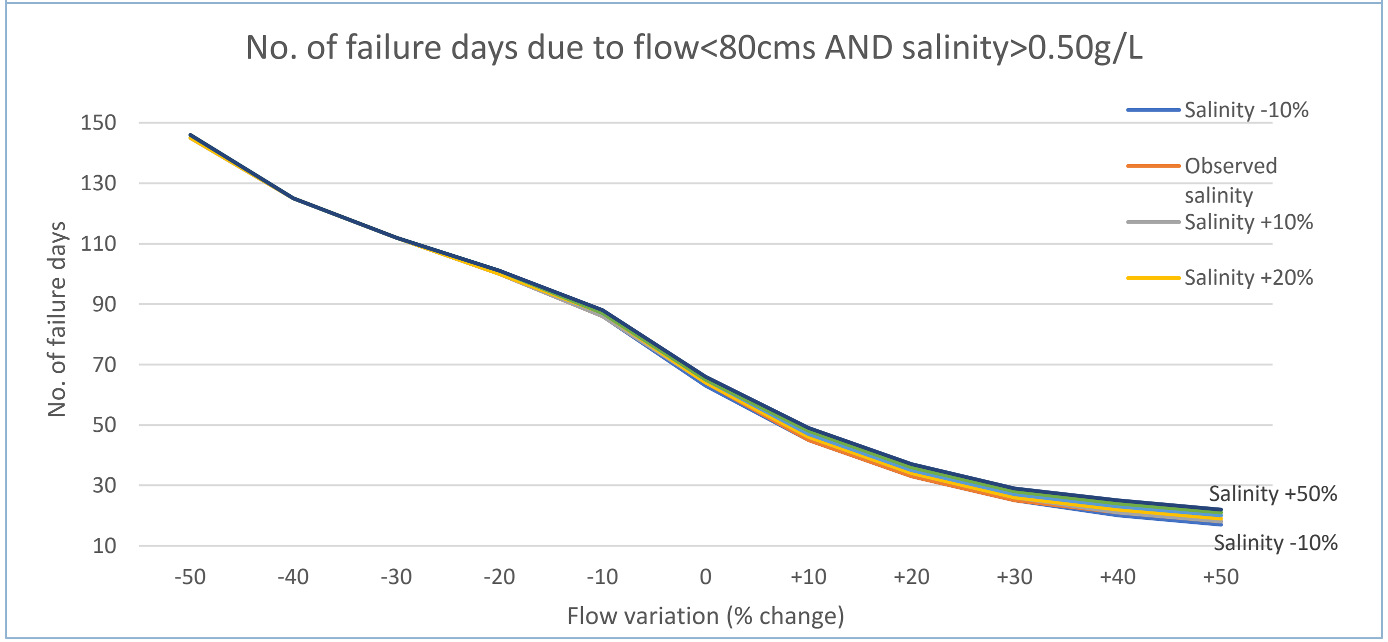
Stress test: Number of failure days due to flow and salinity

Failure mode: Flow < 80cms OR Salinity >0.50g/L OR Both

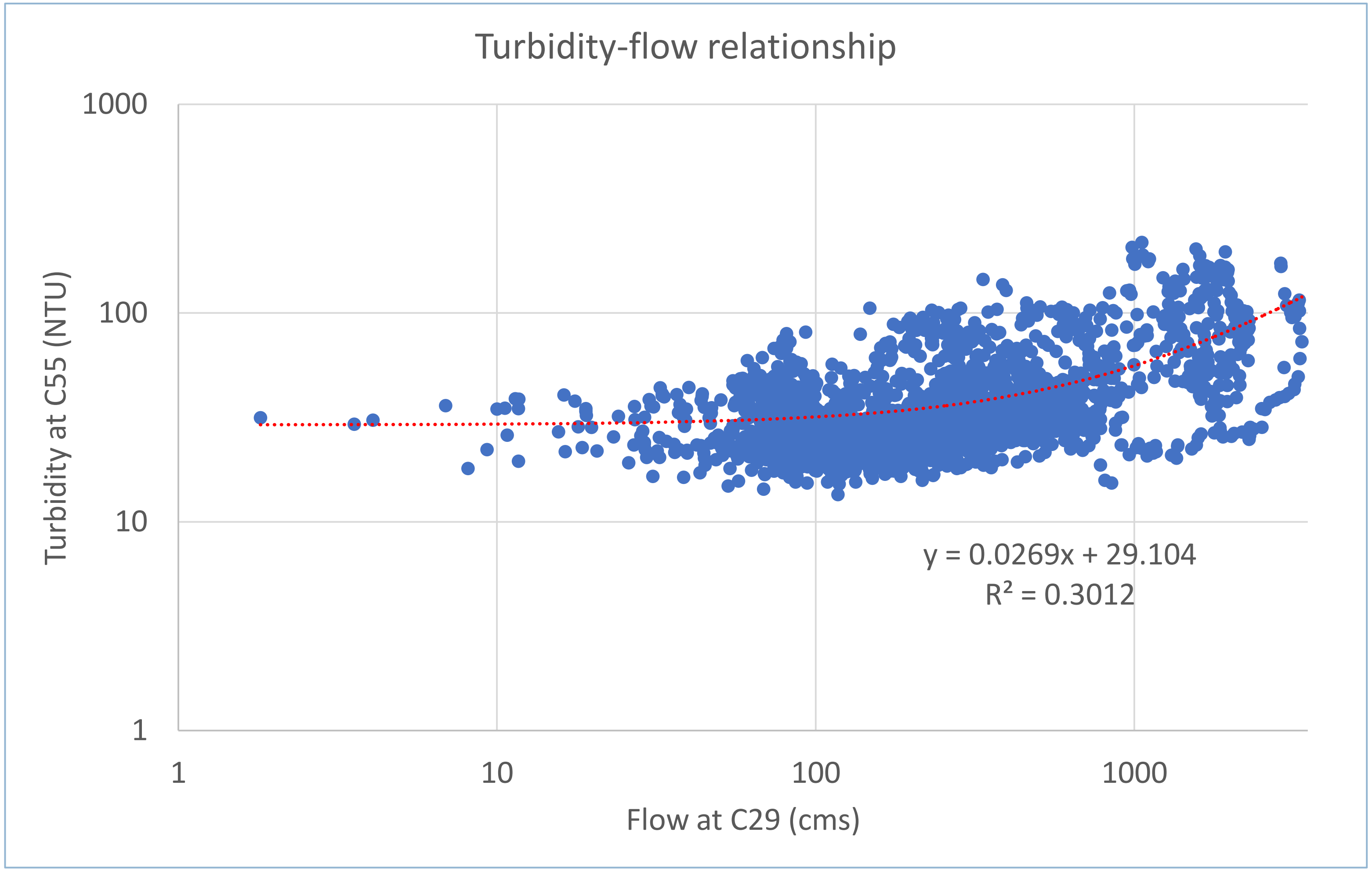
	Salinity -10%	**Observed salinity**	Salinity +10%	Salinity +20%	Salinity +30%	Salinity +40%	Salinity +50%
Flow -50%	145	145	145	145	146	146	146
Flow -40%	125	125	125	125	125	125	125
Flow -30%	112	112	112	112	112	112	112
Flow -20%	100	100	100	100	101	101	101
Flow -10%	86	86	86	87	87	87	88
Observed flow	63	64	64	64	65	65	66
Flow +10%	45	45	46	46	47	48	49
Flow +20%	33	33	34	34	35	36	37
Flow +30%	25	25	26	26	27	28	29
Flow +40%	20	21	21	22	23	24	25
Flow +50%	17	18	18	19	20	21	22

Stress test: Number of failure days due to flow and salinity





Relationship between flow and turbidity



Stress test: Number of failure days due to flow and turbidity

Failure mode: Flow < 80cms OR Turbidity <40NTU OR Both

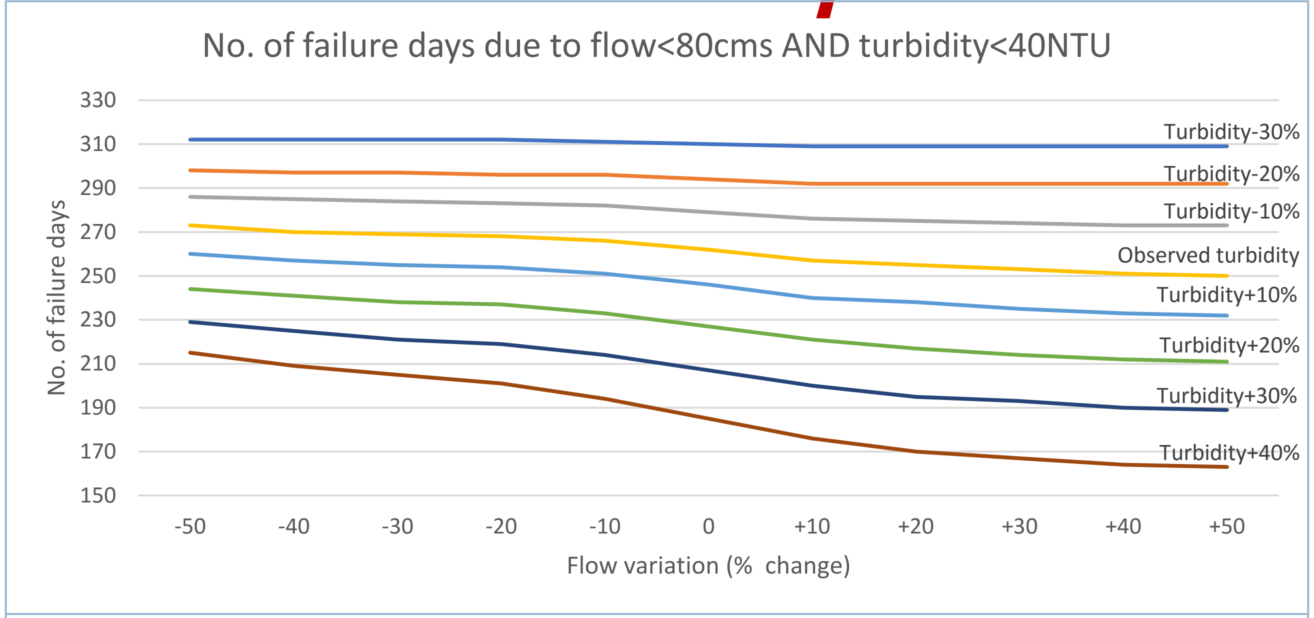
	Turbidity-30%	Turbidity-20%	Turbidity-10%	**Observed turbidity**	Turbidity+10%	Turbidity+20%	Turbidity+30%	Turbidity+40%
Flow -50%	312	298	286	273	260	244	229	215
Flow -40%	312	297	285	270	257	241	225	209
Flow -30%	312	297	284	269	255	238	221	205
Flow -20%	312	296	283	268	254	237	219	201
Flow -10%	311	296	282	266	251	233	214	194
Observed flow	310	294	279	262	246	227	207	185
Flow +10%	309	292	276	257	240	221	200	176
Flow +20%	309	292	275	255	238	217	195	170
Flow +30%	309	292	274	253	235	214	193	167
Flow +40%	309	292	273	251	233	212	190	164
Flow +50%	309	292	273	250	232	211	189	163

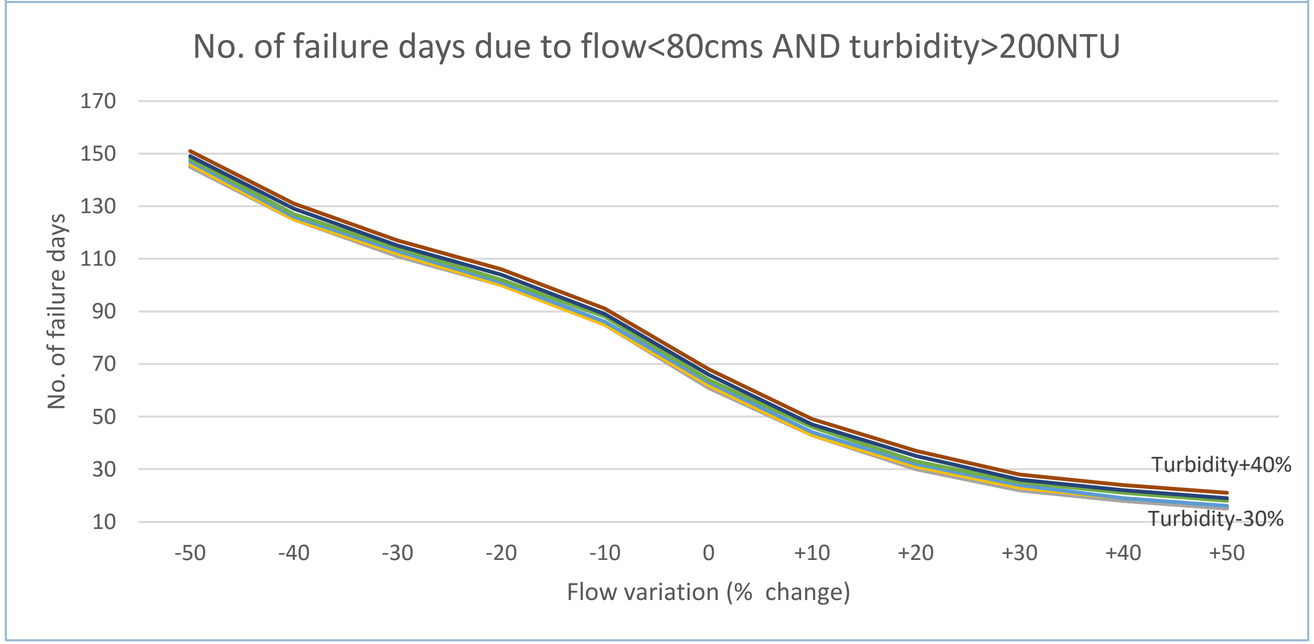
Stress test: Number of failure days due to flow and turbidity

Failure mode: Flow < 80cms OR Turbidity >200NTU OR Both

	Turbidity-30%	Turbidity-20%	Turbidity-10%	**Observed turbidity**	Turbidity+10%	Turbidity+20%	Turbidity+30%	Turbidity+40%
Flow -50%	145	145	145	146	147	148	149	151
Flow -40%	125	125	125	125	126	127	129	131
Flow -30%	111	111	111	112	113	114	115	117
Flow -20%	100	100	100	100	101	102	104	106
Flow -10%	85	85	85	85	86	88	89	91
Observed flow	61	61	61	62	63	64	66	68
Flow +10%	43	43	43	43	44	46	47	49
Flow +20%	30	30	30	31	32	33	35	37
Flow +30%	22	22	22	23	24	25	26	28
Flow +40%	18	18	18	19	19	21	22	24
Flow +50%	15	15	15	16	16	18	19	21

Stress test: Number of failure days due to flow and turbidity





Stress test: Number of failure days due to flow, salinity and turbidity

Failure mode: Flow < 80cms OR Salinity >0.25g/L OR Turbidity <40NTU OR ALL THREE

	Turbidity-30%					Turbidity-20%					Turbidity-10%					**Observed Turbidity**					Turbidity+10%					Turbidity+20%					Turbidity+30%				
Change in Salinity (%)	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50
Flow -50%	313	313	313	313	313	298	298	298	298	298	286	286	286	286	287	273	273	273	273	274	260	260	260	260	261	245	245	245	245	246	230	230	230	230	232
Flow -30%	312	312	312	312	312	297	297	297	297	297	284	284	284	284	285	269	269	269	269	271	255	255	255	255	257	239	239	239	239	242	222	222	222	222	227
Flow -10%	311	311	311	311	312	296	296	296	296	296	282	282	283	283	284	267	267	267	268	270	252	252	252	253	256	234	234	234	235	240	215	215	216	218	224
Observed flow	310	310	310	310	311	294	294	294	294	296	279	279	280	280	283	263	263	263	264	268	247	247	247	249	254	228	229	229	231	238	209	209	210	213	222
Flow +10%	309	309	309	309	310	293	293	293	293	295	276	276	276	278	282	258	258	258	260	267	242	242	242	245	252	223	223	223	227	236	202	203	203	208	219
Flow +30%	309	309	309	309	310	292	292	292	292	295	275	275	275	277	282	254	254	255	258	266	237	237	238	241	251	216	216	217	222	234	195	195	196	203	218
Flow +50%	309	309	309	309	310	292	292	292	292	295	273	273	274	276	282	252	252	253	256	265	234	234	235	239	250	212	213	214	219	233	191	192	194	200	217

Failure mode: Flow < 80cms OR Salinity >0.50g/L OR Turbidity <40NTU OR ALL THREE

	Turbidity-30%					Turbidity-20%					Turbidity-10%					**Observed Turbidity**					Turbidity+10%					Turbidity+20%					Turbidity+30%				
Change in Salinity (%)	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50
Flow -50%	313	313	313	313	313	298	298	298	298	298	286	286	286	286	286	273	273	273	273	273	260	260	260	260	260	245	245	245	245	245	230	230	230	230	230
Flow -30%	312	312	312	312	312	297	297	297	297	297	284	284	284	284	284	269	269	269	269	269	255	255	255	255	255	238	238	238	238	239	222	222	222	222	222
Flow -10%	311	311	311	311	311	296	296	296	296	296	282	282	282	282	282	267	267	267	267	267	251	251	251	252	252	233	233	233	233	234	214	214	214	214	215
Observed flow	310	310	310	310	310	294	294	294	294	294	279	279	279	279	279	262	262	262	263	263	246	246	246	246	247	227	227	227	228	228	207	207	207	208	208
Flow +10%	309	309	309	309	309	293	293	293	293	293	276	276	276	276	276	257	257	257	258	258	241	241	241	241	241	221	221	221	222	222	200	200	200	201	202
Flow +30%	309	309	309	309	309	292	292	292	292	292	274	274	274	274	274	253	253	253	253	254	235	235	235	236	236	214	214	214	215	215	193	193	193	193	194
Flow +50%	309	309	309	309	309	292	292	292	292	292	273	273	273	273	273	251	251	251	251	251	233	233	233	233	233	211	211	211	212	212	190	190	190	190	191

Stress test: Number of failure days due to flow, salinity and turbidity

Failure mode: Flow < 80cms OR Salinity >0.25g/L OR Turbidity >200NTU OR ALL THREE

	Turbidity-30%					Turbidity-20%					Turbidity-10%					**Observed Turbidity**					Turbidity+10%					Turbidity+20%					Turbidity+30%				
Change in Salinity (%)	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50
Flow -50%	146	146	146	148	160	146	146	146	148	160	146	146	146	148	160	146	146	147	148	160	147	147	147	149	161	149	149	149	150	162	150	150	150	152	164
Flow -30%	113	113	113	116	135	113	113	113	116	135	113	113	113	116	135	113	113	114	116	136	114	114	115	117	137	128	116	116	119	138	117	117	118	120	140
Flow -10%	89	90	91	97	123	89	90	91	97	123	89	90	91	97	123	90	90	92	98	123	90	91	93	99	124	92	93	94	100	126	93	94	96	101	127
Observed flow	68	71	73	83	117	68	71	73	83	117	68	71	73	83	117	69	71	73	84	117	70	72	74	85	118	71	73	76	86	120	73	75	77	87	121
Flow +10%	53	56	59	73	112	53	56	59	73	112	53	56	59	73	112	53	57	60	74	113	54	58	61	75	114	56	59	62	76	115	57	60	64	77	116
Flow +30%	33	38	42	62	106	33	38	42	62	106	33	38	42	62	106	34	39	43	62	107	35	40	44	63	108	36	41	45	64	109	38	42	47	66	110
Flow +50%	27	32	37	57	104	27	32	37	57	104	27	32	37	57	104	27	32	37	57	104	28	33	38	58	105	29	35	39	59	107	31	36	41	61	108

Failure mode: Flow < 80cms OR Salinity >0.50g/L OR Turbidity >200NTU OR ALL THREE

	Turbidity-30%					Turbidity-20%					Turbidity-10%					**Observed Turbidity**					Turbidity+10%					Turbidity+20%					Turbidity+30%				
Change in Salinity (%)	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50	-10	**Obs**	+10	+30	+50
Flow -50%	145	145	145	146	146	145	145	145	146	146	145	145	145	146	146	146	146	146	146	146	147	147	147	147	147	148	148	148	148	149	150	150	150	150	150
Flow -30%	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	112	113	113	113	113	113	113	115	115	115	115	115	116	116	116	116	116
Flow -10%	86	86	86	87	88	86	86	86	87	88	86	86	86	87	88	86	87	87	88	88	87	88	88	89	89	89	89	89	90	91	90	90	91	91	92
Observed flow	63	64	64	65	66	63	64	64	65	66	63	64	64	65	66	64	64	65	66	66	64	65	65	66	67	66	66	67	68	69	67	68	68	69	70
Flow +10%	45	45	46	47	49	45	45	46	47	49	45	45	46	47	49	45	46	46	48	49	46	47	47	48	50	48	48	49	50	51	49	50	50	51	53
Flow +30%	25	25	26	27	29	25	25	26	27	29	25	25	26	27	29	25	26	26	27	29	26	26	27	28	30	27	28	28	30	31	29	29	30	31	33
Flow +50%	17	18	18	20	22	17	18	18	20	22	17	18	18	20	22	18	18	19	20	22	19	19	20	21	23	20	21	21	23	24	22	22	23	24	26

Final Reflections

- Traditional approaches for large-scale climate change adaptation are less attractive to policy makers because of the inherent uncertainty associated with climate models.
- Bottom-up vulnerability assessments such as CRIDA are a more practical way for developing adaptation plans.
- Application of bottom-up approaches are still in a nascent stage.
- Establishing the decision context is the most crucial aspect. This becomes more complicated for larger projects with multiple stakeholders.
- The Bangkok case study provides a good reference on performing bottom-up assessments, which will form the basis for adaptation plans.

THANK YOU!!! ☺