TECHNICAL GUIDANCE NOTE

PEG M&E Pathways

Monitoring Distance to Limits

A Pathway-Switching Framework for Dynamic National Adaptation Plans

Supporting implementation of the Global Goal on Adaptation and NAPs

For: National Adaptation Plan teams, sector ministry planners, climate policy advisers, monitoring officers, and finance ministry adaptation focal points

Linked to: UAE Framework for Global Climate Resilience (COP28) | Belém Adaptation Indicators (COP30) | UNFCCC NAP Technical Guidelines (2025) | NAPX v0.1 data model

Covering: tuning epochs and adaptation debt · distance to limit · the rate ratio · the response portfolio of pre-emptive, contingent and loss-accepting measures · the intolerability register · disaggregated essential variables · the trigger–instrument register · the mistuning test

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How to use this guide

This guide helps NAP teams design monitoring systems that answer more useful questions than the one most NAPs currently ask. Most adaptation monitoring asks: What damage occurred? This guide asks three questions instead. The first is: how much safe room remains before our current adaptation strategy stops working? The other two determine whether the answer to the first can be acted on at all:

- How far behind are we already? Every system is tuned to the climate of a particular past period. If that period has passed, the system is already mistuned, and the deficit is measurable today without any model or scenario.
- Can we move fast enough? If the environment is changing faster than the system can be re-tuned, no amount of monitoring discipline will keep the system in the green. That has to be known in advance, because it changes what the pathway library must contain.

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Executive Summary

National Adaptation Plans work best when they are designed as managed adaptive systems — not as static lists of actions. This means knowing in advance when an adaptation strategy is approaching its limits, what the next strategy is, and how long it takes to switch. This guide provides the practical architecture for doing that.

The problem with current NAP monitoring
Most NAP monitoring records: (1) what hazard events occurred, and (2) what adaptation actions were implemented. Both are backward-looking.
A farmer who has adopted drought-tolerant seed varieties and invested in water harvesting has no national monitoring instrument that will tell her government when those measures are running out of room — when heat, shortened seasons, and deepening moisture deficits mean that the current pathway can no longer sustain viable food production.
By the time this becomes visible in historical data, the lead time needed to execute a more fundamental shift may already have been consumed.

The solution: monitor position, not damage
For each GGA system, define the threshold beyond which the current adaptation pathway fails.
Record the tuning epoch — the period whose climate statistics the system's design parameters, standards and operating rules encode — and measure how far the environment has already moved since. This is the system's adaptation debt, and it is measurable today without models or scenarios.
Monitor how far the system currently sits from the failure threshold — the safe room remaining — and how fast that margin is being consumed.
Compare the environment's rate of change with the system's own rate of adjustment. Where the environment is moving faster, the system cannot be kept safe by monitoring alone and must be redesigned for flexibility.
Set trigger rules that fire when projected time to threshold becomes shorter than the time needed to prepare the next pathway — and attach to each trigger the legal or financial instrument that makes activation automatic.
Pre-define the response portfolio, so switching is planned rather than crisis-driven.

Seven key messages

#	Key message
1	Incremental adaptation works within a safe operating window. When conditions approach the edge of that window, a shift to stronger or different measures — including transformational adaptation — becomes necessary.
2	The most important things to monitor are not current damage but three positions: how far behind the system already is (adaptation debt), how much room remains before the current strategy stops working (distance to limit), and whether the system can move fast enough (rate ratio).
3	Action must be triggered before the threshold is reached, not after. If managed retreat takes 15 years, preparation must begin at least 15 years before the settlement becomes unsafe.
4	A trigger without a pre-committed instrument is a wish. Every Type B and Type C trigger must name the standing appropriation, framework contract, contingent credit line or pre-approved safeguard that converts the signal into action without a fresh negotiation.
5	The response portfolio has three parts, not one sequence: pre-emptive measures, contingent arrangements, and consciously accepted loss. They are chosen together, and there is no automatic hierarchy among them.

#	Key message
6	All seven GGA thematic systems — water, food, health, ecosystems, infrastructure, livelihoods, and cultural heritage — can be monitored this way, though with different data requirements.
7	The framework is compatible with the NAPX data model, enabling machine-readable, BTR-ready adaptation monitoring, and it generates the evidence that funders currently request as a “climate rationale” without requiring an attribution study.

Part 1: The Core Concept

1.1 Three questions, not one

Think of an adaptation pathway as a boat on a river. As long as the water level is within a safe range, the boat navigates normally. As the water drops, the boat can still navigate — but with increasing difficulty, rising cost, and shortening margin. At some point, the boat can no longer proceed on its current route. That is the threshold.

Current NAP monitoring tells you how often the boat has grounded. This guide shows how to measure how far the water level is from the point where grounding becomes inevitable — and then adds the two questions that determine whether that measurement can be acted on: the boat was designed for the river as it was surveyed decades ago, so how far has the river already departed from that survey; and can the boat be modified faster than the river is changing?

The monitoring chain
Tuning epoch → Hazard conditions → System state → Functional performance → Distance to threshold → Rate comparison → Pathway decision
Most monitoring chains begin at “hazard conditions”. Beginning one link earlier — at the tuning epoch — is what makes this chain diagnostic rather than merely descriptive. It tells you not just that the system is under stress, but why: because its parameters encode a climate that no longer exists.
The three links most useful for governance are: distance to threshold (how much room is left), adaptation debt (how much room was lost before anyone measured), and the rate ratio (whether the room can be rebuilt in time).

1.2 The safe operating window — and why the window moves

For every GGA system in your NAP, the current adaptation pathway operates within a safe window. Beyond the edge of that window, the pathway begins to fail. The window has four zones:

Zone	What it means	What to do
GREEN Safe	Current pathway is adequate. System delivers its function reliably, with margin intact.	Continue incremental adaptation. Standard monitoring. Maintain the tuning-epoch audit cycle.
AMBER Stress	Still functioning, but margins are shrinking. Reliability is declining, costs rising, recovery from shocks slower.	Increase monitoring frequency. Scope alternative pathways. Begin costing the contingent arrangements that will bridge a transition.
ORANGE Transition	Failure is likely within the planning horizon. Preparation for change is needed now.	Begin pathway transition planning. Commit long-lead preparatory actions. Activate the pre-committed instrument attached to the trigger.
RED Unsafe	Current pathway can no longer reliably deliver system function.	Transform. Relocate. Redesign. Or implement the pre-planned successor pathway, with contingent arrangements covering the transition period.

The window itself is moving

It is tempting to treat a threshold as a fixed value with an uncertainty range. In practice many thresholds are defined by reference to an environmental statistic — “reservoir reliability under a one-in-five dry year”, “the design storm”, “the hundred-year flood”, “days above the crop’s critical temperature in a normal season”. When the underlying distribution shifts, the reference shifts with it. The consequence is important and easy to miss: distance to limit can shrink even when nothing about the system has changed, simply because the reference has been re-estimated on newer data.

Every dashboard update should therefore decompose the change in distance to limit into two parts: how much the system moved, and how much the reference moved. A system whose margin is being eroded entirely by reference drift needs a different response — re-tuning of standards — from one whose margin is being eroded by physical deterioration or rising demand. Recording both also protects against a real governance failure mode: a threshold quietly redefined so that a system stays green on paper.

1.3 The lead-time rule — the most important principle in this guide

Act before the threshold — not when you reach it
Many adaptation transformations take a long time to implement: resettlement programmes, crop system transitions, energy portfolio restructuring, or ecosystem corridor redesign can each take 10–20 years.
If a threshold is projected to be reached in 15 years and transformation takes 15 years, preparation must begin now.
The trigger rule is: begin preparation when (time remaining to threshold) is equal to or less than (lead time for transition) plus a safety buffer.
The lead time to be used is the longest lead time in the pathway, including the social and political lead time — community engagement, land acquisition, legal reform — which is frequently longer than the technical lead time and is routinely omitted from the calculation.

Example – coastal settlement
A coastal settlement is projected to become unsafe due to sea-level rise and storm surge within 18 years.
Managed resettlement requires 12 years of planning, legal process, and physical relocation.
Community engagement and political commitment require a further 5 years, and cannot be compressed by adding budget.
The safety buffer recommended is 5 years.
Since 18 years is less than 12 + 5 + 5, the Commitment Trigger has already been missed. The correct response is a Type D fast-track pathway combined with contingent arrangements to carry the risk during the transition.

1.4 The three core metrics

The framework has three headline metrics. Together they locate a system in time — where it has come from, how much room is left, and whether it can move fast enough — and each is computable by the people who run the system, from data they either hold or know they lack.

Metric	Definition	How to compute it	What it tells you
Adaptation Debt (AD)	How far the environment has moved since the period whose statistics the system's parameters encode.	Re-fit the relevant distribution on the most recent 20–30 years of record. Express the shift in the design variable's own units: e.g. the 1-in-10-year 24-hour rainfall depth is now 92 mm against the 74 mm the network was sized for. AD = 18 mm, or 24%.	The deficit already incurred, before any projection. Answers the funder's question — is there a climate problem here? — with observed data rather than an attribution study.
Distance to Limit (DTL)	How much safe room remains between the system's current modelled state and the decision threshold.	DTL = (decision threshold value − current modelled state) ÷ reference safe range. Report alongside years-to-limit, using the 10th percentile of modelled projections, not the median.	The forward margin, and the basis for trigger timing.
Rate Ratio (RR)	The environment's rate of change divided by the system's intrinsic rate of adjustment.	RR = (rate of change in the design variable, per decade) ÷ (rate at which the system can re-tune that variable, per decade). The denominator comes from asset replacement cycles, code revision cycles, breeding cycles, planning cycles, capital turnover.	Whether monitoring discipline can save this system at all. RR below 1: the system can track the environment if triggers are respected. RR above 1: the system will fall behind even with perfect trigger discipline, and must be redesigned for flexibility or scheduled for transformation.

Reading the three together
High debt, comfortable distance: the system is mistuned but not yet failing. Re-tune the standards now, cheaply, while there is room. This is the most common and most neglected situation.
Low debt, shrinking distance: the system was well tuned but demand or exposure is rising, or the environment is moving fast. Check whether the erosion is coming from the system or from reference drift.
Any debt, rate ratio above 1: the system cannot be kept in range by re-tuning on its current cycle. Either shorten the cycle — faster code revision, shorter-lived assets, modular design — or plan the transformation now, because the arithmetic will not improve.
A system can be GREEN on distance to limit and still be in serious trouble on rate ratio. This is the most dangerous case of all, because everything on the dashboard looks fine.

1.5 The mistuning test: why no counterfactual is required

NAP teams and project proponents are routinely asked to demonstrate a "climate rationale": to show what would have happened without climate change, and to isolate the portion of an investment attributable to it. This is difficult for good reason — it asks for a counterfactual development path that does not exist, and increasingly it asks for event-scale attribution, which is not available at the scale at which it is demanded. The burden falls most heavily on countries with the sparsest observational records, which is precisely the wrong way round.

This framework does not require a counterfactual, and NAP teams should say so explicitly when they submit. The test it applies instead is a mistuning test, and every element of it is observable:

The mistuning test — five statements that constitute a climate rationale
1. This system delivers this function, for these people, and failure looks like this.
2. Its design parameters, standards and operating rules encode the environmental statistics of this period (the tuning epoch), evidenced by this document.
3. Re-fitted on recent record, the relevant distribution has moved by this amount (the adaptation debt).
4. The system's modelled state now sits this far from the threshold at which it stops delivering the function (distance to limit), and is projected to reach it in this many years.
5. The next pathway takes this long to prepare and deliver, which is why action is required now rather than later.
Together these five statements say what a climate rationale is supposed to say — that this investment addresses a climate-driven loss of system performance — without asserting anything about attribution, additionality or a baseline world. They are auditable, and they are answerable from national records.

Two consequences follow. Adaptation is not distinguished from development by intent or by an additional-cost test, but by whether the intervention restores an essential variable to its acceptable range and by which part of the response portfolio it occupies. And the evidentiary burden shifts from modelling a counterfactual economy to documenting the standards a country already uses — a task a ministry can complete from its own filing cabinets.

1.6 The response portfolio replaces the linear pathway sequence

Pathway options are conventionally set out as a sequence that progresses from incremental improvement through diversification and substitution to transformation and, finally, relocation or managed retreat. That ordering is intuitive and it embeds an assumption worth making explicit: that pre-emptive action is always preferable, that contingency instruments are what you fall back on, and that accepted loss is what remains when everything else has failed.

That assumption does not survive contact with practice. A pre-emptive measure that costs more than the losses it avoids, over the period it is needed, is not the responsible choice merely because it is pre-emptive. And contingent arrangements are not a residual: they are the only instruments that operate on the timescale of a transition, which is exactly when a system is most exposed. This guide therefore treats the responses not as a sequence but as a portfolio in three parts, chosen together, with no automatic hierarchy among them.

Part of the portfolio	What it contains	Typical lead time	What it is for
P — Pre-emptive	Re-tuning of standards and rules; structural investment; diversification; substitution; transformation; planned relocation. The classic adaptation pathway.	Years to decades (Annex C)	Moving the system so that the essential variables stay in range.
C — Contingent	Risk transfer and insurance; regional risk pools; contingency reserves and contingent credit; shock-responsive social protection; forecast-based and anticipatory finance; emergency operating rules; standby capacity.	Months to 3 years	Carrying the risk that pre-emptive action has not yet removed — above all during the transition period, when the old pathway is failing and the new one is not yet delivering.
L — Loss acceptance	A deliberate, recorded decision that a specified output will be allowed to fall outside its acceptable range, with who bears it stated, and with compensation, support or exit arrangements where appropriate.	Immediate, but requires prior deliberation	Making explicit what is otherwise decided by default through underinvestment — and identifying what must be reported at the adaptation–loss and damage interface.

The transition-period gap
When a Type C trigger fires, the successor pathway begins a lead time of 5, 10 or 20 years. During that period the system is, by definition, operating beyond the point at which its current pathway was judged adequate. Monitoring frameworks are usually silent about this window.
This is where contingent arrangements belong, and it is why they cannot be treated as a last resort. The correct question at the moment a trigger fires is not only “what is the next pathway?” but “what carries the risk between now and the day it delivers?”
Cape Town is the canonical case: the threshold was known, the successor options were known, but nothing was in place to carry the system through the 6–12 months that emergency groundwater development required. The gap was closed by rainfall and by demand response, not by design.

1.7 Intolerability comes before optimisation

A portfolio approach invites a cost-benefit test across the three parts, and for most decisions that is appropriate. But some losses are not tradeable, and treating them as though they were is both wrong and politically corrosive. Loss of life. Loss of a community’s continued existence in place. Loss of a language, a burial ground, or an irreplaceable cultural site. Permanent loss of a nation's habitable territory. These are not inputs to an optimisation; they are constraints on it.

The first substantive step in building the monitoring framework is therefore a partition, arrived at through a declared consultative process with the people who bear the consequences, and recorded:

Class	Definition	How it is treated
Intolerable	Losses that are not acceptable to the affected society regardless of the cost of avoiding them.	Removed from cost-benefit analysis entirely. Addressed pre-emptively, and the decision threshold is set on a cost-effectiveness basis: what is the least-cost way of preventing this, not whether preventing it is worth it. Triggers for these thresholds are non-discretionary.
Tolerable	Losses society is prepared to weigh against the cost of avoiding them.	Subject to portfolio optimisation across pre-emptive, contingent and loss-accepting responses. Trigger levels may be adjusted with reasons recorded.

Why the partition must come first, and who makes it
If the partition is made after the analysis, it is made by whoever ran the analysis — usually a technical agency, using an implicit valuation that no one has agreed to. Making it first, explicitly, puts the value judgement where it belongs and makes it contestable.
The partition must be made with the people who would bear the loss, not on their behalf. Loss acceptance chosen by a community and loss acceptance imposed on it are identical in a portfolio model and opposite in every other respect.
Record for each intolerable-class threshold: who was consulted, when, through what process, and when the determination will be revisited. An intolerability determination with no named process is not usable.
The intolerability register is also the natural national record of soft and hard limits, and the point at which the NAP connects to loss and damage reporting.

Part 2: Designing Your Monitoring System – Nine Steps

Work through these steps for each GGA system in your NAP. Step 0 is preparatory; Steps 1 to 9 build the registers, the dashboard and the governance arrangements in the order in which each is needed. Outputs feed directly into the NAPX data bundle and the national adaptation dashboard.

Step 0 — Build the source corpus

Register every source document — design standards, code tables, hydrological studies, crop trials, health protocols, past NAP documents — with a DOC-[CC]-xxx identifier in Sheet K of the NAPX bundle before any other work begins. This step carries more weight than it appears to, because the tuning-epoch inventory in Step 2 is built almost entirely from documents that are already in the filing cabinet.

Step 1 — Define systems, functions, essential variables and the intolerability partition

List the GGA thematic systems relevant to your country's NAP. For each system, write a one-sentence statement of the core function it must deliver, and identify the current adaptation pathway — the bundle of measures now in place. Then do three further things.

First, translate the core function into essential variables: the specific outputs whose values determine whether the function is being delivered, stated so that failure is recognisable. "Maintain stable food production" is a function; "household staple availability in kilograms per capita per season, and the frequency of seasons below the viability level" are essential variables. Only the second can be monitored.

Second, and this is the requirement with the widest consequences, state each essential variable disaggregated by the groups whose experience of it differs — by district, by income, by tenure, by gender, by whether a household is connected to the network or at the end of it. The system's status is then the status of the worst-off group, not the population average. A drainage network whose average performance is comfortably green while the informal settlement at the outfall floods twice a year is not a green system; it is a system with a specification failure. Where disaggregated data does not yet exist, record that as a monitoring gap with a date by which it will be closed, and use the best available proxy in the interim.

Third, complete the intolerability partition described in §1.7 for this system, and record the consultative process behind it.

Step 1 outputs
Table 1 – System and Function Register (Annex A, fields 1–5)
Table 1b – Essential Variable Register, disaggregated by exposure group (Annex A, fields 6–9)
Table 1c – Intolerability Register, with process record (Annex A, fields 10–12)

Step 2 — Build the tuning epoch inventory and compute adaptation debt

For most NAP teams this step will be the fastest source of usable findings in the whole framework, because it requires no modelling and no projections — only the documents that already govern how systems are built and operated.

For each system, identify the parameters, design values, standards, thresholds and operating rules that encode an assumption about the climate. Then, for each, find the record period it was estimated from. This is the tuning epoch. Typical examples: the rainfall series behind the intensity–duration–frequency curves used to size drainage; the flood-frequency analysis behind a bridge or spillway; the design temperature table in the building code; the planting calendar in the extension manual; the disease seasonality assumed in the health surveillance protocol; the loss distribution behind an insurance product or a contingency reserve.

Then re-fit the relevant distribution on the most recent record — 20 to 30 years where available — and express the difference in the parameter's own units. That difference is the adaptation debt. Report it three ways: in physical units, as a percentage of the design value, and as the number of years by which the system is effectively out of date.

Field	What to record	Example
Parameter	The design value, standard or rule that encodes a climate assumption.	1-in-10-year 24-hour design rainfall depth, urban drainage code, Table 4.2
Tuning epoch	The record period the parameter was estimated from, and the source document ID.	1961–1990 (DOC-MW-014)
Epoch age	Years since the end of the tuning epoch.	36 years
Re-fitted value	The same statistic re-estimated on the most recent available record.	1996–2025 record: 92 mm
Adaptation debt	Difference, in units and per cent.	+18 mm, +24%
Debt status	Whether the parameter has been revised, is under revision, or is unrevised.	Unrevised
Retirement plan	When this parameter will be re-fitted, by whom, under what authority.	Code revision cycle 2027, Ministry of Works, standards committee

Why this matters more than it looks
It converts a diffuse claim — "climate change is affecting us" — into a specific, documented, national list of parameters that are demonstrably out of date, with the evidence attached. That list is a work programme, a budget request and a climate rationale at the same time.
It is computable at Tier 0: no models, no scenarios, no downscaling. A country with a thin observational record can still complete it for the parameters where record exists, and the gaps it exposes are themselves the specification of what the observing network needs.
It captures a failure mode that distance-to-limit alone cannot see: a system that is already operating outside the envelope it was built for, but whose failures are being absorbed as maintenance cost, deferred renewals and small recurrent losses rather than showing up as a threshold breach.
A national adaptation programme can be organised as a debt-retirement schedule across the parameter inventory — which standards get re-fitted, in what order, at what cost. That is a more defensible programme structure than a list of projects.

Step 3 — Set up the threshold register

For each system function, identify the thresholds beyond which the current adaptation pathway fails. Use all four threshold types: biophysical (physical or biological limits); functional (performance standards below which the system no longer delivers); decision (precautionary trigger points set before actual failure); and social or governance (political, economic, or community tolerance limits). For each threshold record the variable name, threshold value, units, data source, confidence level, and whether the threshold is hard or soft. The decision threshold remains the most important: it is the value that triggers action, placed conservatively before the functional threshold.

Two further fields are required. Reference basis records whether the threshold is stated in absolute terms ("35 °C wet-bulb") or relative to an environmental statistic ("the 1-in-5 dry year"). Thresholds of the second kind drift as the distribution drifts and must be re-stated each time the reference is re-fitted. Reference vintage records the record period the reference statistic was estimated from — in effect, the threshold's own tuning epoch.

When the dashboard is updated, decompose any change in distance to limit into the part caused by system movement and the part caused by reference re-estimation. Report both. A system whose margin is being consumed entirely by reference drift needs its standards re-tuned, not its assets rebuilt; a system losing margin on both counts is in a materially worse position than either figure alone suggests. Record every threshold revision in a threshold change log with the reason, so that the difference between re-estimation and goalpost-moving is visible to the Pathway Review Committee.

Step 4 — Build the indicator register

For each threshold, identify indicators showing how close the system is to it. Four classes of indicator are used, and a complete register draws on all four.

Class	What it is	Examples
Observed	Data from existing monitoring networks. Shows what is already happening.	Rainfall, yields, river discharge, admissions, outage hours.
Modelled	Outputs from system models that translate hazard conditions into system performance. Shows what is likely to happen.	Projected yield from a crop model; projected reservoir reliability from a hydrology model.
Distance-to-limit	Directly measures how much safe room remains: (threshold value − current modelled state) ÷ reference safe range.	Days above critical flowering temperature this season versus the threshold.
Margin and brittleness	Measures whether the system's capacity to absorb shocks is eroding, independently of its mean state. These often move first.	Rising year-to-year variance in the essential variable; lengthening recovery time after a shock; rising autocorrelation in the performance series; falling reserve or buffer levels; rising cost per unit of service delivered; increasing frequency of emergency operating rules.

The fourth class matters because a system can lose resilience without its average performance changing: it goes on delivering, but from a narrower and narrower operating margin, so that a disturbance it once absorbed now tips it over. Monitoring mean state alone certifies such a system as healthy until the year it is not. Recovery time after a shock is the single most practical indicator in this class — how long after a drought, flood or heat event does the system return to normal service — and most agencies can construct it retrospectively from records they already hold.

Where an essential variable is disaggregated, its distance-to-limit indicator is disaggregated too, and the system's reported value is the worst group's value.

Step 5 — Set trigger rules, and attach an instrument to each

Define the rules that determine what happens when an indicator reaches a certain value. There are four trigger levels:

Type	Condition	Response
A – Surveillance	An indicator enters the warning band.	Increase monitoring frequency. Verify data quality. Report to the Pathway Review Committee at the next cycle.
B – Preparation	Projected time to threshold ≤ transition lead time + safety buffer.	Begin scoping and planning the next pathway. Cost the contingent arrangements that will cover the transition. Secure the preparation budget.
C – Commitment	Long-lead investments or policy changes must begin now if they are to deliver before the threshold.	Initiate irreversible preparatory actions: resettlement planning, crop diversification extension, energy portfolio redesign, land acquisition, legal reform.
D – Emergency	The existing pathway has failed and crisis-driven change is needed.	Deploy a bridging solution and activate contingent arrangements while the structural response is initiated. This should be rare in a well-managed NAP; when it occurs, record why the earlier triggers did not fire or were not acted on.

Write each trigger as a precise rule: "If [indicator] exceeds [value] for [duration], then [action]." One further requirement changes what a trigger is.

The Trigger–Instrument Register: a trigger without an instrument is a wish
For every Type B and Type C trigger, name the legal or financial instrument that converts the signal into action without a fresh negotiation. If no such instrument exists, the trigger is a statement of intent and should be recorded as one.
Instruments to name, one or more per trigger: a standing budget line or multi-year appropriation that releases on the trigger condition; a contingent credit line or drawdown facility; a framework contract with pre-qualified suppliers; a pre-approved environmental and social safeguard clearance; land identified, valued and banked; a statutory power already delegated to the responsible authority; a pre-negotiated water, power or supply contract; a parametric insurance or risk-pool policy whose payout condition matches the trigger condition.
Record for each: instrument type, legal basis, holder, ceiling or capacity, activation authority, time from activation decision to funds or works moving, and expiry or renewal date.
The Cape Town lesson generalises: the city knew its threshold and knew its options, but emergency borehole development required 6–12 months of lead time that had not been pre-contracted. Threshold awareness without a pre-committed instrument produced crisis management, not pathway switching.

One further discipline. Where a threshold sits in the intolerable class under §1.7, its trigger is non-discretionary: activation is not subject to a fresh cost-benefit judgement at the moment it fires, because that judgement was made — and recorded — when the partition was agreed.

Step 6 — Build the response portfolio

For each system, pre-define the responses that will be activated when a trigger fires. This is the pathway library, organised as a portfolio with three parts (§1.6). Each entry should include name, part of the portfolio (P, C or L), key measures, estimated lead time to implement, approximate cost range, responsible institution, activating trigger, a benefit statement and a coverage note.

Field	What it records	Why it matters
Portfolio part (P / C / L)	Whether the entry is pre-emptive, contingent, or a loss-acceptance decision.	Makes the portfolio composition visible, and forces the question of what carries risk during a transition.

Field	What it records	Why it matters
Benefit statement	What this response produces, not only what it prevents: health, productivity, employment, service reliability, ecosystem services, fiscal savings.	A Type B or C trigger is in practice a budget request. Framed only as risk reduction it is a cost to be deferred; framed with its returns it is an investment case a finance ministry can act on. This follows the benefits framing in the 2025 NAP Technical Guidelines.
Coverage note	Which failure modes and which exposure groups this response actually covers — and which it does not.	Supports the requisite-variety check below and prevents a library that looks full but addresses only one failure mode.
Boundary note	Whether the response exports risk outside the system boundary — downstream, downwind, to a neighbouring district or a later generation.	A response that moves the problem across the boundary registers as success inside the boundary. This must be visible.

Two checks on the portfolio

The variety check. A regulator can only hold a system inside its safe range if it has at least as many distinct responses available as the system has distinct ways of failing. List the failure modes for the system — for a water supply: drought, contamination, infrastructure failure, demand growth, upstream abstraction, salinity — and check that the portfolio contains a response for each. A library with four entries that all address drought is not a library with four options; it is a library with one, listed four times. Where a failure mode has no response, that is the priority gap, and it is usually invisible until the mode occurs.

The observing check. A response cannot be triggered by a signal the country cannot see. For each trigger, confirm that the indicator is actually observable at the required frequency and spatial resolution, with an institution responsible for producing it. Where it is not, either specify a proxy and record the loss of precision, or record the observing gap as a funded item in the NAP. This is the constructive form of the data-scarcity problem: not a reason to delay the framework, but a specification of what the observing network must deliver, derived from decisions rather than from general aspiration.

Step 7 — Screen the portfolio on rate ratio and flexibility

The purpose of this step is to identify, in advance, the systems that cannot be kept safe by monitoring discipline alone — because the environment is moving faster than the system can be re-tuned — and to change what is asked of them.

For each system, estimate two rates. The environmental rate is how fast the governing design variable is moving, per decade, taken from the re-fitting done in Step 2 and from projections. The intrinsic adjustment rate is how fast the system can actually change that parameter in practice: the code revision cycle, the asset replacement cycle, the breeding cycle, the planning cycle, the tariff review cycle, the political cycle for anything requiring legislation. Their ratio is the Rate Ratio.

Rate Ratio	Interpretation	What the framework requires
RR well below 1	The system can track the environment comfortably if triggers are respected.	Standard monitoring and trigger discipline. Maintain the debt-retirement schedule.
RR near 1	The system can just keep up, with no slack for delay.	Shorten the revision cycle where possible. Reduce the safety-buffer assumption in trigger timing, since there is no margin for slippage. Strengthen contingent arrangements.

Rate Ratio	Interpretation	What the framework requires
RR above 1	The system will fall behind even with perfect trigger discipline. Re-tuning on the current cycle is arithmetically incapable of keeping pace.	Three options, and one of them must be chosen explicitly: shorten the adjustment cycle (modular and replaceable design, shorter asset lives, rolling standards revision, faster procurement); build in over-specification so that a single re-tune covers several decades of drift; or schedule transformation now and use contingent arrangements to carry the interim risk. Continuing to monitor and re-tune on the existing cycle is not an option, and a dashboard that shows GREEN for such a system is misleading.

The rate ratio is also the most useful screen for deciding where flexibility is worth paying for. Where re-tuning is fast and cheap relative to the environmental rate, precise estimates are worth having. Where re-tuning is slow, precision is worth less than optionality: staged and modular designs, real options, reversible commitments, and decisions that perform acceptably across the whole plausible range of the threshold rather than optimally against a single estimate. A practical rule: if the preferred decision changes across the plausible range of the threshold value, choose the flexible option and stop trying to narrow the estimate.

Step 8 — Design the dashboard

Bring the registers together into a monitoring dashboard, one row per system. The core columns are current state, trend, modelled projection, threshold value, distance to threshold, probability of crossing within 5, 10 and 20 years, current pathway, trigger status and next pathway. Five further columns and one rule complete it.

Additional column	What it shows	Source
Tuning epoch / debt	The governing parameter's record period and the size of the adaptation debt.	Step 2
Rate ratio	Environmental rate ÷ intrinsic adjustment rate, with the RR band.	Step 7
Margin trend	Direction of the brittleness indicators — recovery time, variance, buffer levels.	Step 4
Instrument status	Whether the pre-committed instrument for the next trigger exists, is in preparation, or is absent.	Step 5
Worst-group status	The zone of the worst-off disaggregated group, alongside the aggregate.	Step 1

The rule: the system's reported zone is the worst of its aggregate zone and its worst-group zone. A system may not be reported as GREEN while any monitored group within it is in ORANGE or RED. This one rule does more to align monitoring with the equity language of the UAE Framework than any additional indicator would.

The coupling register

Rows in a dashboard invite the assumption that systems fail independently. Frequently they do not: they share a master variable. In Malawi, Lake Malawi's level governs hydropower, irrigation, municipal supply and downstream ecology simultaneously. Maintain a short coupling register listing, for each master variable, the systems that depend on it, and assess their thresholds jointly. Two systems each showing a comfortable independent margin may have almost no joint margin if a single dry sequence moves both at once. Where a coupling exists, the dashboard should show the systems adjacent and flag the shared driver.

Step 9 — Monitor the transition, and govern the trigger

It is tempting to treat the framework as complete at the moment a trigger fires. In practice that is where the risk of failure is highest, and two things need to be monitored from that point.

Transition delivery

Once a pathway switch has been triggered, the lead-time assumption becomes a live commitment that can be checked. Track the early performance indicators listed in Annex C — is the design complete, is procurement moving, are the first hectares restored, is the framework contract signed — and compare actual elapsed time against the assumed lead time. Slippage in delivery consumes the safety buffer directly. Define a re-trigger rule at the outset: if cumulative slippage exceeds the safety buffer, escalate to Type D and activate contingent arrangements to cover the extended exposure. Record the transition-period risk holder explicitly: for the years between trigger and delivery, who carries the consequences if the threshold is crossed early.

Comply or explain

A trigger that fires and is ignored is worse than no trigger, because it converts a monitoring system into a record of warnings that were available and disregarded. The governance rule is simple and should be adopted in the NAP's own institutional arrangements: when a Type B or Type C trigger fires, the responsible institution either activates the pre-committed instrument, or records a written deferral decision naming the decision-maker, the reason, the revised date and the interim risk arrangement. Deferral decisions are tabled at the next Pathway Review Committee meeting and carried in the annual report.

Trigger integrity audit
Each annual review should check three things about the triggers themselves, not only about the systems.
Were any threshold or trigger values changed during the year, and was each change recorded with a technical reason in the threshold change log? Re-estimation on new data is legitimate; adjustment that keeps a system green is not, and only the log makes the difference visible.
Did any trigger fire without either activation or a recorded deferral? This is the framework's own failure indicator.
Did any system reach ORANGE or RED without having passed through AMBER? That indicates the indicator set is not sensitive enough, or the observing frequency is too low — a defect in the monitoring system rather than in the adaptation.

Part 3: Reference Cards for the Seven GGA Systems

Each card provides a compact reference for one GGA thematic system, to be adapted to national context. Each gives the core function and the typical current pathway; the typical tuning epochs to look for in Step 2; the key thresholds; a margin indicator for Step 4; the typical intrinsic adjustment rate that forms the denominator of the rate ratio in Step 7; trigger examples; and the three parts of the response portfolio — pre-emptive options, contingent arrangements, and the loss-acceptance question that the intolerability partition must settle.

1. Water	
Core function	Maintain reliable access to water of acceptable quantity and quality for people, agriculture, ecosystems, and energy production.
Typical current pathway	Water-use efficiency improvements · Small reservoir and water-point rehabilitation · Watershed protection · Seasonal water allocation planning · Demand management
Typical tuning epochs	Reservoir yield and firm-supply rules estimated from a historical inflow series · Design drought and 1-in-N dry-year definitions · Abstraction licences set on a recharge estimate of a given vintage · Flood-frequency curves behind spillway design
Key thresholds	Groundwater abstraction persistently exceeds sustainable recharge | Reservoir reliability falls below 85% under dry-year scenario | Dry-season river flows breach ecological or supply minimum | Salinity intrusion renders current source unusable
Margin indicator	Recovery time of storage after a drought sequence · Number of days per year on emergency operating rules · Falling ratio of live storage to annual demand · Rising unit cost of delivered water
Intrinsic adjustment rate	Allocation rules 1–5 yrs · Tariff review 3–5 yrs · Abstraction licensing cycle 5–10 yrs · Major storage 7–17 yrs · Basin institutional reform 5–13 yrs
Trigger examples	Unmet water demand exceeds 15% in 3 of 5 years | Groundwater level declines below critical trend for 5 years | Projected 10-year reservoir reliability falls below 85%
P — pre-emptive options	Efficiency gains → diversified storage → conjunctive use → basin-scale allocation reform → demand restructuring → flexible water portfolio management
C — contingent arrangements	Drought contingency reserve and pre-approved emergency abstraction · Pre-contracted tanker and emergency borehole capacity · Standing agreement for inter-basin or bulk transfer · Index-based drought insurance for irrigation schemes
L — loss acceptance question	Which uses are curtailed first, at what level of restriction, and who decides? Are ecological flows in the tradeable class or the intolerable class?

2. Food and Agriculture	
Core function	Maintain food production, food access, and agricultural livelihoods within acceptable risk bounds.
Typical current pathway	Improved drought-tolerant seed · Adjusted planting dates · Conservation agriculture · Soil-water conservation · Small-scale irrigation · Pest and disease management
Typical tuning epochs	Planting calendars in extension manuals, derived from a historical onset-of-rains distribution · Varietal release trials conducted under the climate of the trial decade · Agro-ecological zone maps · Crop insurance loss distributions
Key thresholds	Heat stress days above crop tolerance during the critical reproductive stage | Seasonal soil moisture deficit beyond feasible irrigation range | Growing season length falls below viability threshold | Probability of crop failure exceeds 1 in 3 years

2. Food and Agriculture	
Margin indicator	Year-to-year yield variance rising while mean yield holds · Lengthening household recovery time between poor seasons · Falling seed and grain carry-over stocks · Rising share of area replanted
Intrinsic adjustment rate	Planting calendar advice 1 yr · Agronomic practice 1–3 yrs · Varietal turnover 8–12 yrs including delivery · Irrigation scheme 5–12 yrs · Land-use and tenure reform 10–20 yrs
Trigger examples	Probability of yield below food-security threshold exceeds 30–35% within 10-year horizon	Crop failure in 3 of 5 years in hotspot districts	Projected suitable area shrinks below minimum threshold
P — pre-emptive options	Improved seed within current crop → crop diversification → crop substitution → mixed food system → territorial food-system restructuring and livelihood transition
C — contingent arrangements	Strategic grain reserve with pre-agreed release rules · Shock-responsive social protection with climate triggers · Forecast-based anticipatory cash transfer · Area-yield or index insurance · Pre-positioned emergency seed
L — loss acceptance question	Which production systems will not be sustained in which districts, over what period, and what transition support is owed to the households in them?

3. Health	
Core function	Protect population health and health service continuity from climate-sensitive illness, mortality, and facility disruption.
Typical current pathway	Heat advisories · Surveillance and early warning · Vector control · Resilient health facility design · WASH strengthening · Emergency preparedness
Typical tuning epochs	Disease seasonality assumed in surveillance protocols and stock planning · Facility design temperatures and cold-chain specifications · Staffing rosters built on a historical admissions profile · Vector distribution maps
Key thresholds	Heat stress reaches unsafe levels for normal outdoor labour and activity	Climate-sensitive disease suitability shifts permanently into new areas	Health facilities are repeatedly flooded or heat-disrupted	Malnutrition and disease risks combine beyond coping capacity
Margin indicator	Rising surge-capacity utilisation during ordinary seasons · Lengthening return-to-normal time after events · Cold-chain excursion frequency · Stock-out rate for climate-sensitive commodities
Intrinsic adjustment rate	Protocols and rosters 1–2 yrs · Surveillance system upgrade 2–5 yrs · Facility retrofit 3–7 yrs · Service network reconfiguration 5–15 yrs
Trigger examples	Health facility disruption exceeds threshold in 3 consecutive years	Heat-health risk class rises permanently to severe band	Disease suitability expands into new districts with persistence probability above threshold
P — pre-emptive options	Heat alerts → urban cooling and building standards → work-hour regulation and cool-zone infrastructure → settlement redesign or service network relocation
C — contingent arrangements	Standing emergency health financing window · Pre-qualified surge staffing roster · Pre-positioned commodity buffer with seasonal trigger · Mutual aid agreements between districts
L — loss acceptance question	Is any level of heat-attributable mortality treated as tolerable, and if so for whom? This is a paradigm case for the intolerability register.

4. Ecosystems and Biodiversity	
Core function	Maintain ecosystem integrity, recovery capacity, and provision of regulating and supporting services.
Typical current pathway	Protected area management · Restoration and revegetation · Fire management · Invasive species control · Watershed rehabilitation · Habitat protection
Typical tuning epochs	Protected area boundaries drawn around a historical species distribution · Fire return intervals and burn prescriptions from a past fire regime · Environmental flow rules from a historical hydrograph · Species lists and management plans of a given vintage
Key thresholds	Regeneration rate falls below disturbance rate | Fire return interval becomes too short for vegetation recovery | Wetland hydroperiod collapses | Species habitat suitability contracts beyond persistence threshold
Margin indicator	Post-disturbance recovery time lengthening across successive events · Falling recruitment relative to mortality · Rising share of area in early-successional state · Declining connectivity between habitat patches
Intrinsic adjustment rate	This is the system where the rate ratio most often exceeds 1. Management plans revise on 5–10 yrs; ecological adjustment by dispersal and community turnover operates over decades to millennia, against climate velocities of order 0.4 km per year. Assume RR above 1 unless demonstrated otherwise.
Trigger examples	Post-disturbance recovery fails in 2–3 successive cycles | Modelled habitat persistence falls below minimum threshold | Wetland extent drops below critical ecological function level
P — pre-emptive options	Conservation management → assisted regeneration → connectivity and corridor investment → assisted migration → landscape reconfiguration and managed transition to a different community
C — contingent arrangements	Ex-situ conservation and seed banking as a bridging measure · Emergency fire suppression capacity with pre-agreed activation · Standing agreement for emergency environmental flow releases
L — loss acceptance question	Which communities and species will not be maintained in place? Where the rate ratio exceeds 1, this question is unavoidable and is better asked deliberately than answered by attrition.

5. Infrastructure and Settlements	
Core function	Ensure continuity of essential services, access, safety, and habitability under climate stress.
Typical current pathway	Stronger design standards · Drainage upgrades · Local flood protection · Road rehabilitation · Cooling measures · Early warning and contingency planning
Typical tuning epochs	This system has the richest and most accessible tuning record: IDF curves and design storms; flood-frequency curves under a stated guideline; design temperature, wind and snow tables in the building code; pavement design temperature ranges; culvert and spillway return periods. Almost all are dated and documented.
Key thresholds	Infrastructure fails repeatedly before end of design life | Urban heat becomes unsafe for normal habitation during peak periods | Overtopping or erosion risk exceeds feasible defence capacity | Maintenance cost exceeds value or affordability
Margin indicator	Rising maintenance and emergency repair spend per kilometre or per asset · Shortening interval between repairs · Rising share of assets failing before design life · Lengthening service restoration time after events

5. Infrastructure and Settlements	
Intrinsic adjustment rate	Code revision 5–10 yrs; asset lives 30–100 yrs. The gap between these two numbers is the central problem of this system: a code revised today governs only new build, so the stock re-tunes at the replacement rate, not the code rate. Compute RR against the stock turnover rate, not the code cycle.
Trigger examples	Critical route interruption exceeds threshold in 3 of 5 years | Annual expected damage exceeds defined affordability ratio | Projected unsafe heat days exceed tolerance band within planning horizon
P — pre-emptive options	Retrofit to current standard → redesign to higher standard → modular and replaceable design to shorten the adjustment cycle → service relocation → managed retreat and strategic resettlement
C — contingent arrangements	Sovereign or municipal catastrophe risk transfer · Standing post-disaster reconstruction facility with pre-approved designs · Pre-qualified emergency works contractors · Contingent credit line with a parametric activation condition
L — loss acceptance question	Which assets will be allowed to fail and not be rebuilt, and which settlements will not be defended to the current standard? Stating this in advance is what makes retreat a policy rather than an abandonment.

6. Poverty and Livelihoods	
Core function	Maintain viable incomes, productive assets, and recovery capacity for households and communities under repeated climate shocks.
Typical current pathway	Livelihood diversification support · Savings and micro-insurance groups · Productive safety nets · Social protection · Climate information services · Skills upgrading
Typical tuning epochs	Safety-net caseload and budget calibrated to a historical shock frequency · Insurance premiums and payout triggers set on a past loss distribution · Seasonal calendars underpinning public works timing · Poverty targeting formulas built on pre-shock asset profiles
Key thresholds	Repeated shocks drive chronic household asset loss with insufficient time to recover between events | Migration becomes distress-driven and permanent | Dominant livelihood system loses viability | Poverty traps become self-reinforcing
Margin indicator	Median household recovery time relative to the interval between shocks — the single best margin indicator in this system · Rate of negative coping (asset sales, school withdrawal) at a given shock magnitude · Falling savings-group balances
Intrinsic adjustment rate	Transfer values and caseload 1 yr · Programme design 2–4 yrs · Labour market and value-chain transition 4–10 yrs · Household asset rebuilding 3–7 yrs after a major shock, which is the binding constraint when shock intervals shorten
Trigger examples	Median recovery time between shocks exceeds interval between shocks | Share of households below resilience minimum exceeds benchmark | Chronic climate-linked distress migration rises above threshold
P — pre-emptive options	Livelihood protection → diversification → market and labour transition → territorial economic restructuring and anticipatory adaptive social protection
C — contingent arrangements	Scalable social protection with pre-agreed vertical and horizontal expansion rules · Forecast-based cash before the shock · Contingency financing attached to the registry · Micro-insurance with parametric payout
L — loss acceptance question	Which livelihoods will not be sustained, and is the transition support offered adequate and timely enough that the exit is chosen rather than forced?

7. Cultural Heritage	
Core function	Maintain the physical integrity, continuity, use, and social meaning of cultural heritage under climate stress.
Typical current pathway	In-situ site protection · Drainage and flood barriers · Documentation and archiving · Conservation maintenance · Community stewardship support
Typical tuning epochs	Conservation treatment specifications developed for a historical temperature and humidity regime · Site drainage designed to a past rainfall standard · Visitor and access management built on a historical seasonal profile
Key thresholds	Erosion or flooding threatens irreversible loss of heritage fabric | Heat and humidity exceed material conservation limits | Repeated disasters make in-situ protection infeasible | Custodial communities are displaced or disconnected from heritage sites
Margin indicator	Rising conservation intervention frequency per site · Shortening interval between treatments · Rising share of collection or fabric in poor condition · Declining participation of custodial communities
Intrinsic adjustment rate	Conservation practice 2–5 yrs · Site protection works 3–8 yrs · Relocation or digital preservation programmes 5–15 yrs. Note that heritage fabric cannot be replaced at any rate, so for the irreversible component the intrinsic adjustment rate is effectively zero and RR is undefined rather than large.
Trigger examples	Probability of irreversible loss exceeds threshold within planning horizon | Recurring damage outpaces conservation recovery capacity | In-situ protection cost exceeds feasible budget and performance criteria
P — pre-emptive options	Protect in place → partial relocation of movable assets → digital preservation and controlled access → cultural continuity strategies independent of original physical location
C — contingent arrangements	Emergency stabilisation and salvage capacity on standby · Pre-agreed temporary relocation storage · Rapid documentation teams activated on a hazard forecast
L — loss acceptance question	Almost all irreversible heritage loss belongs in the intolerable class, which is precisely why this system's thresholds must be set with custodial communities and why its triggers should be non-discretionary. Where loss is unavoidable, the question becomes what continuity is preserved and by whom — which is a decision for the community, not the conservation agency.

Part 4: Worked Examples

Four worked examples. Malawi is a landlocked sub-Saharan African country with a predominantly rainfed smallholder agricultural economy, a hydropower-dependent electricity system, and exceptional freshwater biodiversity in Lake Malawi, which makes it a useful illustration across multiple GGA systems simultaneously. The Cape Town case is included because it is the clearest documented instance of the failure mode this framework exists to prevent.

Note on status: the trigger statuses shown are illustrative and must be re-derived nationally before use.

Example 1 — Maize-based food system, Malawi

Context
Malawi's food system is structured around maize monoculture, which covers approximately 70% of cultivated area and provides the primary caloric base for most households.
The current incremental adaptation pathway includes drought-tolerant seed varieties, conservation agriculture, adjusted planting dates, and small-scale water harvesting.
Projected temperature increases of 1.5–3.5 °C by 2050, combined with more frequent hot days during the critical tasseling-silking window, are reducing the effective viability envelope of this pathway.

Framework element	Malawi maize system
Core function	Maintain viable staple production and food access for smallholder households in southern and central districts
Essential variables, disaggregated	Household staple availability (kg per capita per season) and frequency of seasons below the viability level — reported separately for southern hotspot districts, female-headed households, and households without irrigation access. System status is the worst of these, not the national mean.
Intolerability partition	Intolerable: seasonal household caloric availability falling below the survival threshold in any district. Tolerable and subject to portfolio optimisation: reduction in maize area, substitution of the dominant crop, income loss from crop switching.
Current pathway	Improved maize seed (drought-tolerant) + conservation agriculture + adjusted planting calendar + small-scale water harvesting + post-harvest storage
Tuning epoch and adaptation debt	Planting calendars in extension manuals derive from a mid-to-late twentieth-century onset-of-rains distribution; varietal recommendations rest on trials conducted under the climate of the trial decade; agro-ecological zone maps are of a stated vintage. Step 2 action: re-fit onset, cessation and dry-spell distributions on the most recent 30 years by district and express the shift in days. This is achievable from existing national rainfall records and is the fastest available evidence that the current advice is out of date.
Key biophysical threshold	Days above 33 °C during the November–January tasseling-silking window exceeding district-specific critical frequency (maize pollen viability collapses above this temperature)
Key functional threshold	Probability of seasonal yield falling below the household food-security viability threshold (approx. 800 kg/ha in southern Malawi) exceeds 35% within a 10-year horizon
Decision threshold (trigger rule)	Begin transition planning if crop failure occurs in 3 of 5 years in hotspot districts, OR if modelled probability of sub-viable yield exceeds 30% within the next decade

Framework element	Malawi maize system
Margin indicator	Yield variance rising while mean yield holds; lengthening household recovery time between poor seasons; falling carry-over stocks; rising replant rate. These are expected to move before the mean yield does.
Model required	Process-based crop model (DSSAT or APSIM) forced with downscaled CMIP6 climate projections + household food access model
Rate ratio	Environmental rate: shift in the heat-day frequency and season-length distribution per decade. Intrinsic adjustment rate: agronomic advice can be re-tuned annually, but varietal turnover including breeding, certification, multiplication and last-mile delivery is 8–12 years. RR is therefore below 1 for calendar and practice adjustments and near or above 1 for varietal substitution — which is precisely why the seed-system trigger must fire far earlier than the extension-advice trigger.
Current trigger status	AMBER–ORANGE in southern Malawi: available evidence indicates hotspot districts entering the stress zone, with flowering-stage heat events approaching the decision threshold by the mid-2030s
Transition lead time	5–10 years for crop diversification; 10–15 years for territorial food-system restructuring; seed system transformation 3–6 years development plus 4–8 years build-out
P — next pathway (Type B)	Maize plus legume intercropping; introduction of sorghum, finger millet, and sweet potato as risk-spreading diversification. Benefit statement: dietary diversity and micronutrient gains, reduced input dependence, more stable seasonal income — an investment case, not only a risk case.
P — following pathway (Type C)	Crop substitution and value-chain development for heat-tolerant systems; irrigated dry-season diversification where water is available
C — contingent arrangements	Strategic grain reserve with pre-agreed release rules; shock-responsive social protection scalable on a seasonal forecast trigger; forecast-based anticipatory transfers before the lean season; pre-positioned emergency seed. These carry the risk during the 8–12 years the seed system takes to turn over.
Trigger–instrument register	Type B: extension budget line with a standing seasonal reallocation authority. Type C: multi-year seed-system appropriation, pre-qualified multiplication contracts, variety release fast-track protocol agreed with the registration authority. Where these do not exist, record the trigger as unfunded intent.

Example 2 — Shire Basin water–energy–food nexus, Malawi

Context
The Shire River drains Lake Malawi southward and provides the hydraulic head for a cascade of hydropower stations generating over 90% of Malawi's grid electricity. The same river supplies irrigation, municipal water, and downstream ecological flows.
Lake Malawi water levels — determined by inflows, rainfall and evaporation — are the master variable. They fell to critically low levels in the early 2010s, curtailing hydropower output severely.
This is a coupled water–energy–food system where threshold breach in one element cascades across all others. It is the primary entry in Malawi's coupling register.

Framework element	Shire Basin system
Core function	Maintain reliable hydropower generation, agricultural water allocation, municipal supply, and downstream ecological flows at economically and ecologically viable levels
Coupling register entry	Master variable: Lake Malawi level. Dependent systems: grid electricity, irrigation, municipal supply, downstream ecology, lake fisheries. These must be assessed jointly — each may show adequate independent margin while the joint margin under a single dry sequence is close to zero. On the dashboard they appear adjacent with the shared driver flagged.
Current pathway	Reservoir operation optimisation + catchment rehabilitation to reduce sedimentation + drought contingency planning + staged irrigation development
Tuning epoch and adaptation debt	Firm-yield and operating rules derive from a historical inflow series; the dry-year definition used in reliability testing is itself a statistic with a vintage; abstraction licences rest on a recharge and yield estimate of a given date. Step 2 action: re-fit the inflow and lake-level distributions on the most recent record and re-state the 1-in-5 dry year. Expect part of the apparent margin loss to be reference drift rather than system deterioration — decompose and report both.
Key threshold	Reservoir reliability falling below 85% under a 1-in-5 dry-year scenario; dry-season Shire River flows falling below minimum hydropower and ecological requirements
Decision threshold (trigger rule)	If modelled 10-year reliability under the dry-year scenario falls below 85%, initiate review of the operating pathway. If allocation deficit is projected to exceed threshold within 10 years, begin basin reallocation planning.
Margin indicator	Recovery time of lake level and storage after a dry sequence; days per year on emergency operating rules; ratio of firm to average generation; frequency of load-shedding attributable to hydrology
Model required	Basin hydrology model + reservoir operation model + sediment yield model + irrigation demand model + hydropower reliability module
Rate ratio	Operating rules can be re-tuned in 1–3 years, so RR is low for that lever. Generation portfolio diversification takes 10–15 years and basin allocation reform 5–13 years, so RR approaches or exceeds 1 for the structural levers. The implication is specific: the operating-rule lever will be exhausted long before the structural lever delivers, and contingent arrangements must bridge that decade.
Current trigger status	AMBER: progressive lake-level variability and increasing evaporative demand indicate shrinking reliability margins under high-emission scenarios by the 2040s
Transition lead time	10–15 years for utility-scale solar and regional grid integration to reduce single-river hydropower dependence

Framework element	Shire Basin system
P — next pathway (Type B)	Diversified energy storage portfolio; satellite reservoir development to reduce single-point dependence on the Shire cascade. Benefit statement: reduced outage cost to industry and health facilities, improved investment climate, lower fuel import exposure.
P — following pathway (Type C)	Basin-scale allocation reform; structural energy diversification (solar, wind); reduction of hydropower's dominant role in the national grid
C — contingent arrangements	Pre-negotiated regional power import agreement with a hydrology-linked activation condition; standing emergency generation capacity; drought contingency reserve with pre-agreed allocation curtailment order; index-linked contingent credit for the utility
L — loss acceptance question	In a severe dry sequence, which uses are curtailed and in what order: irrigation, industrial supply, municipal supply, ecological flows? Setting the curtailment order in advance, with those affected, is the difference between a policy and a scramble. Ecological flows in particular should be explicitly assigned to the tolerable or intolerable class rather than curtailed by default because they have no constituency in the room.

Example 3 — Urban heat exposure in Blantyre and Lilongwe

Context
Malawi's urban centres, particularly Blantyre and Lilongwe, are experiencing progressive urban heat island intensification combined with background warming. Low-income informal settlements — dense metal-roofed housing, minimal thermal mass, high surface albedo, limited vegetation — are already exposed to indoor temperatures substantially above outdoor ambient.
The current adaptation pathway — heat action plans, cooling centres, public advisories — has a well-defined safe window that is narrowing.
Unlike the other examples, urban heat involves a threshold that is partly social and political as well as biophysical: it concerns what communities and governments will accept. That dimension shapes both the pathway sequence and the trigger design.

Framework element	Malawi urban heat system
Core function	Maintain safe habitation and productive labour in urban settlements during heat events
Essential variables, disaggregated	Indoor peak temperature and night-time minimum by settlement type and tenure; hours of unsafe outdoor labour conditions by occupation; heat-attributable excess mortality by age group and settlement. Reported for informal metal-roofed settlements separately — the city-wide mean is not a meaningful statistic here, and reporting it is itself a specification failure.
Intolerability partition	Intolerable: indoor conditions incompatible with survival for infants and older people during peak events; heat-attributable mortality among outdoor workers. Tolerable and optimisable: loss of labour productivity, discomfort, cooling cost, restrictions on outdoor work hours.
Current pathway	Heat action plans + cooling centre provision + public heat advisories + water distribution during heat events + building retrofit pilot programmes
Tuning epoch and adaptation debt	Building practice and any applicable design temperature guidance derive from a twentieth-century temperature record; informal construction encodes no formal tuning at all, which is a distinct case — a system with no design epoch is not therefore well adapted, it is simply undocumented, and its effective epoch is whatever the vernacular practice was calibrated to. Step 2 action: re-fit peak temperature and heat-wave duration distributions on recent record and compare with any design values in use; where none exist, record the absence as the finding.
Key biophysical threshold	Wet-bulb temperature or heat index combinations exceeding physiological safety limits for sustained outdoor labour (approximately 35 °C wet-bulb globally; context-adjusted for acclimatisation and vulnerability profile). Indoor temperatures in metal-roofed informal housing exceeding sleep-disrupting and health-threatening levels (typically 38–40 °C indoor peak) during heat events.
Key functional threshold	Projected unsafe heat days exceed a tolerance band within the planning horizon such that cooling centre provision and advisory systems can no longer protect exposed populations reliably
Decision threshold (trigger rule)	If projected unsafe heat days in hotspot settlement zones exceed the tolerance band within a 10-year planning horizon, begin neighbourhood-level urban form redesign planning. If indoor temperature surveys show that building stock in high-density zones systematically exceeds health thresholds during moderate (not extreme) heat events, begin mandatory retrofit standard development.

Framework element	Malawi urban heat system
Margin indicator	Cooling centre utilisation rate during ordinary rather than extreme events; night-time minimum temperature trend, which determines whether the body recovers between days; health facility surge utilisation during heat periods; share of households reporting sleep disruption. Night-time minima are the best single margin indicator here and are usually already recorded.
Model required	Urban heat island model + population exposure map + building thermal performance model (accounting for metal-roof heat gain and thermal mass deficits) + labour productivity function linking wet-bulb temperature to economic output
Rate ratio	Advisory and cooling-centre measures re-tune in 1–2 years; reflective roofing standards in 3–5; meaningful retrofit of the stock in 8–15; urban form redesign in 10–20; settlement reconfiguration in 15–25 and only with sustained engagement. Against a heat distribution moving detectably per decade, RR is comfortably below 1 for advisories and above 1 for anything involving the building stock or urban form. That asymmetry is the whole strategic problem: the fast levers are the weak ones.
Current trigger status	AMBER: current heat events already stressing vulnerable populations, particularly during the October–November pre-rains heat period. Projections show rapid deterioration in hotspot zones under 2 °C+ warming scenarios, with unsafe heat day frequency doubling in Blantyre by the mid-2040s under high-emission pathways.
Transition lead time	Heat action plans and cooling centre network: 1–2 years. Urban greening and reflective roofing standards for new construction: 3–5 years. Building retrofit programme at meaningful scale: 8–15 years. Urban form redesign incorporating ventilation corridors, passive cooling and density regulation: 10–20 years. Strategic reconfiguration of settlement densities in highest-exposure zones: 15–25 years, and only with sustained community engagement and political commitment.
P — next pathway (Type B)	Urban greening programme (tree planting, green roofs, cool corridors) + mandatory reflective roofing standards for all new construction + expanded cooling centre network with guaranteed access for most vulnerable households + targeted building retrofit support for highest-risk informal settlement blocks. Benefit statement: reduced heat mortality and morbidity, recovered labour productivity in outdoor and informal sectors, lower peak electricity demand, improved school attendance and learning during heat periods, urban amenity and property value.
P — following pathway (Type C)	Urban form redesign: density regulation in highest-exposure zones, ventilation corridor requirements in development approvals, passive cooling design standards, mandatory green cover ratios. In extreme exposure zones: strategic reconfiguration of settlement patterns, requiring co-designed relocation options with affected communities.
C — contingent arrangements	Pre-positioned emergency cooling and water distribution capacity activated on a forecast trigger rather than on observed mortality; standing health surge financing for heat periods; pre-agreed work-hour regulation triggered by forecast wet-bulb conditions; emergency shelter agreements. These are the only instruments that operate on the timescale at which heat events arrive, and they carry the entire risk during the 8–15 years the retrofit pathway needs.
Trigger–instrument register	Type B: building code amendment authority (who can mandate reflective roofing, and on what statutory basis); municipal budget line for greening with multi-year commitment. Type C: land-use planning powers, development approval conditions, and — the binding constraint — a negotiated framework with settlement communities. Without the last of these, the Type C trigger cannot fire regardless of the evidence.

Framework element	Malawi urban heat system
Social acceptability dimension	Unlike biophysical thresholds, the social and political acceptability threshold for urban heat is not a fixed value. It depends on income levels, alternative housing options, government housing stock, and community trust in public institutions. Pathway transitions requiring relocation or major housing investment require 5–10 years of community engagement before any physical transition begins. This engagement lead time must be included in the trigger timing calculation alongside the technical lead time.
Key lesson for NAP teams	Urban heat thresholds have three dimensions: biophysical (wet-bulb limits), functional (cooling capacity exceeded), and social (community and political acceptance of pathway change). The slowest dimension — social acceptability — determines the trigger timing, not the fastest. Trigger rules must be calibrated to the longest lead time in the pathway, which in urban heat cases is typically the community engagement and political commitment requirement for settlement redesign.

Example 4 — Urban water security: the Cape Town Day Zero case

Context
Cape Town, South Africa, came within days of becoming the first major city to exhaust its municipal water supply. A three-year drought from 2015–2018 reduced combined reservoir storage from over 100% capacity to below 20%, triggering cascading restrictions and the near-activation of emergency groundwater supply points.
The city's response moved through successive pathway stages with increasing speed as the threshold approached: voluntary reduction targets, mandatory allocation cuts, tiered pricing penalties, then a near-collapse of the entire demand management paradigm as Day Zero — the projected date at which municipal taps would be turned off — was reached. The crisis was ultimately averted by dramatic demand reduction, exceptional rainfall in 2018, and emergency groundwater development.
The case illustrates both the value and the limits of the framework. The threshold was well-defined and known in advance. The failure was in trigger timing and, above all, in the absence of a pre-committed instrument: preparations for the next pathway were not activated early enough relative to the rate of reservoir decline, leaving the city in reactive crisis management during the final approach.

Framework element	Cape Town urban water system
Core function	Maintain reliable municipal water supply at or above minimum viable service levels for a city of four million people
Current pathway at crisis onset	Multi-dam reservoir system + demand management + tiered pricing + seasonal restrictions + water-saving awareness campaigns
Tuning epoch and adaptation debt	System yield and the assurance-of-supply rule were estimated from a historical inflow series. The critical point for other cities reading this case: had the inflow distribution been re-fitted on recent record before the drought, the yield figure the city was planning against would have been shown to be an overestimate — and the debt would have been visible years before the storage curve made it obvious. Adaptation debt is a leading indicator; storage level is a lagging one.
Key biophysical threshold	Combined reservoir storage falling below 13.5% (Day Zero trigger level) — the point at which normal municipal supply must cease and emergency groundwater collection points activated
Key functional threshold	Per-capita allocation below minimum viable level (50 litres per person per day) under sustained restriction; groundwater emergency supply network operationally unable to meet demand at this scale
Decision threshold (trigger rule)	If reservoir storage falls below 30% by May (start of dry season) with no recovery modelled within 12 months, activate emergency groundwater development and begin negotiation of alternative bulk water contracts
Margin indicator	The decisive one, and it was available: rate of storage decline relative to historical recovery rates, and the shortening interval between restriction escalations. Both moved well before the storage level itself became alarming.
Model required	Reservoir hydrology model with probabilistic seasonal inflow scenarios + demand model with behavioural response functions + groundwater yield model + regional transfer capacity assessment
What happened in practice	The city had 30% threshold awareness but lacked pre-committed emergency pathway contracts. Groundwater field development began in earnest only when storage was already below 25%. Emergency borehole drilling at crisis scale required 6–12 months of lead time that was not available. Day Zero was averted by rainfall and demand response, not by pre-planned pathway switching.

Framework element	Cape Town urban water system
Trigger status (retrospective)	ORANGE crossed to RED: the decision threshold was crossed but pre-committed pathway activation did not follow automatically. The system entered emergency management rather than planned pathway transition. Under the comply-or-explain rule in Step 9 this would have required a recorded deferral decision naming a decision-maker — which is precisely the record that did not exist.
Transition lead time	Emergency groundwater field development: 6–12 months. Bulk water transfer infrastructure: 3–7 years. Desalination capacity at meaningful scale: 2–5 years. Demand restructuring to permanently lower per-capita baseline: 2–4 years with strong institutional commitment.
P — next pathway (Type B)	Emergency aquifer development (Cape Flats, Table Mountain Group) + accelerated pressure management + mandatory water recycling requirements for commercial and industrial users + emergency demand reduction to 50 litres per person per day
P — following pathway (Type C)	Structural water portfolio diversification: desalination, water recycling and reuse at municipal scale, managed aquifer recharge, regional transfer agreements, and permanent demand ceiling below 500 million litres per day for the metro area
C — what was missing	This is the case's central lesson. What Cape Town lacked was not knowledge and not options but instruments: a pre-qualified drilling framework contract, a standing appropriation releasing on the 30% condition, a pre-negotiated bulk transfer agreement, pre-cleared environmental approvals for emergency abstraction. Any one of these would have converted a 6–12 month lead time into weeks. The C part of the portfolio is not a fallback here; it is the difference between a managed transition and a near-catastrophe.
Key lesson for NAP teams	Knowing that a threshold exists is not sufficient. The response portfolio must pre-commit specific actions to specific trigger levels, with pre-negotiated contracts and pre-approved budgets recorded in the Trigger–Instrument Register. In Cape Town's case, the lag between threshold awareness and pathway activation consumed the safety buffer and required crisis-mode management. The trigger rule must include the lead time calculation and the named instrument, not just the threshold value.

Part 5: Getting Started

5.1 You do not need sophisticated models to start

The framework is designed for tiered adoption. Start with what you have. A simple threshold estimate using expert judgement is better than no threshold at all. Improve the model tier as capacity develops. Note that the lowest tier requires no modelling at all: the tuning-epoch inventory is a documentary exercise.

Tier	What it involves	Good for
Tier 0 – Documentary	The tuning-epoch inventory (Step 2). Find the standards, design values and operating rules; record the record period each was estimated from; re-fit on recent observed data where a record exists. No modelling, no projections, no downscaling.	Every country, immediately. Produces a documented national list of out-of-date parameters, and identifies exactly where the observing gaps are.
Tier 1 – Empirical	Observed relationships, expert judgement, historical failure frequency. No modelling required.	Immediate start-up. All systems.
Tier 2 – Reduced-form	Simple statistical relationships and index models (e.g. yield response functions, heat thresholds, hydrology balance estimates).	Systems where relationships are well documented. Suitable for most NAP teams.
Tier 3 – Process-based	Crop growth models, reservoir operation models, flood inundation models, disease transmission models, urban heat models.	High-stakes, non-linear systems where early warning matters most: food, water, coastal infrastructure.
Tier 4 – Coupled	Multiple systems modelled together: water-food-energy nexus, climate-health-urban, coastal-settlement-infrastructure.	Complex coupled systems with cross-sector cascades. Requires specialist capacity. Use the coupling register to decide which couplings justify it.

5.2 Minimum institutional setup

The monitoring architecture requires a small but disciplined set of institutional roles. These do not need to be new organisations — they can be assigned to existing bodies. Two of them are easily overlooked in practice, and without them Steps 2, 5 and 7 have no owner: the Instrument Custodian and the Intolerability Process Owner.

Role	Responsibilities	Typical home
NAP Analytics Unit	Maintains threshold, indicator, tuning-epoch and trigger–instrument registers. Compiles the national dashboard. Coordinates annual review. Flags trigger status to decision-makers. Maintains the threshold change log.	Ministry of Natural Resources / Environment / Climate Change
Sector Model Custodians	Maintain sector-specific models. Update model runs against latest climate projections. Validate threshold values. Re-fit design distributions on current record. Propose adjustments to trigger rules.	Agriculture ministry (crop models), water agency (hydrology), health ministry (disease/heat), infrastructure agency
Climate Services Interface	Provides observational climate data, seasonal forecasts, and downscaled projections to all sector custodians. Delivers the re-fitted distributions that Step 2 and Step 3 require.	National meteorological service

Role	Responsibilities	Typical home
Subnational Observatories	Validate local relevance of national thresholds. Collect community-level impact evidence. Report local signals that may not appear in national data. Supply the disaggregated values on which system status depends.	District-level environment or agriculture offices
Instrument Custodian	Maintains the Trigger–Instrument Register. Establishes and renews the standing appropriations, framework contracts, contingent credit lines, risk transfer policies and pre-approved clearances attached to each trigger. Reports instrument status to the dashboard.	Ministry of Finance, with the national disaster risk financing function where one exists
Intolerability Process Owner	Convenes and records the consultative process that produces the intolerability partition, ensures the affected population is represented, and schedules its periodic revisit.	The NAP coordinating body, working with local government and civil society; must not be the same body that runs the cost-benefit analysis
Pathway Review Committee	Reviews trigger status annually. Receives deferral decisions under the comply-or-explain rule. Reviews the threshold change log and the trigger integrity audit. Recommends when to intensify, prepare, or transform. Has authority to recommend policy-level pathway changes.	Cross-ministerial committee with senior representation

5.3 Handling uncertainty

Thresholds are rarely known with certainty. This is not a reason to avoid setting them — it is a reason to document the uncertainty explicitly and to set decision thresholds conservatively, further from the functional threshold. For each threshold record: best estimate; lower and upper bounds; confidence level (high / medium / low); source type (direct measurement / modelled / expert judgement / literature); and review frequency. A decision threshold should always be placed before the functional threshold, and the more uncertain the functional threshold, the greater the precautionary gap.

Two disciplines on uncertainty
The decision-robustness rule. Before commissioning work to narrow a threshold estimate, test whether it would change the decision. Run the choice at the lower bound, the best estimate and the upper bound. If the preferred option is the same across the range, the uncertainty is not decision-relevant and the estimate is good enough; act now. If the preferred option changes across the range, do not spend the years required to narrow the estimate — choose the flexible, staged or reversible option, which is the correct response to a decision that is genuinely uncertain.
Re-estimation is not always an improvement. Under a changing climate, statistical models fitted to short recent records carry large parameter uncertainty, and a re-tuned design value can carry more error than the value it replaced. This is an argument for margins, staging and reversibility rather than for precise re-estimation — and it is a reason to state adaptation debt as a range with its own confidence level, not as a point estimate.

5.4 NAPX data infrastructure

If your NAP uses the NAPX v0.1 data bundle format, this framework maps directly onto it, adding fields rather than entity classes.

Framework element	NAPX entity / relation
Source documents (corpus)	document entity (Sheet K) – registered in Step 0 before all other work

Framework element	NAPX entity / relation
Risk pathways and threshold metrics	risk_pathway entity (Sheet D) – add threshold value, distance-to-limit, reference basis, reference vintage
Tuning epoch and adaptation debt	risk_pathway or a new parameter registry – add tuning_epoch_start, tuning_epoch_end, refitted_value, adaptation_debt_value, adaptation_debt_pct, debt_status, retirement_plan_date, source document ID
Adaptation functions and pathways	adaptation_function and solution entities (Sheets E, H) – add portfolio_part (P/C/L), benefit_statement, coverage_note, boundary_note
Monitoring indicators and trigger rules	indicator entity – add trigger_type, trigger_rule, indicator_class (observed / modelled / distance-to-limit / margin), disaggregation_group
Rate ratio	adaptation_function – add environmental_rate, intrinsic_adjustment_rate, rate_ratio, rate_ratio_band
Trigger–instrument register	new relation: trigger → instrument, with instrument_type, legal_basis, holder, ceiling, activation_authority, activation_lag, expiry
Intolerability partition	risk_pathway – add tolerance_class (intolerable / tolerable), process_record, consulted_groups, revisit_date
Investment concepts for next pathways	programme and project_concept entities (Sheet I)
Institution responsibilities	institution entity – linked via implemented_by and tracked_by predicates
Cross-system traceability	traceability relation table (Sheet J) – P → H → RP → AF → IC chain
Coupling register	new relation: master_variable → dependent systems, with joint assessment flag

5.5 Sequencing the first year

For a team starting from nothing, the following order gets a usable framework standing within twelve months and produces something reportable at each stage. Months 1–3: Step 0 corpus and Step 2 tuning-epoch inventory for the three highest-priority systems — this alone yields a defensible national statement about out-of-date standards. Months 3–6: Steps 1 and 3, essential variables with disaggregation, intolerability partition, threshold register at Tier 1. Months 6–9: Steps 4 to 6, indicators including at least one margin indicator per system, trigger rules, and the first pass at the Trigger–Instrument Register — expect most instruments to be absent, and record that as the finding. Months 9–12: Step 7 rate-ratio screening, Step 8 dashboard, and the governance arrangements in Step 9. Model tiers can be raised in later cycles; the architecture does not need to wait for them.

5.6 Boundaries and coupling

Two cross-cutting checks belong in every annual cycle. The coupling check asks which systems share a master variable and assesses their thresholds jointly, because independent margins can conceal a near-zero joint margin. The boundary check asks, for each proposed response, whether it moves risk outside the system boundary rather than reducing it: a drainage scheme that discharges faster downstream, an abstraction that lowers a neighbouring water table, a defence that redirects erosion along the coast, a land-use decision that displaces exposure onto a poorer district. A response that improves the essential variables inside the boundary while worsening them outside it is not adaptation; it is a transfer. Record it in the boundary note, and where the affected party is outside the reporting jurisdiction, say so.

Part 6: Reporting

The purpose of this Part is to show NAP teams that the framework's outputs are directly reportable — into the Belém Adaptation Indicators, into the BTR adaptation chapter, and at the interface with loss and damage — so that the monitoring system serves domestic decision-making and international reporting from a single set of registers rather than two parallel exercises.

6.1 Mapping to the Belém Adaptation Indicators

The indicators adopted at COP30 are voluntary, non-prescriptive and non-punitive, and countries retain full discretion over what they report. That discretion is an opportunity: a country reporting the metrics in this framework is reporting something considerably more informative than an activity count, and it maps naturally onto the dimensional targets of the UAE Framework.

UAE Framework dimensional target	What this framework supplies
Impact, vulnerability and risk assessment	The tuning-epoch inventory and adaptation debt figures constitute a documented, parameter-level assessment of where national systems are already mistuned — evidence of assessment that is specific rather than generic. Threshold registers with confidence levels and reference vintages record the state of knowledge and its gaps.
Planning	The response portfolio (P/C/L), the pathway lead times, and the intolerability register with its process record demonstrate country-driven, participatory planning with an explicit account of who was consulted on what was deemed unacceptable.
Implementation	The Trigger–Instrument Register is the strongest available evidence of implementation readiness: not a list of intentions but a list of appropriations, contracts, facilities and delegated powers, each with a named holder and an activation lag.
Monitoring, evaluation and learning	The dashboard, the trigger integrity audit, the deferral record under comply-or-explain, and the transition delivery tracker together constitute an operational MEL system — including, unusually, evidence about whether the monitoring system itself is working.

Two of the metrics are also strong candidates for national indicators in their own right. The share of critical design standards whose tuning epoch ends before a stated date is a single number that captures adaptation debt across a portfolio and can be tracked annually. The share of Type B and Type C triggers with a live pre-committed instrument captures implementation readiness in a way that project counts cannot.

6.2 The BTR adaptation chapter

The dashboard structure maps to the reporting sections of the BTR adaptation chapter. Three elements are worth drawing on directly: national circumstances and institutional arrangements can cite the institutional roles in §5.2 including the Instrument Custodian; impacts, risks and vulnerabilities can cite adaptation debt by sector, which is observational and does not require attribution; and progress on implementation can cite instrument status and transition delivery against assumed lead times, which is a more honest account of progress than expenditure.

6.3 The adaptation–loss and damage interface

This framework locates the boundary with loss and damage where it belongs — at the point where the response portfolio runs out — and it produces the evidence needed to report that boundary without asserting anything about liability.

What the registers say about limits
A soft limit is visible in this framework as a threshold whose only available responses lie outside the country's current means: the pathway exists in the library, its lead time and cost are known, and the Trigger–Instrument Register records that no instrument exists to activate it. That is a precise, evidenced statement of a soft limit, and it identifies exactly what support would remove it.
A hard limit is visible as a system where the rate ratio exceeds 1 with no available lever to shorten the adjustment cycle, and where the pre-emptive portfolio contains no option capable of holding the essential variables in range at any cost. Ecosystems and irreplaceable heritage fabric are the common cases.
Deliberate loss acceptance — the L part of the portfolio — is the category that connects to loss and damage reporting, and recording it as a decision, with the process behind it, is what distinguishes a national policy choice from a loss imposed by absence of means.
Reporting these three things does not require attribution science, and it does not prejudge any question of responsibility. It reports what the country can and cannot do with the instruments it holds.

Implementation Checklist

Use this checklist to track progress in setting up the framework. Complete each item before moving to the next.

Phase	Action	Done?
Preparation	Complete Step 0: build source corpus (Sheet K) and assign DOC-[CC]-xxx IDs to all source documents	☐
Preparation	Convene core team: NAP Analytics Unit, sector model custodians, climate services	☐
Preparation	Identify the Instrument Custodian and the Intolerability Process Owner	☐
Step 1	List all GGA-relevant systems and write a core function statement for each	☐
Step 1	Document the current adaptation pathway for each system	☐
Step 1	Translate each core function into essential variables, disaggregated by exposure group	☐
Step 1	Complete the intolerability partition with a recorded consultative process	☐
Step 2	Build the tuning-epoch inventory: parameters, record periods, source document IDs	☐
Step 2	Re-fit the governing distributions on recent record and compute adaptation debt	☐
Step 2	Assign a retirement plan (date, owner, authority) to each unrevised parameter	☐
Step 3	Identify at least one threshold for each system function (start with Tier 1: empirical)	☐
Step 3	Set a decision threshold for each system, placed before the functional threshold	☐
Step 3	Record threshold confidence level, source, and review frequency	☐
Step 3	Record reference basis and reference vintage; open the threshold change log	☐
Step 4	Identify observed indicators for each threshold (existing monitoring data)	☐
Step 4	Identify model-based distance-to-limit metric for each threshold	☐
Step 4	Identify at least one margin or brittleness indicator per system (recovery time is the default)	☐
Step 5	Write at least one Type B (Preparation) trigger rule for each system	☐
Step 5	Calculate transition lead time for the next pathway in each system, including social lead time	☐
Step 5	Confirm Type B trigger is set so that (time-to-threshold) ≥ (lead time + safety buffer)	☐
Step 5	Complete the Trigger–Instrument Register; mark triggers with no instrument as unfunded intent	☐
Step 6	Pre-define at least two successor pathways for each system	☐
Step 6	Record lead time, responsible institution, and activation trigger for each successor pathway	☐
Step 6	Classify every entry as P, C or L; ensure at least one contingent arrangement covers each transition period	☐
Step 6	Add a benefit statement, coverage note and boundary note to each entry	☐
Step 6	Run the variety check (a response for every failure mode) and the observing check	☐
Step 7	Estimate environmental rate and intrinsic adjustment rate; compute the rate ratio	☐
Step 7	For every system with RR ≥ 1, record which of the three responses has been chosen	☐

Phase	Action	Done?
Step 8	Build national dashboard with current state, trend, threshold, distance, and trigger status	☐
Step 8	Add debt, rate ratio, margin trend, instrument status and worst-group columns	☐
Step 8	Apply the worst-group rule: no system reported GREEN while any group is ORANGE or RED	☐
Step 8	Compile the coupling register for systems sharing a master variable	☐
Step 8	Schedule annual dashboard review plus review after major climate events	☐
Step 9	Adopt the comply-or-explain rule and the deferral record in the NAP institutional arrangements	☐
Step 9	Define the re-trigger rule for transition slippage and name the transition-period risk holder	☐
Step 9	Schedule the annual trigger integrity audit	☐
NAPX	Map framework outputs to NAPX entity registries (Sheets B–K) and relation tables (Sheet J)	☐
NAPX	Confirm all fields listed in §5.4 are present in the bundle	☐
Reporting	Confirm dashboard can generate structured data for BTR adaptation chapter	☐
Reporting	Map outputs to the UAE Framework dimensional targets (Part 6)	☐

Annex A: Monitoring Sheet Template

Complete one sheet per GGA system. The 52 fields are grouped into nine blocks so that a team can complete blocks A–C at Tier 0 and add the rest as capacity develops. This template maps to the NAPX entity registries and the national dashboard.

Block A — System and function (fields 1–9)	
1. System name	
2. Subsystem (if applicable)	
3. Core function	
4. Current adaptation pathway	
5. Main hazard / stressor set	
6. Essential variables (outputs that define success)	
7. Disaggregation groups used	
8. Acceptable range, per group	
9. Group currently worst placed	

Block B — Intolerability partition (fields 10–12)	
10. Losses classified as intolerable for this system	
11. Consultative process: who, when, how	
12. Date partition will be revisited	

Block C — Tuning epoch and adaptation debt (fields 13–19)	
13. Governing design parameter(s)	
14. Tuning epoch (record period encoded)	
15. Source document ID (DOC-[CC]-xxx)	
16. Epoch age (years since epoch end)	
17. Re-fitted value on recent record (with record period)	
18. Adaptation debt (units, per cent, confidence)	
19. Debt status and retirement plan (date, owner, authority)	

Block D — Thresholds (fields 20–28)	
20. Threshold type (biophysical / functional / decision / social)	
21. Threshold description	
22. Threshold value (with units)	
23. Reference basis (absolute, or relative to which statistic)	
24. Reference vintage (record period the reference was fitted on)	
25. Confidence level: High / Medium / Low	
26. Threshold source (DOC-[CC]-xxx ID from corpus)	
27. Hard or soft	
28. Last revision date and reason (threshold change log reference)	

Block E — Indicators (fields 29–36)	
29. Indicator name	
30. Indicator class (observed / modelled / distance-to-limit / margin)	
31. Indicator unit	
32. Data source (DOC-[CC]-xxx ID)	
33. Observation frequency	
34. Model used (if applicable) and tier	
35. Margin indicator and its current trend	
36. Observing gap, if any, and plan to close it	

Block F — Position (fields 37–42)	
37. Current indicator value (and worst-group value)	
38. Reference safe value	
39. Decision threshold value	
40. Failure threshold value	
41. Distance to decision threshold	
42. Change in distance since last review, split into system movement and reference movement	

Block G — Rates and timing (fields 43–47)	
43. Projected time to decision threshold (10th percentile)	
44. Environmental rate of change (per decade)	
45. Intrinsic adjustment rate (per decade), and what sets it	
46. Rate ratio and band	
47. Lead time required for next pathway, technical and social	

Block H — Triggers, instruments and portfolio (fields 48–51)	
48. Trigger status (Green / Amber / Orange / Red) and trigger type (A / B / C / D)	
49. Next response, with portfolio part (P / C / L) and benefit statement	
50. Pre-committed instrument: type, legal basis, holder, ceiling, activation authority, activation lag, expiry	
51. Contingent arrangement covering the transition period, and the transition-period risk holder	

Block I — Governance (field 52 and closing fields)	
52. Boundary note: does the chosen response export risk outside the system boundary?	
Responsible institution	
Deferral record, if a trigger fired without activation (decision-maker, reason, revised date, interim arrangement)	
Review date	

Annex B: National Dashboard Template

One row per GGA system. Review annually and after major climate events. Share with the Pathway Review Committee. The values below are illustrative only — they are not national findings.

Table B1 — Position and trigger status

System	Current pathway	Threshold metric	Current vs threshold	Distance	Yrs to limit	Trigger
Water	Efficiency + small reservoirs	Reservoir reliability (%)	88% vs 85%	3 pts	~8 yrs	AMBER
Food	Improved maize + CA	Prob. of yield failure (%)	22% vs 35%	13 pts	~7 yrs	AMBER
Health	Surveillance + heat plans	Facility disruption days	4 vs 10 days	6 days	>10 yrs	GREEN
Ecosystems	Protected areas + restoration	Regeneration success rate	72% vs 60%	12 pts	>15 yrs	ORANGE
Infrastructure	Design upgrades + drainage	Annual damage (% GDP)	0.4% vs 1.0%	0.6 pts	~12 yrs	AMBER
Livelihoods	Diversification + safety nets	Recovery time vs shock interval	0.7 vs 1.0	0.3 ratio	~6 yrs	AMBER
Cultural heritage	In-situ protection + docs	Prob. of irreversible loss (%)	8% vs 25%	17 pts	>20 yrs	GREEN

Table B2 — Debt, rate and readiness

System	Adaptation debt	Rate ratio	Margin trend	Instrument	Worst group	Next response (P / C / L)
Water	+14% on the design dry year	0.6	Recovery time lengthening	Partial	AMBER	P: diversified storage · C: standing transfer agreement
Food	Planting calendar 30+ yrs old	1.1	Yield variance rising	None	ORANGE	P: crop diversification · C: reserve + scalable social protection
Health	Surveillance protocol vintage 2009	0.5	Stable	Yes	GREEN	P: urban cooling standards
Ecosystems	Fire regime pre-1990	>1	Recovery failing after successive events	None	ORANGE	P: assisted regeneration · L: partial managed transition
Infrastructure	IDF curves 1961–90, +24%	>1	Repair interval shortening	Partial	ORANGE	P: redesign standard, modular design · C: catastrophe risk transfer

System	Adaptation debt	Rate ratio	Margin trend	Instrument	Worst group	Next response (P / C / L)
Livelihoods	Caseload set on 1990s shock frequency	0.8	Recovery time approaching shock interval	Yes	AMBER	C: scalable social protection · P: market transition
Cultural heritage	Conservation specification vintage	n/a	Intervention frequency rising	None	GREEN	P: digital preservation

Note the rows where the two tables disagree. Infrastructure reads AMBER on position but carries a rate ratio above 1 and a 24% adaptation debt, so its comfortable years-to-limit figure is misleading: the standard governing new build is out of date and the stock turns over more slowly than the environment is moving. Ecosystems reads ORANGE on both. Food reads AMBER on position while the worst-placed group is already ORANGE — under the worst-group rule the system is reported ORANGE.

Dashboard notes
Trigger status colour codes: GREEN = safe operating zone. AMBER = stress zone, enhanced monitoring. ORANGE = transition zone, preparation triggered. RED = unsafe zone, transformation required.
The reported zone is the worse of the aggregate zone and the worst disaggregated group’s zone. A system is never reported GREEN while any monitored group within it sits in ORANGE or RED.
Years-to-limit estimates use the 10th percentile of modelled projections (precautionary), not the median.
Debt column: the size of the gap between the governing parameter’s tuning epoch and current conditions. A large debt with a comfortable distance is a cheap problem now and an expensive one later.
RR column: rate ratio. A value at or above 1 means the system cannot be kept in range by re-tuning on its current cycle, whatever the trigger status says. Read this column before the trigger column.
Instr. column: whether the pre-committed instrument for the next trigger exists (Yes), is partial or in preparation (Partial), or is absent (None). A trigger with no instrument will not fire in practice.
All source document IDs (DOC-[CC]-xxx) for threshold and tuning-epoch evidence are recorded in the full Monitoring Sheet (Annex A) and Sheet K of the NAPX data bundle.

Annex C: Lead Times for Adaptation Solutions

Two tables of reference lead times: one for the long-lead pre-emptive solutions that appear most frequently in NAPs, and one for contingent arrangements, whose lead times are short by design and are the reason they can cover a transition that pre-emptive measures cannot.

Purpose

Threshold monitoring and pathway switching only work if decision-makers can act before limits are crossed. That requires knowing, in advance, how long it takes to design, finance, procure, and operationalise an adaptation solution — before it can begin delivering outcomes. This Annex provides reference lead times for the long-lead adaptation solutions that appear most frequently in NAPs, organised by the seven GGA thematic systems.

The lead-time rule
For any pathway switch requiring a long-lead solution, the Commitment trigger (Type C) must be set so that: $T_{trigger} \le T_{threshold} - (T_{development} + T_{build\text{-}out} + T_{social} + T_{safety\_buffer})$.
The T_{social} term is stated explicitly because it is routinely omitted. Community engagement, land acquisition, legal reform and political commitment cannot be compressed by adding budget, and in settlement and land-use cases they are the binding constraint.
Example: if a watershed system needs an integrated storage facility (development 5 years, build-out 7 years), the Type C trigger must fire at least 12–14 years before the water-supply threshold will be crossed.
Never set the trigger at the threshold year. By the time a threshold is crossed, it is already too late to develop and deploy a structural adaptation solution.

Summary: lead times by solution category

Solution category	Dev lead	Build-out	Outcomes visible	Impact quantifiable	Trigger tier
Hard infrastructure (reservoirs, flood defences, coastal works, transport, energy)	2–7 yrs	4–10 yrs	0–2 yrs after commissioning	3–10 yrs	Tier C or D
Ecosystem restoration (watersheds, wetlands, mangroves, landscape)	2–4 yrs	5–15 yrs	2–5 yrs	5–15 yrs	Tier C
Institutional / governance reform (basin authorities, social protection, EWS)	2–5 yrs	3–8 yrs	1–3 yrs	4–10 yrs	Tier B–C
Service systems (forecasting, anticipatory finance, health, grain logistics)	2–4 yrs	2–5 yrs	0–2 yrs	2–6 yrs	Tier B
Land-use transition and resettlement (planning reform, managed retreat)	3–10 yrs	5–20 yrs	2–4 yrs	5–20 yrs	Tier C or D

Contingent arrangements: the short-lead column

The lead times below are what make contingent arrangements the instrument of choice for the transition period. Note the distinction between the time to establish an instrument and the time to activate one that already exists — the second is what matters when a trigger fires, and it is short only if the first was done years earlier.

Contingent arrangement	Time to establish	Time to activate once established	Covers
Sovereign or municipal parametric risk transfer / regional risk pool	1–3 yrs	Days to weeks after the parametric condition is met	Sudden-onset losses; liquidity in the weeks after an event
Contingent credit line / drawdown facility	1–2 yrs	Days to weeks	Fiscal shock; emergency works financing
Shock-responsive social protection with pre-agreed scaling rules	2–4 yrs	Weeks, if the registry and payment rails exist	Household consumption and asset protection during and after shocks
Forecast-based / anticipatory financing	2–4 yrs	Days, on the forecast trigger — before the event	Pre-event protective action; livestock, seed, evacuation, prepositioning
Strategic reserve (grain, fuel, medical commodities) with release rules	1–3 yrs	Weeks	Supply and price shocks during the lean or peak season
Framework contract with pre-qualified emergency contractors	1–2 yrs	Weeks	Emergency works: drilling, repair, temporary defences
Pre-negotiated bulk supply or import agreement (water, power, food)	1–3 yrs	Weeks to months	Service continuity during a supply threshold breach
Standing appropriation with trigger-linked release authority	1–2 yrs (legislative)	Immediate on the trigger condition	Any pre-defined pathway activation without a fresh budget negotiation
Pre-approved environmental and social safeguard clearance	1–2 yrs	Immediate	Removes the approval lag that typically dominates emergency works timelines

How to use the two tables together
Read the pre-emptive lead time from the first table and the activation lag from the second. The gap between the trigger date and the delivery date is the exposure window, and the contingent arrangement is what covers it.
Cape Town's exposure window was 6–12 months of emergency drilling. A pre-qualified framework contract, establishable in 1–2 years at modest cost, would have reduced it to weeks. The cost of not having established it was a metropolitan water crisis.
If the combined pre-emptive lead time exceeds the years remaining, a Type D fast-track pathway or a bridging solution must be deployed while the structural solution is initiated — and the contingent arrangement is the bridge.

Outputs, outcomes and impacts — a practical distinction

For NAP monitoring and trigger design, three terms have distinct meanings. Outputs: the solution is deployed — kilometres of drainage built, forecast platform operational, hectares under restoration, grain reserve stocked. Outcomes: the system begins to function better — fewer outage hours, improved dry-season water reliability, reduced post-harvest loss; these typically appear one to five years after a solution becomes operational. Impacts: risk or vulnerability is materially reduced — avoided flood losses, lower mortality, fewer crop failures, reduced income volatility; these typically require three to fifteen years of operation and often depend on multiple hazard events to demonstrate statistically.

A common error in NAP M&E is evaluating long-lead solutions exclusively against impact metrics and concluding they are failing because impacts are not yet visible. Monitoring plans should track outputs and early-outcome indicators first. Expect robust impact data only after the full time horizon has elapsed. There is a corollary: this is also why the transition delivery tracker in Step 9 monitors elapsed time against assumed lead time rather than waiting for outcomes — during a transition, schedule adherence is the only performance signal available.

This Technical Guidance Note supports the implementation of the Threshold-Pathway Framework for National Adaptation Plans. It is designed for use alongside the NAPX v0.1 data model specification and the Open NAP workflow package. August 2026.