Water Board Basin Plans have An Narrative Biostimulatory Objective

WB Staff Plans for Phase 1: Guidance for consistent interpretation of narrative objective across all waterbody types, and numeric guidance for wadeable streams

Toxic cyanobacterial bloom in Clear Lake

Hypoxia-induced fish kill

Impact to fish habitat and aesthetics of trout stream

"waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses"
 - Central Coast Water Board Basin Plan 1990

Biostimulatory Science Products

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Scientific Foundation for Assessment of Eutrophication in California Waterbodies (TR871)

- Biostimulatory operating assumptions

Part I

Wadeable Stream Eutrophication Synthesis (TR 1048)

- Conceptual model and review of indicators
- Scientific bases for numeric targets
  - Aquatic life related uses (including **Mazor et al. in prep**)
  - Human related uses

“Scientific Foundations” Document Represents Tech Team’s Operating Assumptions Supporting Approach to Biostimulatory

- Intended as general resource for conceptual models and indicators where no numeric guidance exist
  - Across all waterbody types
- Based on literature reviews of 40 + years of global eutrophication science
  - Including peer-reviewed California eutrophication science on estuaries and wadeable streams
- States operating assumptions on approach to eutrophication assessment
  - Builds off of Tetra Tech (2006) Nutrient Numeric Endpoint approach

Scientific Foundation for Assessment of Biostimulatory Impacts to California Estuaries, Enclosed Bays, and Inland Waterbodies

DRAFT

Prepared for:
The California Environmental Protection Agency
State Water Resources Control Board
(Agreement Numbers D15-15001 and D15-15002)

By
Martha Sutula
Southern California Coastal Water Research Project

November 2018

SCCWRP Technical Report #871

What Science Could Be Used to Support Consistent Interpretation of Narrative Objective?

- Definitions of eutrophication (the problem) and biostimulatory
- Typology of waterbodies
- Generic conceptual models of risk pathways, indicators and linkage to beneficial uses
- Evidence of eutrophication impacts to California Waterbodies (problem statement)
- Key assumptions and principles (foundation for science we've conducted on wadeable streams & estuaries thus far)

KEY DEFINITIONS THAT FRAME BIOSTIMULATORY SCIENCE

Eutrophication (the Problem): the accelerated delivery, *in situ* production, and/or accumulation of organic matter within an aquatic ecosystem (Nixon 1995, Cloern 2001)

Nutrient Management

Low Impact Development

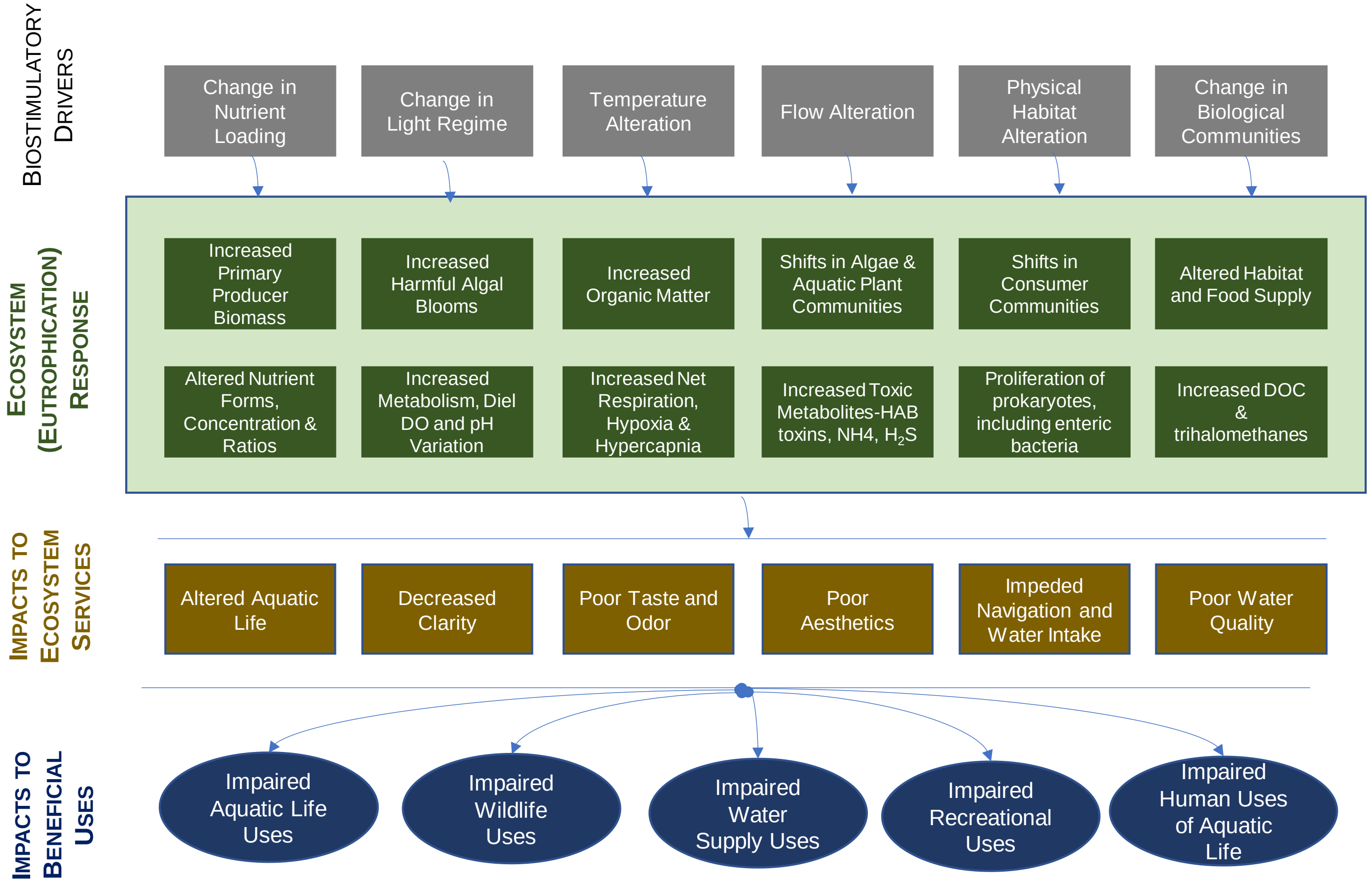
Watershed Restoration

Environmental Flows

Biostimulatory Substances and Conditions: substances such as nutrients (i.e. nitrogen, phosphorus, organic matter) or conditions, such as altered temperature, hydrology, etc. that can cause eutrophication (Cloern 2001, Paerl et al. 2011)

We Use a Waterbody Typology that is Consistent with California's Existing Definitions

- Wadeable Streams
- Non-wadeable Streams and Rivers
- Lakes
- Estuaries and enclosed bays
- Depressional Wetlands



Generic Conceptual Models

Link Impairment Pathways to Indicators

Generally Applicable Across All Waterbody Types

Table 2.3. Linkage of generic indicator groups to pathways of increased risk of beneficial use impairment. Precise metric used to measure response indicator may vary by waterbody type.

Response Indicator	Altered Aquatic Life	Contaminated or Low Yield Fisheries	Poor Taste and Odor	Poor Aesthetics	Impeded Navigation and Water Intake	Poor Water Quality
DO	x	x	x			x
pH, carbonate saturation state	x	x				x
Secchi Depth, Turbidity, TSS, light attenuation	x			x		x
Benthic and/or Planktonic Algal Biomass (e,g, chl-a)	x	x	x	x	x	x
Benthic or floating algal percent cover	x	x	x	x	x	x
Benthic or planktonic ash free dry mass, particulate organic C, N and/or P	x	x	x	x	x	x
Planktonic or benthic algal community composition	x	x	x			
Planktonic or benthic macroinvertebrate community composition	x	x				
Aquatic macrophytes Diversity, biomass, shoot height, density and percent cover, epiphyte load	x	x		x	x	
Harmful algal species abundance and toxin concentrations	x	x	x	x		x
Toxic nutrients or redox products (e.g. nitrate, phosphate, ammonia or sulfide)	x	x	x			x
Heterotrophic bacteria biomass or abundance	x		x			x
Increased DOC and trihalomethanes						x

Table 2.2. Most Important Risk Pathways Associated with Impairment of Sensitive Uses by Nutrient Pollution and Eutrophication. Aquatic life -related uses, ALU, are grouped to include: EST, MAR, COLD, WARM, MIGR, RARE, and SPWN beneficial uses. Birds, amphibian and terrestrial wildlife represented under WILD, MIGR, and RARE. Poor water quality can be linked to human or aquatic/wildlife uses.

Use	Altered Aquatic Life	Contaminated or Low Yield Fisheries	Poor Taste and Odor	Poor Aesthetics	Impeded Navigation and Water Intake	Poor Water Quality
ALU	X					X
WILD/MIGR/RARE	X	X				X
COMM/AQUA/SHELL	X	X	X			X
TRIB/CUL	X	X	X	X	X	X
MUN			X		X	X
NAV/IND					X	
REC-1			X			X
REC-2	X	X	X	X		X

Link Impairment Pathways to Uses

“Biostimulatory” Science

10 Key Assumptions and Principles

1. “Biostimulatory drivers” are defined as substances such as nutrients (i.e. nitrogen (N) and phosphorus (P) and associated organic matter) or conditions, such as altered physical habitat, temperature, hydrology, etc. that can cause eutrophication.
2. Assessment of biostimulatory impacts is based on the diagnosis of eutrophication and its consequences; inclusion of causal nutrients or other biostimulatory drivers are part of a comprehensive causal assessment and risk prevention approach.
3. Biostimulatory impacts to beneficial uses can be assessed through a framework developed for each waterbody type, with indicators that represent lines of evidence.
4. Assessment of biostimulatory impacts can consider evidence for impacts to both human and wildlife (aquatic and terrestrial) related beneficial uses.
5. Statewide bioassessment indices can be used as assessment endpoints from which to derive biostimulatory targets protective of aquatic life and related beneficial uses.

"Biostimulatory" Science

10 Key Assumptions and Principles

6. To account for total "biostimulatory" potential, thresholds should be based on total nutrients (as opposed to dissolved inorganic form) and for both N and Ps, as opposed to just controlling what is considered limiting on-site (either N or P).
7. Eutrophication symptoms may be caused by biostimulatory drivers far-field from the waterbody; thus assessment of biostimulatory impacts should take a watershed-wide approach.
8. Biostimulatory conditions can be a focal point of development of watershed-specific numeric targets and adaptive management strategies.
9. Implementation options to address biostimulatory conditions and substances should recognize the complexity of these drivers and how they can vary spatially and temporally from watershed to watershed and among certain waterbodies.
10. Generic conceptual models provide a starting point for more specific model development at a watershed- or waterbody-specific scale.

Evidence of Eutrophication Impacts in California Waterbodies

Intended to Support the Staff Report Problem Statement

- Organized by type of impacts
  - Toxigenic harmful algal blooms
  - Non toxic nuisance blooms
  - DO, pH Swings, Hypoxia and Acidification
  - Aquatic Vegetation

Provides Background on Biostimulatory "Drivers"

- Nitrogen, phosphorus (both inorganic forms and organic or particulate forms)
- Irradiance, water clarity and temperature
- Hydromodification
- Physical habitat change

Outline of Eutrophication Synthesis Report

Report is not complete; We expect advisory group questions and comments to inform additional work

- Definitions, with citation of “Approaches…” report
  - Eutrophication
  - Biostimulatory substances and conditions
  - Wadeable streams
- Wadeable Streams conceptual models and literature review of pathways of adverse impacts on beneficial uses
- ★ Evaluation of candidate eutrophication indicators
  - Eutrophication Response
  - (Causal) Biostimulatory Drivers
- ★ Synthesis of Threshold Science, As Basis for Policy Decisions on Numeric Targets
  - Aquatic Life
  - Human

EUTROPHICATION IMPACTS ON AQUATIC LIFE

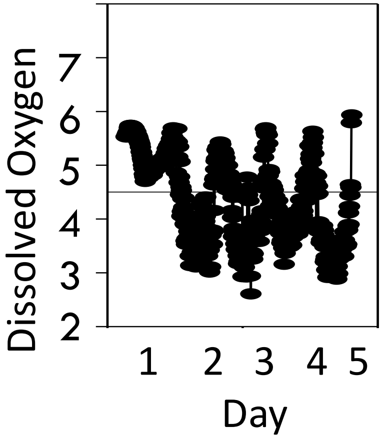
Biostimulatory Drivers

Smother habitat

excessive organic matter (OM) accumulation

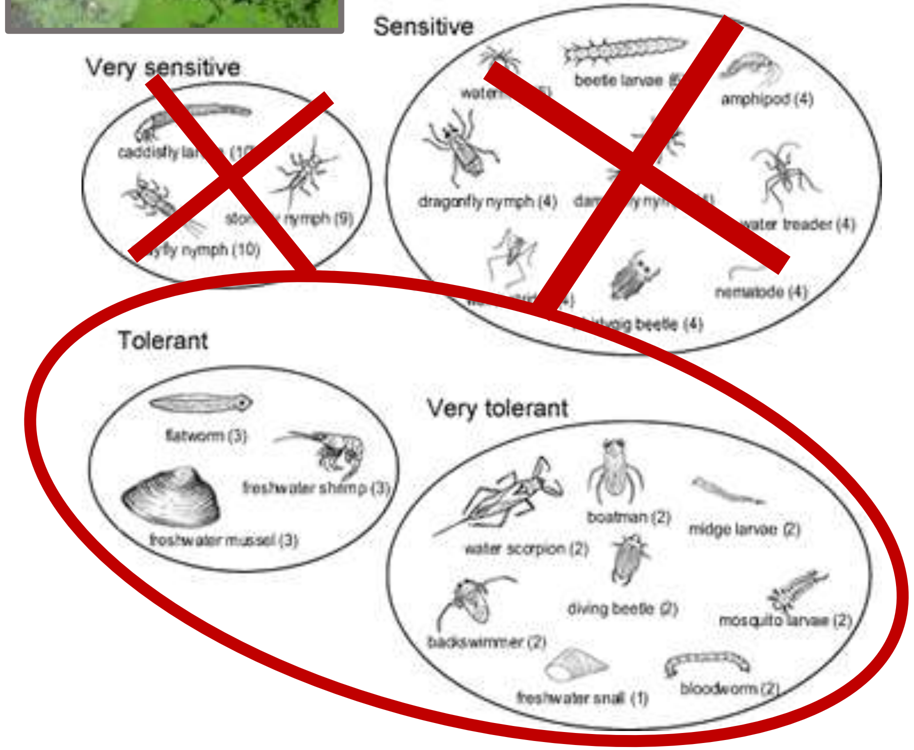
bacteria consume DO as they respire OM

Live biomass causes wide DO and pH fluctuations



Direct Effects

Toxicity



Eutrophication Impacts on Human Uses

Biostimulatory Drivers

excessive organic matter (OM) accumulation

Reduced Aesthetics

Pathogenic bacteria proliferate

Higher Risk of Toxic Blooms

Conceptual Models Provide Basis for Candidate Indicator Selection

Table 2.2. Linkage of eutrophication impairment pathways to specific measures of organic matter accumulation, altered benthic and water column chemistry and harmful algal blooms and associated toxins in wadeable streams.

Response Indicator	Altered Aquatic Life	Contaminated or Low Yield Fisheries	Poor Taste and Odor	Poor Aesthetics	Impeded Water Intake	Poor Water Quality
Organic Matter Accumulation						
Benthic and/or Planktonic Algal Biomass (as chl-a)	X	X	X	X	X	X
Benthic or floating macroalgal percent cover	X	X	X	X	X	X
Benthic or planktonic AFDM, or organic C, N, P	X	X	X	X	X	X
Aquatic macrophytes: biomass, shoot height, density	X				X	X
Aquatic macrophyte percent cover	X			X	X	
Water Column or Benthic Chemistry						
Continuous DO and pH; Diel range	X	X				X
Water colum biological or sediment oxygen demand	X	X				X
Gross Primary Production or Trophic State	X	X		X		X
Dissolved organic carbon, trihalomethane		X				X
Aquatic Community Measures						
Planktonic or benthic algal community composition	X	X				
Benthic macroinvertebrate community composition	X	X				
Harmful Algal Bloom						
Benthic CyanoHAB cell density and toxin	X	X	X	X		X
Particulate CyanoHAB cell density and toxin	X	X	X	X		X
CyanoHAB toxin concentration in tissue	X	X	X			X
SPATT Toxin concentration	X	X				X

Response Indicator Review Criteria

Met Criteria= Primary

Incompletely Met Criteria= Supporting

Indicators Should:

- Have a clear link to beneficial uses
- Show a trend either towards increasing or/and decreasing eutrophication with an acceptable signal: noise ratio
- Have a predictive relationship with biostimulatory drivers that can be modeled (empirical or mechanistic modeling)
- Have a scientifically sound and practical measurement process, with available SOP
- Have a scientific basis for a numeric target

It would be beneficial if indicators also:

- Were easy to understand to a non-technical audience (unambiguous)
- Is currently in routine use in statewide ambient monitoring programs
- Were adaptable for use at a range of spatial scales

Candidate Response Indicators Were Reviewed Using these Criteria

Table 2.3. Evauation of wadeable stream eutrophication response measures vis-à-vis evaluation criteria. Asterick (*) denotes applicability to eutrophication diagnosis at the metric level. Number represents strength of measure for each evaluation criterion, from 3 = best to 1= worst, while no number indicates no basis. Y= used in SWAMP or PSA assessments. H= human uses (REC1, MUN); AL = Aquatic life uses (WARM, COLD, WILD, RARE, SPAWN, MIGR)

Biostimulatory Indicator	Linkage to BU	BU Type	Robust Signal: Noise	Cost Effective	In Routine Use	SWAMP or PSA?	Model to Biostimulatory Drivers?	Basis for Numeric Target?
Organic Matter Accumulation								
Benthic and/or planktonic algal biomass (benthic chl-a, water column chl-a)	3	AL	3	3	3	Y	3	3
Benthic or floating macroalgal percent cover	3	AL, H	1	3	3	Y	1	AL= 1, H = 3
Benthic or planktonic AFDM, or organic C, N, P	3	AL	3	3	3	Y	3	3
Aquatic macrophytes: biomass, shoot height, density	2	AL		1	1		1	
Aquatic macrophyte percent cover	1	AL		3	3	Y	1	
Water and Benthic Chemistry								
Continuous DO and pH; Diel range	3	AL	3	2	3		3	3
Water column or sediment oxygen demand	1	AL	1	1	1		3	
Ecosystem metablism and trophic state	2	AL	2	1	1		3	
Dissolved organic carbon, trihalomethane	3	H	3	3	3		3	1
Aquatic Community Measures								
Planktonic or benthic algal community composition	3	AL	3 *	3	3	Y	2	3
Benthic macroinvertebrate community composition	3	AL	3*	3	3	Y	2	3
Harmful Algal Blooms								
Benthic cyanoHAB cell density and toxin	3	H, AL	2	3	3	Y	2	1
Particulate cyanoHAB cell density and toxin	3	H, AL	3	3	3	Y	2	3
CyanoHAB toxin concentration in tissue	3	H, AL	3	3	3		2	3
SPATT toxin concentration	2	H, AL	3	3	2		1	1

In Some Wadeable Streams With High Turbidity, Sestonic (water column) > Benthic Algal Biomass

- Water column chl-a is not a routine parameter in SWAMP wadeable stream bioassessment protocol
- In some streams, high turbidity and erodible soils limits benthic algal biomass
- Can also have high water column chl-a downstream of lakes and reservoirs
- Nationally, sestonic (water column) chl-a is a good measure of eutrophication and routinely measured parameters in many non-wadeable streams and some ag- or timber dominated landscapes
- We are summarizing literature on sestonic chl-a thresholds relating to aquatic and human uses, for consideration by the Water Board

Photo credit: NRCS.usda.gov

Sestonic Phytoplankton Blooms in Ag-dominated channel in the Central Coast

Applicability of Key Indicators and Bases for Threshold Science

Wadeable Streams

Good Light Penetration

Poor Light Penetration (Turbidity, Flow)

Best evidence derived from CA bioassessment data

Benthic Chla

AFDM

% Cover

TN and TP

TN and TP

Sestonic Chla

Evidence Comes from Literature (other States)

Benthic Cyanobacteria Cell Density & Toxins

Diel DO

Diel DO

DO, pH, Sestonic Cyanobacteria Cell Density, Particulate Toxins, tissue toxins

Basin Plan WQO, Statewide Guidance, Other State Literature

Non wadeable Streams

Following Indicators Were Advanced for Threshold Review

Table 3.1. Scientific basis for wadeable streams biostimulatory indicator numeric target. Beneficial use (BU) type refers to major pathway of impact to aquatic life (AL) related uses or to human (H) uses.

Indicator	BU Type	LOE	Key Literature Sources
Aquatic Community Structure			
Benthic algal community composition (ASCI)	AL	Supporting	ASCI (Theroux et al. in prep), Expert Biological Condition Gradient Interpretation (Paul et al. in prep)
BMI community composition (CSCI)	AL	Supporting	CSCI (Mazor et al. 2016), Expert BCG) Interpretation (Paul et al. in prep)
Causal (Biostimulatory Substances and Conditions)			
Nitrogen and phosphorus	AL	Primary	CA Stress-Response, changepoint and reference percentiles (Mazor et al. in prep, Fetscher et al. 2014)
Organic matter accumulation			
Benthic algal biomass (benthic chl-a)	AL	Primary	CA Stress-Response, Changepoint, reference percentiles (Mazor et al. in prep, Fetscher et al. 2014)
Water column all biomass (water column chl-a)	AL	Primary	Central Coast Basin Plan, US stress response and reference percentile (various)
Benthic AFDM	AL	Primary	Stress-Response, changepoint, reference percentiles (Mazor et al. in prep, Fetscher et al. 2014)
Benthic or floating macroalgal percent cover	H	Primary	Suplee et al. 2009, Jakus et al. 2017
	AL	Supporting	Stress-Response and reference percentiles (Mazor et al. in prep, Fetscher et al. 2014)
Water column or benthic chemistry			
Continuous DO and pH	AL	Primary	All Regional Water Board Basin Plans
DO Diel range	AL	Primary	Central Coast Basin Plan, Jessup et al. 2015
Dissolved organic carbon, trihalomethane	H	Supporting	Literature, Basin Plan
Harmful Algal Bloom			
Benthic cyanoHAB toxin	AL, H	Supporting	Literature
Benthic cyanoHAB cell density	AL, H	Supporting	Literature
Particulate cyanoHAB toxin	H	Primary	CCHAB State Guidance
Particulate cyanoHAB cell density	H	Supporting	CCHAB State Guidance
CyanoHAB toxin concentration in tissue	H	Primary	State Guidance
	AL	Supporting	Literature
SPATT toxin concentration	H, AL	Supporting	Literature

Key Findings, Part I: Conceptual Models and Indicators

- 40 year of eutrophication science of wadeable streams provides a robust basis for conceptual model and candidate indicators

- We've identified response or causal indicators that can serve as either primary and/or supporting lines of evidence in biostimulatory assessment (ultimate choice is a policy decision)
  - Organic matter accumulation
  - Water column or benthic chemistry
  - HAB cell density and toxins
  - Biostimulatory drivers (nutrients)

Many of these measures have strong scientific basis for thresholds.

Summarized in Part II of this presentation

Water Board Charge Questions:

Scientific Foundation for Assessment of Biostimulatory Impacts to California Estuaries, Enclosed Bays, and Inland Waterbodies, Sutula SCCWRP TR 871.

- Comment on the adequacy of conceptual models and indicators/measures reviewed in **Sutula TR 871** to provide a conceptual, scientific foundation for understanding pathways of impact of eutrophication and linkage to biostimulatory substances and conditions, across all waterbody types in California.
- Are there technical ways to address stakeholder concerns?

Scientific Bases for Assessment, Prevention, and Management of Biostimulatory Impacts in California Wadeable Streams, Sutula et al, SCCWRP TR 1048.

Comment on the degree to which the conceptual models and indicators/measures reviewed provide a strong foundation for pathways of impact of eutrophication and linkage to biostimulatory substances and conditions in wadeable streams, in particular:

- **Conceptual models** of **impact**s to **human and aquatic life** related uses **capture all major pathways of impact**??

Comment on the completeness of the review of indicators, in particular:

- Are there **additional eutrophication indicators** that should be reviewed?
- Should all measurement of indicators and nutrients occur during the index period for bioassessment?
- When considering the multiple indicators included in the eutrophication synthesis, **which indicators** do the SAP member feel **are most critical for biostimulatory impact assessments**?
- How should the **multiple indicators be evaluated in combination** to assess biostimulatory impacts?
- Are there any **technical reasons** to exclude any of the indicators from an assessment?
- How **frequently** should they be measured?
- Are the **conclusions of the eutrophication indicator review appropriate**, given the stated evaluation criteria?

Are there technical ways to address stakeholder concerns?

Overview of Products, Timeline of Completion vis-a-vis Policy Development

Finalize Spring 2019	Finalize as Policy Options Become Clarified	Finalize Before Staff Report
(Biointegrity Tools and Products) ASCI (Theroux et al. in prep), Channels in Developed Landscapes, Beck et al in review) Biological Condition Gradient Model (Paul et al.)		
(Biostimulatory Tools and Products) Biostimulatory Thresholds Protective of Biointegrity (Mazor et al)	Iterations to reflect refined policy options?	
(Biostimulatory Tools and Products) Scientific Foundations for Eutrophication Assessment (TR 871) Wadeable Stream Eutrophication Synthesis (TR 1048)	Iterations on both reports anticipated in response to requests to include more information (e.g. policy options become clarified)	