Improving biointegrity in engineered channels

Report to the Stormwater Monitoring Coalition on Project 5.3

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SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

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Executive Summary

As biointegrity tools take on greater roles as water quality indicators in monitoring and management programs, watershed managers are confronted with the challenge of how to maintain or improve biological conditions in engineered channels. Many stream channels in urban parts of southern California have been straightened, partly or completely hardened, or otherwise engineered as part of urban development and to provide services like flood protection or water conveyance, and these modifications can affect biological communities living in the stream. These effects often co-occur with poor water quality and flow alteration, and it can be difficult to tease apart their relative contributions to poor biological conditions in engineered channels. Although these impacts are sometimes mitigated through off-site restoration or land conservation activities, there remains an interest in improving conditions within the engineered channels themselves. In 2021, the Stormwater Monitoring Coalition (SMC) undertook a multi-pronged effort to identify strategies to improve biological condition in engineered channels.

Definition and types of engineered channels

Engineered channels (also referred to as modified channels) are streams that have a deliberately altered channel form for the purposes of flood protection, water conveyance, or other services for human use. Modifications include realignment, recontouring, or armoring of bed and/or banks. Unintentional modification (e.g., channels eroded by unmanaged runoff) are not considered engineered channels. For the purposes of this report, channels are classified based on bed and bank material:

- HB: Hard-bottom channels, which typically also have hardened banks.
- SB0: Soft-bottom channels with no hardened banks.
- SB1: Soft-bottom channels with one hardened bank.
- SB2: Soft-bottom channels with two hardened banks.

Constructed channels (i.e., channels established in historically terrestrial environments where streams did not previously occur; see Mazor et al. (2024) for definitions and examples of constructed channels) are another type of engineered channel, but none of the sites in this study are classified as constructed channels.

Evaluating the potential benefits of flow management

Urbanization across Southern California has resulted in extensive stream channel modifications, such as concrete lining and bank armoring, which disrupt natural flow regimes and degrade ecological conditions. Given that these structural modifications are expected to remain in place if they are essential for flood protection or other services (and other methods of providing these services have not been identified), this study presents a new framework for evaluating the potential benefits of flow management to improve ecological health in engineered streams.

Using data from nearly 400 bioassessment sites and a suite of Functional Flow Metrics (FFMs), the relationship between altered flow and stream condition was assessed using statistical models that account for different channel types. Channels were categorized from natural to highly engineered and used the California Stream Condition Index (CSCI) to measure biointegrity (i.e., ecological condition). To help guide management decisions, a classification tool was developed to identify which sites are most likely to benefit from flow adjustments, and how much change is needed. Specifically, we looked at multiple biointegrity goals (i.e., reference thresholds, thresholds based on best observed conditions in engineered channels, and incremental improvements in CSCI scores) with small (i.e., <10%), modest (10% to 50%) and large (>50%) improvements in flow metrics.

The analysis found that flow alteration (i.e., delta FFM) varies by channel type: hard-bottom channels were more likely to exhibit augmented baseflows and reduced peak flows. Importantly, the flow components most critical to ecological health—dry-season baseflow and fall pulse magnitude—were often the most altered and required the largest adjustments to meet ecological targets. Only a small percentage of sites could achieve reference conditions with small flow changes, but more could benefit from small improvements in flow, especially for FFMs including peak flows. However, additional data collection (especially at soft-bottom channels) and further refinements to the models to estimate flow alteration are recommended to overcome some of the limitations discovered in this study.

This approach allows managers to prioritize actions based on feasibility and expected ecological gain. In many cases, large-scale flow restoration may be challenging, especially in highly engineered channels. However, smaller flow improvements could still yield improved CSCI scores.

Rapid screening causal assessment in engineered channels

Most engineered channels in southern California have poor CSCI scores. For example, only about 8% of soft bottom channels, and only a single hard-bottom channel (out of more than 200) had CSCI scores > 0.79. In order to identify the stressors that are likely causing poor biological conditions at these sites, monitoring data needs to be evaluated in a process known as causal assessment.

Automated causal assessment tools have recently been developed to rapidly evaluate evidence for four stressors (i.e., eutrophication, salinization, habitat degradation, and temperature alteration) that could cause poor biological conditions. In this study, the SMC adapted those methods for use in engineered channels. Standard approaches to causal assessment rely heavily on the use of comparator sites. For example, stress levels at a site in poor condition are compared to stress levels at healthier comparator sites; higher stress levels are considered evidence that the stressor is a likely cause. In the SMC's modified approach, only similarly engineered sites are used as comparators. When the two approaches provide a similar conclusion, the poor conditions are not likely due to the channel engineering alone but to the added effect of the stressor, and managers have more confidence in the potential benefits of stressor reduction, even if the channel engineering remain in place. When the two approaches disagree, managers seeking to improve CSCI scores may need to consider more substantial remediation efforts, such as removal or reduction of the engineered features, before seeing benefits from stressor reduction.

The modified approach confirmed and reinforced the conclusions of the standard approach at about two-thirds of the engineered channels in the region, meaning that stressor reduction would likely help these sites, even if channel modifications remain in place. Disagreements between the two methods were most common at hard-bottom channels, suggesting that many of these sites are unlikely to benefit from stressor reduction alone.

Next steps for this study include case studies to validate these findings, and to broaden the number and types of stressors incorporated into analysis, such as flow alteration and toxic pollutants.

The impacts of channel maintenance activities

Many engineered channels require routine maintenance, such as removal of vegetation or cleanout of sediment. The potential biological impacts of these activities have not been thoroughly investigated. A pilot project at two sites in Riverside County was conducted to gain insights into the potential impacts on measures of stream biointegrity. Although the data generated by the study was insufficient to answer questions about the impacts of channel maintenance, it identified some of the major challenges that confront such a study. Chief among them is insufficient documentation about the timing, location, and type of maintenance that complicate the alignment of bioassessment locations and maintenance activities.

Based on the findings of this pilot effort, the member agencies have learned that the preexisting tracking mechanisms and recordkeeping for maintenance, including financial, mapping, data systems, and documentation for project related activities has great variability in extents and detail. Finding the appropriate relationship between the sampling location and maintenance activity can be burdensome, and it may not always be possible to extract the site-specific maintenance data at the granular, 150-meter reach level as relevant to the temporal and spatial extent of the bioassessment activities. As a lesson learned, each agency was left to consider how to improve records for possible future use to better link the extents and timing of maintenance to the locations of biological field surveys.

An evaluation of engineered channels with relatively good biological conditions

While most engineered stream channels in Southern California exhibit poor biological conditions, a few show unexpectedly high CSCI scores. To understand what sets these sites apart, the SMC resampled high- and low-scoring engineered channels across the region, focusing on hard-bottom and soft-bottom types. Additional data analyses on the top-performing sites were used to build a more robust dataset for comparison.

Results showed that CSCI scores in engineered channels can vary but are generally more stable than in natural streams, particularly in hard-bottom types. Environmental stressors like water quality and land use were relatively poor predictors of biological condition in engineered channels compared to natural ones, although some patterns emerged: High-scoring sites often had more fast-water habitat, greater riparian vegetation, and were surrounded by less developed land. However, the muted response to environmental variables suggests that physical modifications may constrain biological recovery.

The findings suggest that habitat or water quality improvements could benefit certain engineered channels, but may not be sufficient to achieve reference-like conditions. Based on this study, we recommend increased sampling of high-scoring soft-bottom channels and leveraging restoration projects as natural experiments to better understand the potential for ecological improvement.

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Abstract

Stream channel modification is a widespread practice aimed at providing flood control and managing urban stormwater. While they may provide essential infrastructure benefits, modifications such as channelization and bank armoring can degrade aquatic systems. Because modifications are likely to remain in place for as long as their flood protection or other benefits are needed, managers may want to identify other strategies to support healthy ecological conditions, such as improving water quality or managing flows. This study presents a framework for evaluating flow management potential based on a range of ecological benchmarks. We developed a tailored flow-ecology assessment for engineered channels evaluating where, when and how much flow management is needed to improve ecological health. Using generalized additive mixed models (GAMMs), we linked Functional Flow Metrics (FFMs) to the scores of a bioassessment index based on benthic macroinvertebrates to assess the relationships between biological condition and flow alteration. By applying this framework, the study revealed that hard-bottom channels predominantly required large (i.e., >50% flow change) in dry-season baseflow and fall pulse magnitude to improve bioassessment index scores, whereas soft-bottom channels more frequently required large flow adjustments in peak flow metrics. Sites requiring small flow changes (less than 10%) to achieve reference bioassessment scores were rare across all FFMs. However, incremental biological improvements (i.e., +0.1 bioassessment index score) were more feasible with small flow changes, particularly for peak flows and fall pulse magnitude. Additionally, inaccuracies were noted in predicting large flood peak flows, particularly in fully constrained, urbanized channels. This study provides a screening tool to prioritize flow management efforts, using achievable targets to guide short-term progress, while recognizing that substantial flow modifications are often required to support meaningful ecological recovery in highly altered hard-bottom channels.

Introduction

Channel modification, such as channelization and stream bank armoring, is a widespread management strategy to control flooding, project infrastructure, and manage urban stormwater. These modifications can directly impact aquatic life by altering habitat, reducing productivity and disrupting ecological processes (Schoof 1980, Stein et al. 2013, Buffagni et al.

2016). While channel modifications can be a response to flow alteration from urban run-off, changes to the channel's geomorphology can also drive further change in hydrological regime (Brookes 1987). Such alterations can augment or deplete flow magnitude, reduce seasonality, shift the timing, and change duration of high- or low-flow events (White and Greer 2006, Poff and Zimmerman 2010), with substantial consequences for biological communities (Poff et al. 1997, Bunn and Arthington 2002, Poff and Zimmerman 2010). Yet specific assessments of flow alteration in modified channels are often lacking.

Southern California is a highly urbanized region where stream modification is common, ranging from partially hardened banks to fully concrete-lined channels. While these modifications can provide essential infrastructure benefits, they are often associated with poor ecological conditions (Bylak and Kukuła 2018, Gomes and Wai 2020, Tank et al. 2021, Mazor et al. 2024) and many of these channels exhibit significant flow alteration (e.g., Wolfand et al. 2022, Taniguchi-Quan et al. 2022). Because modifications are likely to remain in place for as long as their flood protection or other benefits are needed, managers may want to identify other strategies to support healthy ecological conditions, such as improving water quality or management of flows (e.g., Anim et al. 2019, Zerega et al. 2021). In addition, in-stream physical habitat restoration has been found to be unsuccessful when upstream water quality and flow alteration stressors have not been addressed (Bernhardt and Palmer 2007, 2011, Palmer et al. 2010).

Flow-ecology assessments are commonly applied to inform flow management decisions (Stein et al. 2017, Cartwright et al. 2017, Mazor et al. 2018b, Maloney et al. 2021). They are helpful in stream condition evaluations and can be used to define flow targets by linking flow alteration to ecological endpoints (Poff et al. 2010, Taniguchi-Quan et al. 2022). Given that modified channels often experience significant flow alteration, applying flow-ecology assessments in these contexts could be particularly beneficial. Current flow-ecology assessments, however, are typically anchored in comparison to "reference" biological conditions (Mazor et al. 2018b, Peek et al. 2022, Irving et al. 2022) meaning that the high standard associated with reference conditions may be impractical for modified channels to reach (Booth et al. 2003). For example, channels that are straightened experience increased velocity and altered in-stream flow characteristics (Brookes 1987, Gurnell and Downs 2021), which may result in changes to biological condition. As a result, models aimed at achieving reference conditions may not accurately represent the ecological dynamics in these modified environments. This highlights the need to develop a flow-ecology approach specifically tailored for modified channels enabling more accurate assessments and effective flow management strategies.

Bioassessment tools based on consumers (e.g., benthic macroinvertebrates) have been developed as indicators of ecological health. The California Stream Condition Index (CSCI) is a predictive multi-metric index for California streams, comprising multiple measures of taxonomic composition (Mazor et al. 2016). This bioassessment index measures biological alteration by comparing observed taxa and metrics to expected values under undisturbed (i.e., reference) conditions based on site-specific landscape-scale environmental variables, such as watershed area, climate, and geology. The CSCI has been integrated into unified assessments of stream health and used to aid stream management and decision-making including to evaluate regulatory compliance in California regions (Beck et al. 2019, Loflen 2020). The index has been applied to derive flow targets through flow-ecology relationships to aid management decisions (Stein et al. 2017, Mazor et al. 2018b, Irving et al. 2022).

Natural flows during different seasons contribute uniquely to ecological processes through specific flow functions, for example, summer baseflows provide critical habitat for benthic macroinvertebrates, while natural winter peak flows can scour habitats, removing sediment and replenishing habitat for benthic macroinvertebrates (Rosenberg and Resh 1993, Merritt et al. 2019). Key seasonal components of the annual hydrograph have been identified for California streams, which have been selected based on literature to represent ecological processes important to California's stream communities (Yarnell et al. 2020). This approach is the foundation of California Environmental Flows Framework (CEFF; Stein et al. 2021) and several empirical studies have linked FFMs to CSCI (Peek et al. 2022, Irving et al. 2022).

Our goal was to develop a framework to evaluate the potential ecological benefit of flow management based on a range of biologically relevant benchmarks. Specifically, we aimed to identify which channel types, season and amount of flow change offer the greatest opportunities for ecological improvement. This study is designed to support watershed managers in southern California set priorities for flow-based stream management that enhance or protect biological conditions in modified channels. Unlike typical approaches that focus on achieving reference condition targets, this framework quantifies the potential benefit of improved flow management, enabling managers to focus efforts where greater improvements are most achievable.

Through this assessment, we address the following questions:

- Which types of modified channel would benefit most from flow management?
- What seasonal components of flow would benefit most from targeted flow management?
- How much change in flow is required to reach standard and modified targets for CSCI scores?

Methods

We developed flow-ecology models to evaluate the relationship between flow alteration and bioassessment scores across different channel engineering classes ranging from hard bottom to natural channels. The models were used to predict flow ranges relative to different channel types and flow metrics. For each site, we calculated the degree of flow change required to improve bioassessment scores to target levels specific to the channel type. To determine flow management potential, sites were evaluated based on the relative flow changes required to achieve these outcomes, i.e., identify those where flow management is likely to help, and by how much.

Study area

Coastal southern California (i.e., the South Coast) is a semi-arid region with a Mediterranean climate, which experiences nearly all its precipitation as rainfall during winter months. Lower elevations are characterized by chaparral, oak woodlands, grasslands, and coastal sage scrub. The region is bordered by the Transverse Ranges to the North, and the Peninsular Ranges to the East, and continues to the Mexican border to the South. Both Transverse and Peninsular ranges contain peaks that exceed 10,000 feet and regularly experience snow, although contributions to stream flow are limited. Much of the higher elevations are undeveloped and remain protected in a network of national, state, and county parks and forests. The lower elevations have been largely urbanized or converted to agriculture. Wildfires and drought are frequent in the region, with extensive fires occurring in 2009, 2013, 2017, and 2018 throughout much of the area. By area, the overall region is 59% undeveloped open space, 28% urban, and 13% agricultural (Jon Dewitz 2024).

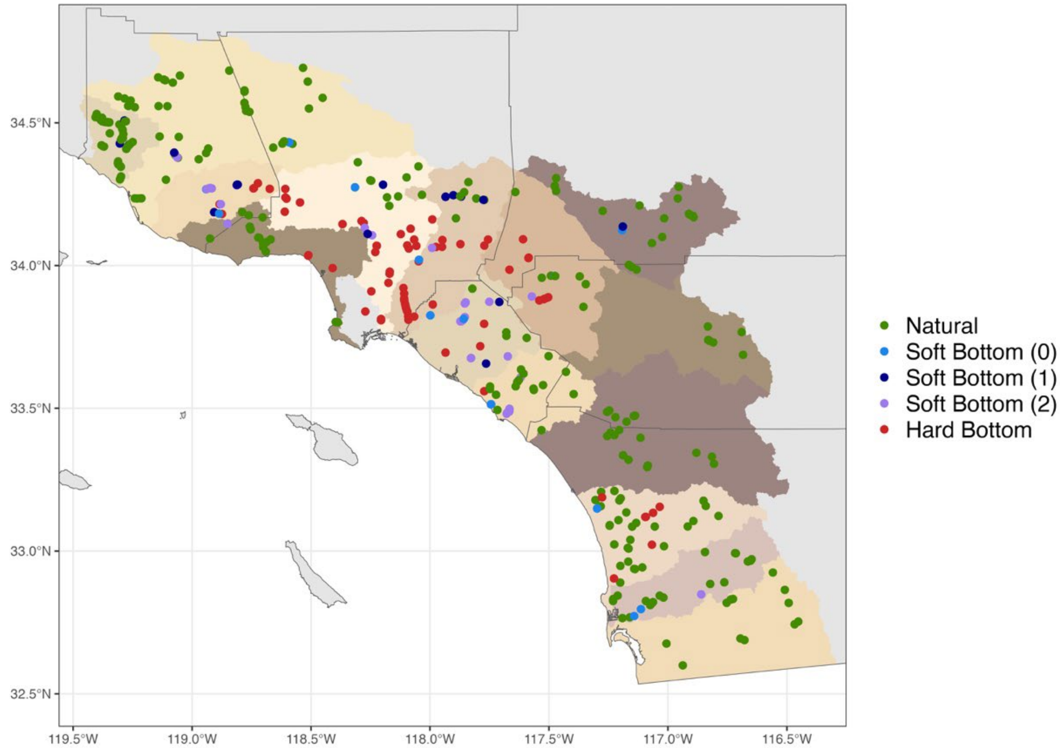


Figure 1. Map of region with all sites coded by channel type. The region's major watersheds are shown in different colors.

Bioassessment data

We collated data from 396 unique bioassessment sites sampled under the Stormwater Monitoring Coalition (SMC) program in the southern California region (Figure 1; Mazor 2024). Sites were selected probabilistically and visited between 1996 and 2023. Benthic macroinvertebrates were collected using a D-frame kick net from a 150-m assessment reach that was divided into 11 equidistant transects following Ode et al. (2016). Samples were therefore taken from microhabitats (e.g., riffles, pools, fallen wood) within the reach. Taxonomic analyses were performed according to Woodward et al. (2012); taxa were identified to the standardized effort described in Richards and Rogers (2011). We calculated CSCI scores for all samples following Mazor et al. (2016). The CSCI comprises two components: a multi-metric index and a ratio of observed/expected (O/E) taxa. Index scores were calculated for each site for the year in which the sampling took place, for sites with multiple sampling events within a year, we calculated the mean CSCI score. Multiple sampling events in different years were kept in the analysis for the model development; however, only the most recent sample was taken when applying the models to modified streams. This resulted in 826 sampling events included in the model.

Channel engineering data

Channel engineering information was obtained through direct observation by field crews. Channels whose morphology or alignment have been deliberately altered were classified as engineered channels, while other channels (including those with degraded but not deliberately altered habitat) were classified as natural. Engineered channels were further categorized based primarily on bed and bank material following the process outlined in Mazor et al. (2024). Through site-visits, examination of photos, and interpretation of aerial images, the 396 sites were classified into one of five stream classes:

- Natural (NAT)
- Hard-bottom channels (HB)
- Soft-bottom channels with two hardened banks (SB2)
- Soft-bottom channels with one unhardened banks (SB1)
- Soft-bottom channels with unhardened banks (SB0)

Within the data set, all HB channels also had hardened banks; HB channels with earthen banks are rare but have been observed in other parts of the state (Mazor et al. 2024). Hardening could result from concrete, rocks, sandbags, wood, or other resistant material, and needed to affect at least 25% of the reach-length to affect a classification.

All sites were assigned a standard CSCI target score based on reference condition (RC); in addition, engineered channels were assigned a second, modified target best on best observed (BO) conditions described by Mazor et al. (2024). The RC target (0.79) was derived from the 10th percentile of CSCI scores among reference sites, following the standard approach described in Mazor et al. (2016, Table 1). For SB1, SB0, SB2 & HB channel types, target scores were based on the "best observed" (BO) condition, defined as the 90th percentile of CSCI scores within each respective channel type (Table 1, Mazor et al., 2024). However, the BO score for SB1 channel type (1.0) exceeds the standard score (0.79), in this case the standard score (0.79) was applied for SB1 channels (Table 1). For more information about modified channels with relatively high CSCI scores, see Part 4 of this report.

Table 1. CSCI threshold and number of bioassessment sites in each stream class. The RC target is from Mazor et al. (2016), whereas the BO targets correspond to the "intermediate stringency" thresholds reported in Mazor et al. (2024).

Stream class	Target Type	Target Score	Number of sites
Natural	Reference Condition (RC)	0.79	259
Soft-bottom 0 hardened sides	Best Observed (BO) and RC	0.78 and 0.79	14
Soft-bottom 1 hardened side	BO and RC	0.79 and 0.79	20
Soft-bottom 2 hardened sides	BO and RC	0.75 and 0.79	29
Hard Bottom	BO and RC	0.67 and 0.79	74

Functional flow alteration in modified channels

We utilized the Function Flows Metrics (FFMs) outlined by Yarnell et al. (2020; 2015) in this study (Table 2). The FFM approach comprises 24 distinct metrics that describe the magnitude, timing, frequency, and duration of seasonal flow components. These functional flows are specific components of the natural flow regime that supports ecological, physical and biogeochemical processes. Maintaining these flows in managed systems helps support ecological health. Yarnell et al. (2020) identified five functional flow components that are important for supporting biological communities in California streams: Fall pulse flow, wet-season baseflows, peak magnitude flows, spring recession flows and dry-season baseflows.

Contemporary functional flow metrics were readily available from Taniguchi-Quan et al. (2023) for all stream reaches in the study area predicted through a Random Forest (RF) model (Breiman 2001). In brief, we first calculated annual FFMs for observed gage data (n = 429) using the Functional Flow Calculator API client package in R (version 0.9.7.2, https://github.com/ceff-tech/ffc_api_client). The RF model then related the observed FFMs at gage sites to contemporary climate and landscape conditions throughout California for the years 1990-2014. FFMs were predicted for each NHDPlus COMID (National Hydrography Dataset (NHD, https://www.usgs.gov/national-hydrography; McKay et al. 2014) associated with a bioassessment site in our study area (Figure 1) and the median FFM across the period of record was calculated.

As our measure of alteration, deviations (Delta FFM) were estimated by calculating the difference between the contemporary FFM and reference FFM available statewide from Grantham et al (2022). Delta FFM values can be positive (e.g., peak flow magnitudes are higher under present-day conditions compared to natural conditions) or negative (e.g., base flow magnitudes are lower under present-day conditions). A total of 271 COMIDs with bioassessment sites were predicted successfully. However, due to limitations in model performance (see Taniguchi-Quan et al. 2023), only metrics describing flow magnitude were predicted, resulting in 9 FFMs for this analysis. The metrics described dry and wet season baseflow, fall pulse flow, spring recession flow and peak magnitude flows (Table 2).

Table 2. Functional Flow Metrics (FFMs) used in the analysis

Functional Flow Metric	Description	Flow Component
Spring Recession Magnitude	Spring peak magnitude (daily flow on start date of spring-flow period)	Spring Recession Flow
Dry Season Baseflow Magnitude	Baseflow magnitude (50th percentile of daily flow within summer season, calculated on an annual basis)	Dry Season Base Flow

Functional Flow Metric	Description	Flow Component
Fall Pulse Flow Magnitude	Peak magnitude of fall season pulse event (maximum daily peak flow during event)	Fall Pulse Flow
Wet Season Baseflow (Low) Magnitude	Magnitude of wet season baseflows (10th percentile of daily flows within that season, including peak flow events)	Wet Season Base Flow
Wet Season Baseflow (Median) Magnitude	Magnitude of wet season baseflows (50th percentile of daily flows within that season, including peak flow events)	Wet Season Base Flow
Magnitude of Largest Annual Storm	Annual 99th percentile of mean daily flow (Q99)	Peak Flow
2-Year Flood Magnitude	Peak-flow magnitude (50% exceedance values of annual peak flow --> 2 year recurrence intervals)	Peak Flow
5-Year Flood Magnitude	Peak-flow magnitude (20% exceedance values of annual peak flow --> 5 year recurrence intervals)	Peak Flow
10-Year Flood Magnitude	Peak-flow magnitude (10% exceedance values of annual peak flow --> 10 year recurrence intervals)	Peak Flow

Flow-ecology models

The bioassessment sites were related to available flow data by NHD COMID. Importantly, not all bioassessment sites had corresponding modified channel data, however all sites were included in analysis to develop the model. FFMs were assumed to reflect long-term conditions, and thus were associated to all samples at a site, regardless of the date of biological sample collection. Using the CSCI scores as the response variable, generalized additive mixed models (GAMMs) were built for each FFM separately. The GAMMs were made up of two types of models: generalized additive models (GAMs) and mixed effects models (M). The GAM component of the GAMM is a non-parametric extension of Generalized Linear Models (GLMs) that is useful for uncovering complex relationships within data, effectively letting the data speak for itself. The mixed effects model component of the GAMM incorporates both fixed and random effects, enabling the evaluation of flow alteration effects in the different channel types. The five levels of channel type (NAT, SB0, SB1, SB2 & HB) were specified in the models as random effects, whereas the delta FFM values were specified as the fixed effects. The criteria for GAMs include a smoothing function that denotes the smoothness (or “wiggliness”) of the curve; a high level of smoothness allows the model to reflect nonlinear patterns in the data, although if smoothness is set too high, the model may reflect noise rather than a meaningful relationship between CSCI scores and delta FFM. We tested multiple smoothing functions, ranging from 3-20, and the most appropriate function for each model was chosen through visual inspection. We assessed the smoothing functions using a standard GAM with mixed effects in R package 'mgcv' (Wood 2017).

We tested three GAMM configurations, 1) intercept only, 2) slope only, and 3) slope and intercept combined, to determine the best fit for the data. An "intercept only" model assumes that each type of channel engineering has, on average, different CSCI scores, but they exhibit identical responses to flow alteration; that is, the different intercepts reflect differences in average CSCI scores among channel types when flow alteration is absent. A "slope only" model assumes that flow alteration affects channel types in different ways (i.e., some more than others), but in the absence of any flow alteration, each channel type will have the same channel score. A "slope and intercept" model allows each channel type to have a different intercept (that is, different average CSCI score when flow alteration is absent), as well as different slopes (that is, different responses to flow alteration for each channel type). The optimal model configuration was selected based on model performance (deviance explained & R Squared) and visual inspection of the resulting curves.

Determining the Delta FFM required to improve CSCI Scores

We determined the delta FFM values required to reach specific CSCI targets, such as increasing the CSCI score from its current value (e.g., 0.5) to a target value (e.g., 0.79). The CSCI targets included the reference condition (RC, 0.79), and "best observed" (BO) score (Table 1, Mazor et al. 2024). These targets represent specific points in the flow-ecology curve used to determine associated delta FFM ranges. In addition to RC and BO targets, we included a target of an incremental improvement of 0.1 in CSCI. This approach was to acknowledge that meaningful improvements in CSCI can occur even if they do not surpass a specific CSCI threshold. The choice of 0.1 CSCI score increment was based on the authors' professional judgement, and it represents a change greater than the typical natural variation observed in CSCI scores (Mazor et al. 2016); however, individual sites sometimes exhibit greater variation upon resampling (see Part 5 for examples of sites with greater within-site variation).

The delta FFM values associated with CSCI targets were derived from the flow-ecology response curves. For each curve, the target CSCI value on the y-axis was mapped to its corresponding x-axis (delta FFM) value (Figure 2). The change in delta FFM was calculated as the difference between the current delta FFM value and the delta FFM associated with each CSCI target. The resulting differences were then converted to percentages, representing the relative change in delta FFM required to achieve ecological improvement at each site.

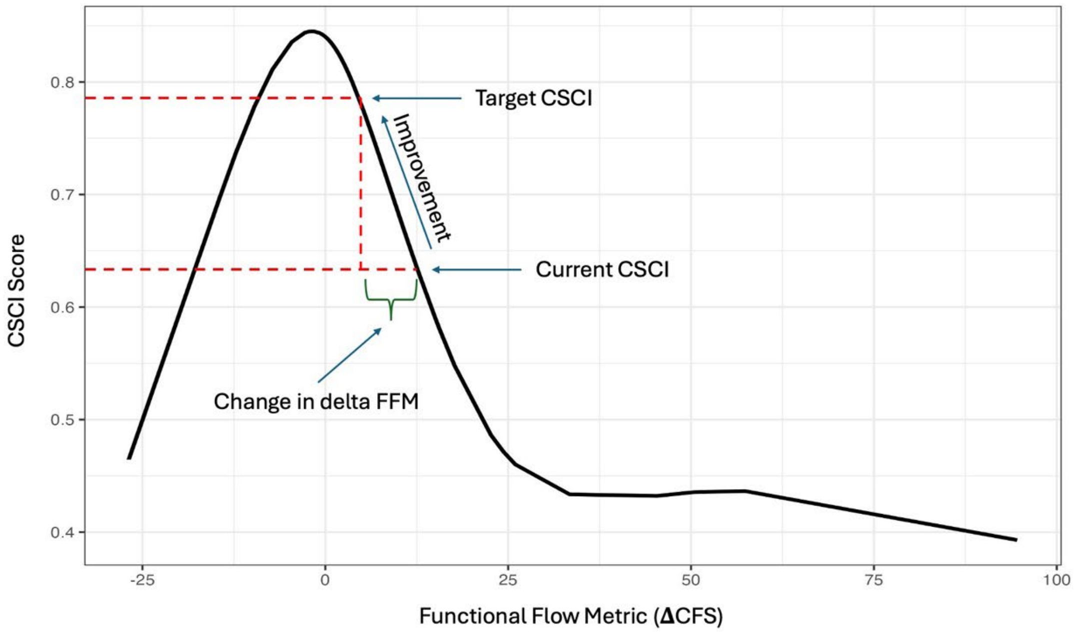


Figure 2. Conceptual illustration of how the change in delta FFM was calculated to improve biological condition as measured by CSCI. The target CSCI value (y-axis) was used to identify the corresponding delta FFM (x-axis, contemporary FFM minus reference FFM) from the flow-ecology curve. The difference between this target delta FFM and the delta FFM associated with the current CSCI represents the change needed to improve biological condition, expressed as a percentage.

Sites were categorized based on how much change in delta FFM (Table 3) was required to reach different CSCI targets. Sites were categorized first by their CSCI score (Above RC, Above BO, Below BO) then the delta FFM context (Within the range associated with CSCI scores above RC, Outside RC). Sites above biological RC were classed as "no Action" as no improvement in CSCI was needed. For sites above BO, when delta FFM was within RC, they were classed as non-flow-related, as flow alteration was already within the realms associated with a good CSCI score. However, if delta FFM was outside RC, the sites were classed as identify improvements needed, as to achieve RC or incrementally increase CSCI by +0.1. For sites Below BO, if within RC hydrology, they were classed as non-flow related. If the site was outside the RC, the sites were classed as identify improvements needed to achieve RC, BO, or an incremental increase CSCI by +0.1. The required relative change in delta FFM for all sites was classified as small (<10%), moderate (10% to 50%), or large (>50%). Note that sites with poor biology and altered hydrology often experience other stresses unrelated to flow, and reducing flow alteration alone without addressing other factors may not be sufficient to improve biology in these channels.

The categories were summarized and presented in bar plots. For simplicity, SB1 & NAT were combined, as were SB0 & SB2 sites, representing moderately modified channels (SB1 channels within this data set and in other parts of California are typically—but not always—in undeveloped mountainous areas and often have biological conditions that are similar to NAT channels; Stormwater Monitoring Coalition 2017, Taniguchi-Quan et al. 2020, Mazor et al. 2024). We visualized the results in two ways, 1) the amount of change in delta FFM needed to reach each target and 2) the target achieved for each change in delta FFM.

Table 3: Site evaluations dependent on how much change in Delta FFM needed to reach a goal RC: reference condition, BO: best observed, +0.1 CSCI (Incremental improvement). RC hydrology represents the Delta FFM associated with 0.79 CSCI score. Sites are categorized based on Action column, if Identify Improvement then how much relative change (small: <10%, moderate: 10% to 50%, and large: >50%) in delta FFM was calculated.

CSCI score	*Hydrology*	*Categories*
Above RC	Within RC	No action/protect
	Outside RC	No action/monitor
Above BO	Within RC	Non-Flow Related
	Outside RC	Identify improvement needed to get RC (<10%, 10% to 50%, >50%)
		Identify improvement needed to get +0.1 CSCI (<10%, 10% to 50%, >50%)
Below BO	Within RC	Non-Flow Related
	Outside RC	Identify improvement needed to get RC (<10%, 10% to 50%, >50%)
		Identify improvement needed to get BO (<10%, 10% to 50%, >50%)
		Identify improvement needed to get +0.1 CSCI (<10%, 10% to 50%, >50%)

Case studies

We examined specific sites located in two counties within the study area: Riverside and San Diego. In each county, we selected two sites representing different channel types to verify the accuracy of the delta FFM ranges. This site-specific investigation improves our understanding of flow modification and its potential impact on CSCI scores. Furthermore, it evaluates whether the delta FFM ranges predicted by the GAMM are realistic and achievable based on actual conditions.

Results

Overall, there was much more data available for NAT and HB streams than for any class of soft-bottom stream. For example, there were only 14 SB0 channels with sufficient data to include in analysis. Therefore, conclusions about soft-bottom streams may be less robust and more likely to change with additional data collection (Table 1).

Functional flow alteration in modified channels

Overall, ranges in delta FFMs (i.e., deviation from reference conditions) were larger in hard bottom channels than natural or soft bottom channels. This pattern held across most FFM, except for 2-year flood magnitude, which showed smaller deviations in hard and soft bottom channels compared to natural channels. The FFM ranges in natural channels (Figure 3Figure 3 & Supplement 1: Figure S - 1) demonstrated the smallest deviation from reference, as expected since these channels should be closest to zero (i.e., reference flows). In contrast, FFM ranges in hard-bottom channels showed the largest deviation from reference flows. The direction of alteration varied across FFMs; augmentation was observed in dry season baseflow and fall pulse magnitude. Counterintuitively, depletion occurred in peak flows (largest annual storm, 2-, 5-, & 10-year events). The direction of FFM ranges was mixed for both wet season baseflow (low and mid) and spring recession flows.

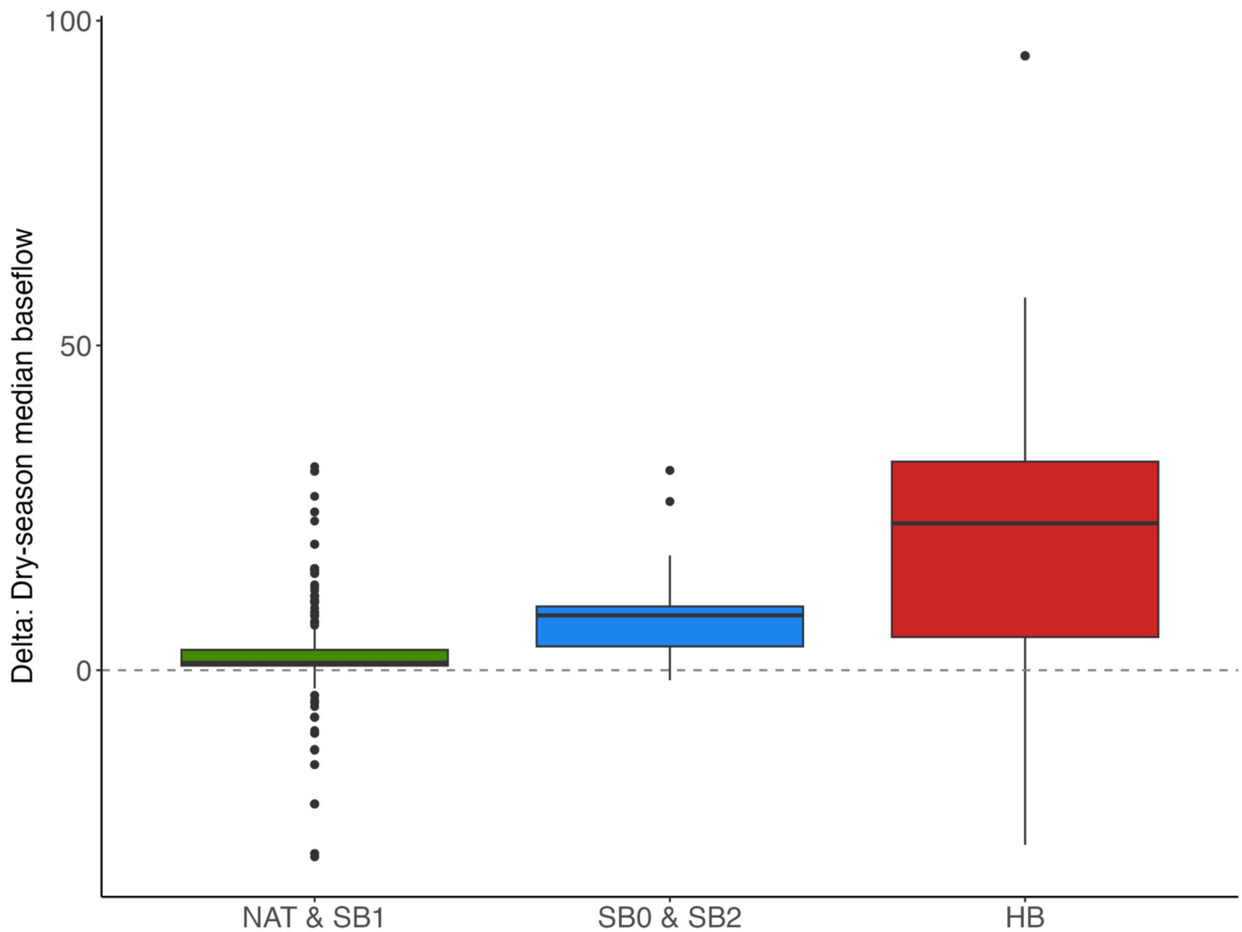


Figure 3. Boxplots of example ranges of delta dry-season baseflow in all channel types. The horizontal bar is the median, the box represents the interquartile range, and the whiskers (vertical lines) represent 1.5 * the interquartile range. Zero delta on the y axis represents reference flow. NAT & SB1; Natural and soft bottom channels with one hard side channels, SB0 & SB2; Soft bottom channels with zero and two hard sides, HB; Hard bottom channels.

Flow-ecology models

We compared three configurations of GAMM, that incorporated channel type as a random effect. The best-performing models included both random slopes and random intercepts, explaining approximately 40% of the variance (Table 4), based on both R-squared and deviance explained. The intercept-only model, performed similarly (Figure 4, Supplement 1: Figure S - 1), indicating that the CSCI scores (i.e., baseline conditions) vary significantly by channel type, aligning with our expectations. However, the inclusion of random slopes highlights that the relationship between flow alteration and CSCI score also varies depending on channel type. To account for both differences in baseline conditions and relationship with flow alteration, we selected the model with random slopes and random intercepts for the remaining analysis. We applied models with smoothing factors ranging from 3 to 20; a lower value results in a “stiffer” fit, more similar to a linear regression, whereas a higher value results in a more “wiggly” fit. Dry-season baseflow and fall pulse flow were modelled with a smoothing factor of 6, while the remaining FFMs were modelled with a smoothing factor of 3.

Table 4. Deviance explained, R squared (RSq), degrees of freedom (DF) and Akaike Information Criterion (AIC) for each flow-ecology mixed effects GAM with random slope and intercept (Intercept only and slope only values in Supplement 1: Table S - 1 and Table S - 2).

Functional Flow Metric	Deviance Explained	RSq	DF	AIC
Spring recession magnitude	0.40	0.39	10.70	-454.71
Peak Flow Magnitude (Q99, cfs)	0.39	0.39	10.34	-450.97
Dry-season median baseflow	0.43	0.43	14.62	-496.60
Fall pulse magnitude	0.42	0.41	13.21	-481.93
10-year flood magnitude	0.41	0.40	10.72	-466.55
2-year flood magnitude	0.43	0.42	10.23	-497.88
5-year flood magnitude	0.40	0.40	10.46	-463.67
Wet-season low baseflow	0.42	0.42	12.95	-486.20
Wet-season median baseflow	0.40	0.40	10.73	-460.02

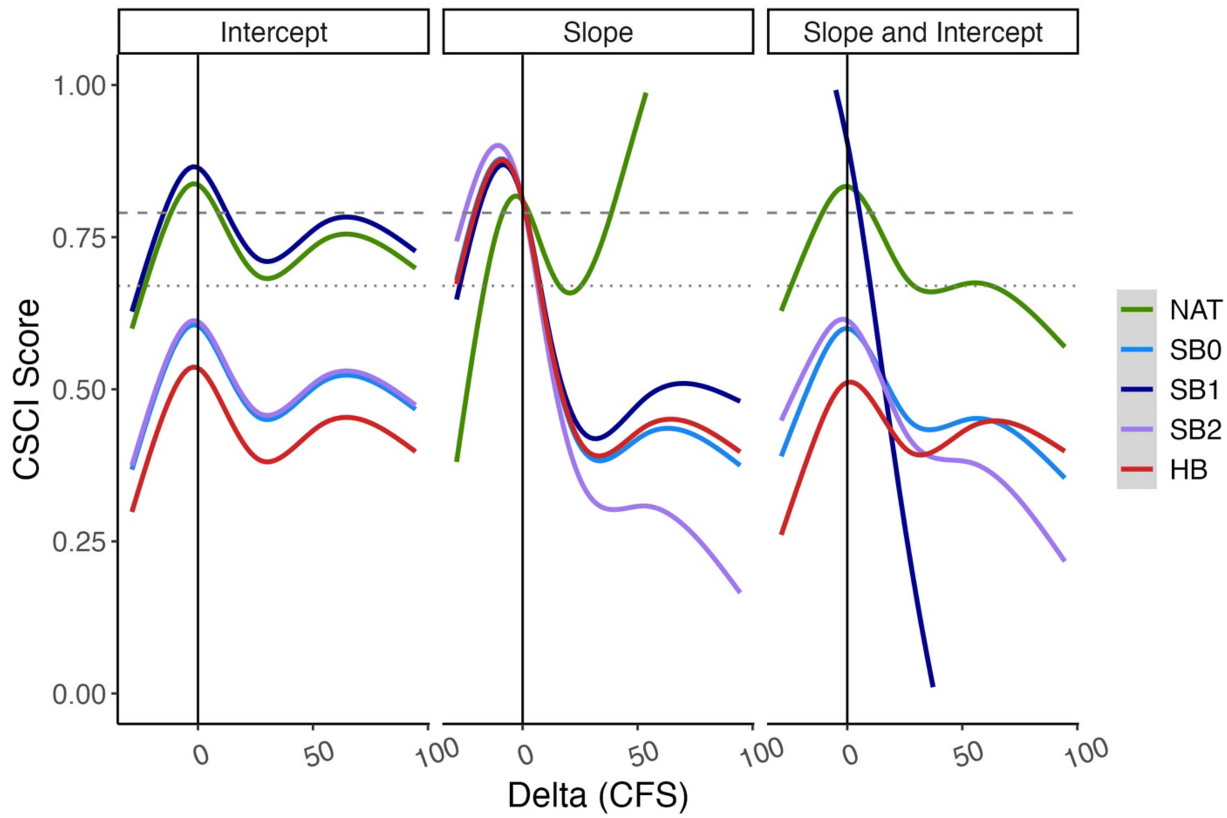


Figure 4. Mixed effects GAMs for Dry Season Baseflow FFM, showing models with random intercept (left panel), slope (middle panel), and both slope and intercept (right panel). Horizontal lines are best observed for hard bottom channels (dotted, 0.67) and natural channels (dashed, 0.79). HB; Hard Bottom, NAT; Natural, SB0; Soft Bottom (zero hard sides), SB1; Soft Bottom (one hard side), SB2; Soft Bottom (two hard sides). Vertical line (zero delta) represents flow values with no deviation from reference. The intercept-only model illustrates that CSCI scores vary across channel types. The slope-only model illustrates that the response of CSCI to delta FFM varies across channel types. The model with both slope and intercept illustrates variations in both CSCI scores and the relationship with delta FFM. CFS: Cubic feet per second.

Assessing the potential benefits from flow management

We assessed the potential for flow management to improve biological conditions and categorized sites based on the flow change required to improve CSCI scores (Table 3). Under reference conditions (Figure 5), 'No Action' (healthy CSCI, delta FFM within reference flows) and 'Non-Flow Related' (unhealthy CSCI, but delta FFM within reference flows) were the most common categories, especially at natural (NAT) and soft-bottom (SB) sites. Spring recession flow showed the highest proportion of 'Non-Flow Related' sites. Sites requiring small, moderate, or large flow improvements were less common, but their proportions varied by channel type and Functional Flow Metric (FFM).

Dry-season median baseflow and fall pulse magnitude showed higher proportions of sites requiring 'Over 50%' flow change, especially in hard-bottom channels. In contrast, 10-year, 2-year, 5-year flood and peak flow magnitude were mostly 'Non-Flow Related', requiring a lower amount of 'Over 50%', particularly for 2-year and 5-year flood magnitudes. Soft-bottom channels showed higher proportions of sites requiring substantial flow changes than hard-bottom channels, an unexpected result given that hard bottom channels would require larger flow changes. This pattern may reflect the relatively small number of soft-bottom sites (n=43; Table 1).

Sites requiring 'Less than 10%' flow change to meet a BO target were the least represented across all FFMs and channel types. When targeting a CSCI score increase of +0.1 (Supplement 1: Figure S - 2), 'Less than 10%' flow change sites were more common, especially for peak flows and fall pulse magnitude. Achieving Best Observed Condition required fewer sites needing 'Over 50%' flow change, but more sites needing '10 - 50%' change (Supplement 1: Figure S - 3)

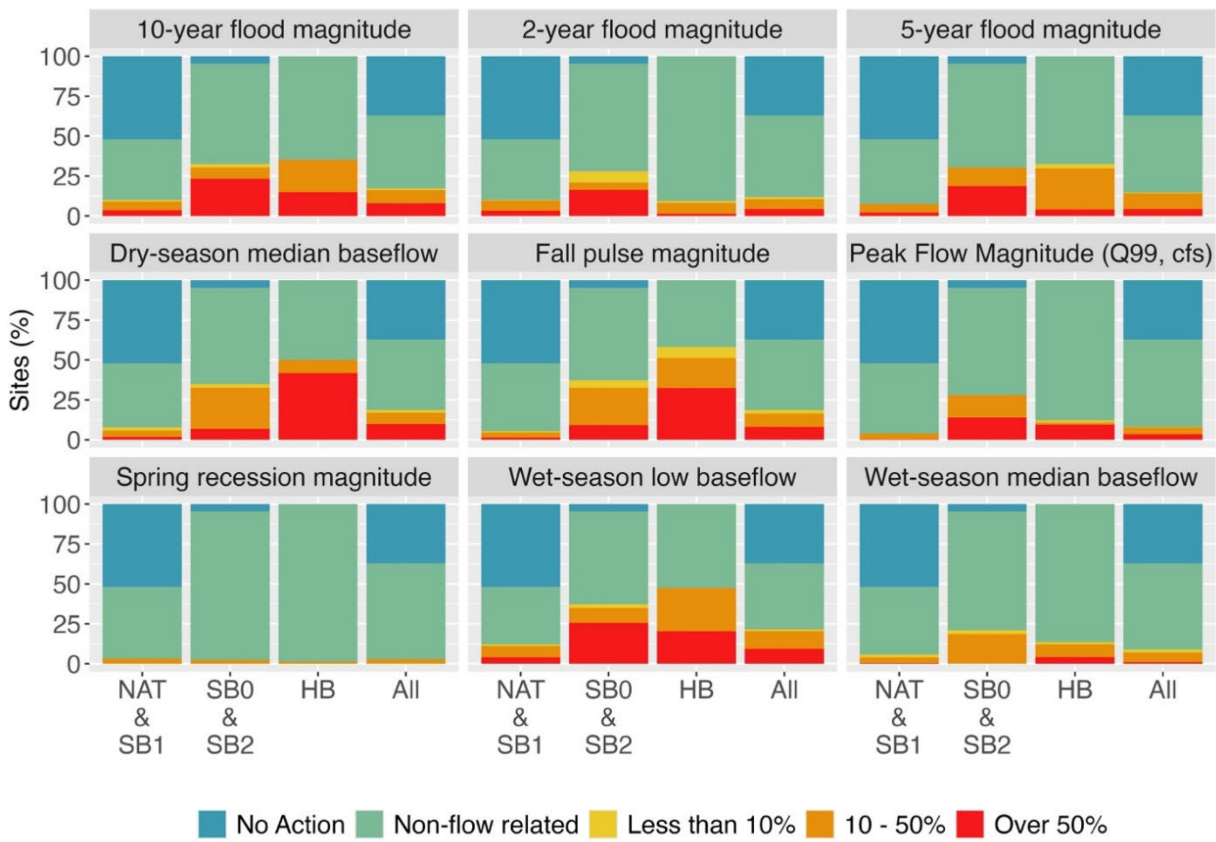


Figure 5. Improvements in delta FFM needed to achieve delta FFM associated with reference condition (i.e., CSCI ≥ 0.79). Categories based on Table 4. NAT & SB1; Natural and soft bottom channels with one hard side channels (n = 279), SB0 & SB2; Soft bottom channels with zero and two hard sides (n = 43), HB; Hard bottom channels (74), All; All channel types together (n = 396).

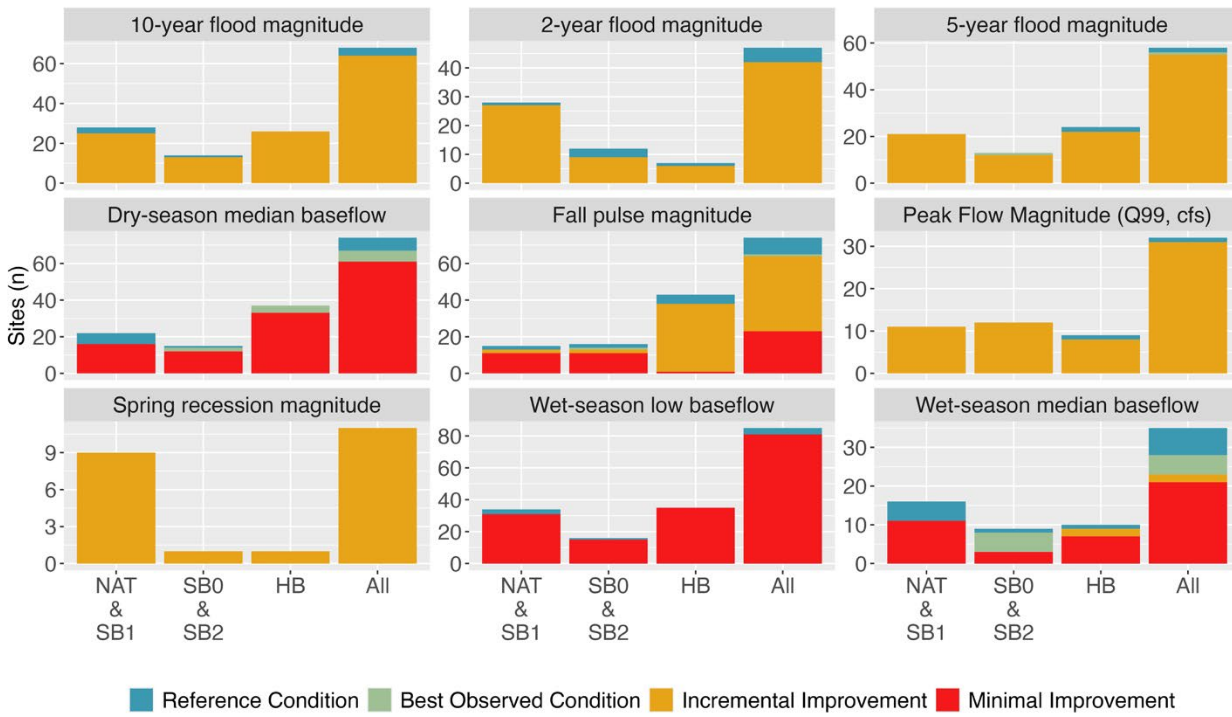


Figure 6. Number of sites that can reach different target conditions with less than 10% change in delta FFM: reference, best observed and incremental improvement, or minimal improvement if site does not achieve a target, for all FFMs and channel types. Note that sites assigned "No Action" and "Non-flow related" were removed. NAT & SB1; Natural and soft bottom channels with one hard side channels (n = 56), SB0 & SB2; Soft bottom channels with zero and two hard sides (n = 22), HB; Hard bottom channels (47), All; All channel types together (n = 125).

The number of sites achieving each target with less than 10% flow change varied by channel type and FFM (Figure 6). Peak flow metrics and fall pulse magnitude were most likely to achieve incremental improvement with less than 10% flow change. In contrast, dry and wet season baseflow would achieve only a minimal improvement with small change in flow for most sites. In general, a much higher number of sites required 10-50% or over 50% flow change to meet their targets (Supplement 1: Figure S - 4 and Figure S - 5).

Case studies

Riverside County

In Riverside County, five HB sites and one SB2 site were assessed between 2011 and 2013. All HB sites were situated within a fully concrete-lined box channel, all sharing the same FFM values. These sites were fully constrained for flood protection and visually similar. Sites had CSCI scores ranging from 0.31-0.51. The augmented delta FFM values for dry- and wet-season baseflow appeared to be accurate as typical dry weather flows consisted of minimal urban runoff from an extensive drainage area. Wet-season baseflow was essentially equivalent to dry season baseflow with increases only during storm events. Predicted augmented (positive delta) fall pulse flow and 2-year flood peak, which were consisted with expectations, as stormflow drains from a large, mostly urbanized impervious area. However, the predicted depleted (negative delta) values for largest annual storm and 10-year flood peak flows were inaccurate, as these flows would likely show increases instead.

The soft bottom site (CSCI score = 0.70 in 2022), which is downstream of all five HB sites described above, is characterized by riprap sides, and is also fully constrained for flood protection. The bioassessment reach was located just downstream of a fully lined trapezoidal channel, and this upstream modification could influence flows within the assessed reach. It has multiple water recycling plants in the upstream catchment, including one about 1.5 miles upstream of the sampling location. In this site, only the dry-season baseflow delta was accurately augmented. All other FFMs were predicted as depleted, some to an infeasible degree. However, spring-recession and both wet season baseflow deltas might be plausible, considering their relatively low values.

San Diego County

In San Diego, one soft-bottom site and one natural site were investigated. The soft bottom site (Los Coches Creek, site code 907S11430), modified with two hardened sides, achieved a good CSCI score of 0.87 (assessed in 2012). In contrast to the Riverside County case soft-bottom site, FFM deltas were consistent with expectations. The delta FFMs indicated that flow modification was insufficient to significantly impact the CSCI, despite some increased magnitude values. However, 2-year flood magnitude showed a depleted delta, inconsistent with the flow conditions of the reach.

The natural site (Soledad Canyon; SMC00710) scored poorly for CSCI (0.66, assessed in 2022). Elevated dry-season flows are a known issue at this site, and the upstream watershed has extensive development. Consequently, the augmented delta for dry-season baseflow and magnitude appears accurate. Therefore, this site is a priority for addressing the modified flow regime. However, the prediction of a depleted delta for 10-year flood magnitude is inaccurate, as an augmented delta FFM would be expected.

Discussion

This study demonstrates a framework for evaluating the potential for flow-based management to improve biological conditions in modified channels. In systems where flood protection, infrastructure, or other critical functions require channels modifications to remain, flow management and pollutant reduction may be the only viable tool for ecological improvement.

Although it may not be practical at every reach, flow-based management is particularly relevant in an increasingly arid world where water availability and hydrological regimes are shifting due to factors like climate-change and increased water recycling. As flow management strategies evolve, integrating biointegrity-informed flow management can help future modifications support both ecological and water resource sustainability.

Which types of engineered channels are most affected by altered flow?

Overall, FFM were more altered in hard bottom channels compared to soft bottom or natural channels, a finding consistent with expectations given the extensive hydrological modifications in fully channelized streams (Konrad and Booth 2005). Dry season baseflow and fall pulse flows were notably augmented, aligning with previous studies (Vietz and Finlayson 2017), which suggests that changes to channel form can lead to increased overall flow volume and prolonged low flows. However, peak flows in hard bottom channels tended to be depleted, indicating that peak flows were lower than expected under reference conditions. This pattern was most pronounced for 10-year peak flows, while 2 and 5-year peak flows showed depletion but remained within or similar to the ranges observed in natural channels. This finding contradicts expectations that high flows would increase in modified streams, particularly in urban settings where impervious surfaces typically lead to greater surface runoff (e.g., Leopold 1968, Booth and Jackson 1997, Chin 2006, Gregory 2011, Ferreira et al. 2016). However, the depletion shown for 10-year peak flows may not be accurate, as both case studies identified inconsistencies with this metric. This discrepancy may stem from limitations in the FFM dataset as there is not much range for positive peak flow values, meaning that peak flows are constrained within a relatively narrow range above zero (0 to 8,059), whereas negative deviations have a wider range for depletion (-1.72 to -25,261). This imbalance in data distribution could lead to an overrepresentation of depleted peak flows, potentially skewing the direction of flow alteration. In other words, these FFMs may not have been estimated with sufficient accuracy for our purposes, making them less useful than other metrics, such as dry season baseflow, where predictions are more reliable.

What seasonal components of flow would benefit most from targeted flow management?

To achieve flows associated with reference conditions, sites requiring the most substantial flow change (Over 50%) were most common for dry season baseflow and fall pulse magnitude, particularly in hard-bottom channels. Baseflow and fall pulse flows are widely recognized as critical drivers of benthic macroinvertebrate communities (McManamay et al. 2013, Patrick and Yuan 2017, Peek et al. 2022, Irving et al. 2022). Fall pulse flows play a critical role in shaping spring and summer conditions, i.e., when bioassessment samples are collected. These early-season flows help flush accumulated fine sediments and organic matter, reset streambed conditions, and initiate key habitat processes (Kennen et al. 2010, Yarnell et al. 2020) that influence macroinvertebrate communities throughout winter, spring, and into summer—ultimately setting the stage for the biological conditions observed at the time of sampling. Alterations in baseflow, whether through depletion or augmentation, can reduce macroinvertebrate diversity and abundance, promote the loss of sensitive species and increase non-natives (Poff and Zimmerman 2010). These biological shifts directly impact CSCI scores, ultimately influencing the overall ecological health of modified channels.

Across all FFM, only a limited number of sites could attain reference conditions with a small flow change (less than 10%), though many sites were identified as able to achieve an incremental improvement (+0.1). These findings highlight that the flow components most critical for ecological health may require the most effort to manage, as they generally require the largest flow adjustments to achieve ecological targets. They also suggest that achieving reference conditions may be particularly challenging for certain FFMs and modified channel types.

FFMs related to peak flows were often the most relevant to CSCI scores, especially in soft-bottom channels. Ecologically, peak flows are important because they maintain channel form, move sediment and organic matter, and replenish microhabitats for biota (Nichols et al. 2006, Buchanan et al. 2013, McManamay et al. 2013, Stein et al. 2017). However, considering the potential inaccuracy of peak flows from the hydrological model, further investigation would be needed into how to manage peak flows effectively. Flow models to estimate altered peak flows can be improved with some additional hydrologic data collection, as described below (Next Steps). In the meantime, managers should consider additional lines of evidence to verify if peak flow metrics (and, in fact, any FFM found to be altered by this framework) are valid for the site in question. Such validation might include consultation of California's Natural Flows Database (https://rivers.codefornature.org/; Grantham et al. 2022), or evaluating potential causes for the observed alteration (e.g., depleted peak flows might be expected from dam operated to reduce flood risk). In the absence of corroborating information, outcomes of this study's framework should be viewed as inconclusive. This type of verification is recommended for all FFMs, although it is most valuable for FFMs related to peak flows.

How much change in flow is required to reach standard and modified ecological targets?

Sites requiring small (<10%) and moderate (10-50%) flow change are strong candidates for flow management, as relatively minor adjustments to flow conditions could lead to significant ecological improvements. However, relatively few sites require such adjustments to achieve reference conditions. Achieving incremental improvements or flow associated with the best observed may be more feasible, at least for some FFM, as sites requiring modest or moderate flow changes are more prevalent.

Altered flow is potentially impacting biology in many engineered channels. Sites requiring over 50% flow change are particularly concerning, as they have been identified as having flow alteration as well as unhealthy biology but can only achieve biological improvements with substantial flow changes. These sites often correspond to highly engineered hard bottom channels with highly altered flow. However, they are present on some natural channels. Moreover, some stormwater agencies may not have mechanisms for achieving such large changes in FFMs at some or all of these sites.

Many sites with unhealthy scores were identified as “non-flow related”, which may reflect impacts from other stressors such as poor water quality, physical habitat degradation, or elevated temperatures known to have adverse effects on stream communities (Burgmer et al., 2006, Vorosmarty et al., 2010) (Burgmer et al. 2007, Vörösmarty et al. 2010, Los Angeles County 2022, Abdi et al. 2022). Incremental flow adjustments are unlikely to improve biological conditions. Therefore further investigation such as causal assessment is needed to identify and address non-flow-related factors (Norton et al. 2014, U.S. Environmental Protection Agency 2017).

Although HB channels are typically found in developed areas where flow alteration is often observed, a large number of these sites were not found to have flow alteration substantial enough to be a likely contributor to poor biointegrity. Non-flow stressors may play a role, as fully channelized streams often lack natural substrates, riparian cover and in-stream habitat that are critical for supporting ecological communities. The absence of detected flow alteration in these sites may stem from several factors. First, the flow model’s reliance on imperviousness and landscape characteristics may overlook localized drainage, storm drains, and wastewater discharges, making flow conditions appear closer to reference than reality. This is particularly problematic for spring recession magnitude, where the model likely underestimates flow alteration. Second, even without significant flow alteration, habitat loss and physical constraints, such as high velocities, in concrete-lined channels, negatively affect CSCI scores by making conditions unsuitable for sensitive organisms. Third, many channels are hardened for flood control or urban planning rather than direct flow alteration. However, hardening alters flow dynamics, exacerbating the divergence from reference conditions. Fourth, channel capacity is also not considered by the model. Smaller channels with low baseflows may appear within reference ranges despite significant hydrological changes, as demonstrated by site SMC04132, which has a reference dry-season baseflow range of 0 to 0.083 cfs, but its observed delta is 9.82 cfs. This shows a substantial deviation from reference conditions but is still classified as non-flow-altered.

Limitations and next steps

The study faced several key limitations, underscoring the challenges of modeling flow-ecology relationships in highly modified environments. The flow model's coverage was limited, as it did not fully account for smaller tributaries, and the flow metrics focused on large-scale catchment characteristics but failed to incorporate local hydrological factors such as velocity and turbidity, which are known to influence ecological health (Monk et al. 2018, Wegscheider et al. 2023, Forio et al. 2023). This limitation makes it challenging to determine whether flow alterations result from land use changes (e.g., urban imperviousness), catchment characteristics or direct channel modifications. The interplay between these factors often compounds hydrological changes, making it difficult to differentiate specific drivers known and interpret their individual contributions (Roberts et al. 2016, Anim et al. 2019).

Additionally, the model primarily assesses flow magnitude, but research suggests that the timing of dry-season and fall pulse flows is equally, if not more, important, highlighting the need to expand the model's scope beyond magnitude alone (Peek et al. 2022, Irving et al. 2022). Ultimately, improving flow management in modified channels will likely require a combination of refined hydrological modeling, alternative flow metrics, and complementary strategies that extend beyond flow alteration to include water quality improvements and habitat enhancements.

Models to estimate peak flows could be improved by collecting additional flow data at sites experiencing augmentation. These flow models were trained with data sets in which depleted flows were disproportionately represented (Taniguchi-Quan et al. 2023). Different approaches to modeling (e.g., mechanistic models) may provide better estimates of peak flow alteration than the empirical models developed by Taniguchi-Quan et al. (2023), although these models would need extensive refinement in order to apply at a regional scale. This approach has been attempted before, with mixed success (Mazor et al. 2018b, Sengupta et al. 2018); in contrast to the models developed by Taniguchi-Quan et al. (2023), the models developed by Sengupta et al. (2018) generally had better estimates of peak flows, but poor estimates of base flows.

Implications for management

This study can help identify both priority sites for intervention and specific seasonal flow components that have the greatest ecological impact and facilitate management efforts are targeted and effective in addressing flow-related challenges.

The site's potential to improve CSCI can serve as a screening tool to prioritize flow management efforts by identifying where flow alterations are most likely to impact biological health. Sites which require only small flow modifications to reach a biological objective can be flagged as high-priority candidates for targeted flow management. Sites where modest flow adjustments could still yield measurable biological improvements, could potentially guide flow management strategies for maintaining or improving biointegrity; subsequent to identifying such sites, agencies can then determine where they have mechanisms to improve flow and prioritize these sites over sites where they lack opportunities for flow management. In contrast, sites that require a large amount of flow change indicate where flow restoration alone is unlikely to be effective, helping managers recognize where other factors, such as water quality improvements or habitat restoration, should be prioritized instead. By using these classifications as an initial screening tool, resource managers can efficiently allocate restoration efforts, focusing on sites where flow interventions are most likely to succeed while identifying areas that require broader, multi-factor management approaches.

The flow change thresholds, while only used in the categorization, may not always be sufficient to drive meaningful biological improvements. For example, a low-scoring site may be predicted by the model to need only a 10% flow adjustment to reach its target, but this may not be enough to achieve biological improvement. A diversion of 6-20% of natural flows is generally regarded as causing minimal harm to aquatic ecosystems (Richter et al., 2011). Therefore some sites may require more substantial flow modifications to achieve meaningful ecological benefits. With this in mind, the flow change thresholds in this report are only provided as a guide and would need to be adjusted based on specific management objectives and locations to support ecological recovery.

Flow thresholds modified for engineered channels, such as best observed (BO) or incremental targets, can help prioritize flow management and restoration efforts in modified streams. For example, soft-bottom channels may benefit from incremental or BO targets, while hard-bottom channels often require more extensive interventions due to their highly altered hydrological and ecological conditions. However, BO or incremental targets may not be the ultimate management goal as they can still represent "poor" ecological health rather than "good" ecological health. In cases where the goal is to achieve "good" ecological health, BO or incremental targets could be viewed as interim benchmarks, helping avoid the further degradation of conditions while also guiding progress toward long-term ecological improvement.

PART 2: CAUSAL ASSESSMENT IN ENGINEERED CHANNELS

Automated causal assessment tools have recently been developed to rapidly evaluate evidence for likely causes of poor biological conditions. In this study, the SMC adapted those methods for use in engineered channels. Standard approaches to causal assessment rely heavily on the use of comparator sites. For example, stress levels at a site in poor condition are compared to stress levels at healthier comparators; higher stress levels are considered evidence that the stressor is a likely cause. In the SMC's modified approach, only similarly engineered sites are used as comparators. When the two approaches provide a similar conclusion, managers have greater confidence in the potential benefits of stressor reduction, even if the channel modifications remain in place. When they disagree, managers may need to consider more substantial remediation efforts, such as channel restoration, before seeing benefits from stressor reduction.

The modified approach confirmed and reinforced the conclusions of the standard approach at about two-thirds of the engineered channels in the region, meaning that reducing stress (e.g., from eutrophication) would likely help these sites, even if channel modifications remain in place. Disagreements between the two methods were most common at hard-bottom channels, suggesting that many of these sites are unlikely to benefit from stressor reduction alone.

Introduction

In many urban and agricultural settings, stream channels are frequently engineered to improve water conveyance, control flooding, protect infrastructure, and other purposes; however, these modifications can reduce or eliminate habitat for aquatic life, imposing constraints on the ecological conditions the channels might attain. Thus, watershed managers are challenged to identify ways to improve biological conditions (e.g., through water quality improvements or flow management) if modifications will remain in place to support competing uses. In this study, causal assessment tools were adapted (Norton et al. 2014, U.S. Environmental Protection Agency 2017, Gillett et al. 2023) to evaluate the potential for improving conditions within different types of modified channels in southern California's coastal watersheds.

The poor conditions of engineered channels in California have been previously documented (Mazor et al. 2018a, 2024), and the general impacts on benthic communities have been widely documented (Bylak and Kukuła 2018, Gomes and Wai 2020, Tank et al. 2021). Bioassessment indices based on benthic macroinvertebrates (i.e., the California Stream Condition Index [CSCI]; Mazor et al. 2016) or benthic algae (i.e., the Algal Stream Condition Index for diatoms [ASCI];

Theroux et al. 2020) typically have ranges of scores in engineered channels well below those observed in unmodified channels. Channels with hardened streambeds have particularly poor CSCI scores, whereas those with soft streambeds have particularly poor ASCI scores (Mazor et al. 2024). Because channel engineering typically co-occurs with extensive watershed development, it remains unclear if constructed features alone substantially affects stream biota independent from the associated impacts of poor water quality and hydrologic alteration. Relatively high CSCI scores can be observed in engineered channels, more often in areas with low levels of watershed development (Mazor et al. 2024). Engineered channels with scores above 0.79 are rare (e.g., about 8% of soft-bottom channels, and <1% of hard-bottom channels; Mazor et al. 2024).

Causal assessment tools can shed light on stressor types and the magnitude of likely effects (Schoolmaster et al. 2013, Norton et al. 2014, U.S. Environmental Protection Agency 2017). The process of causal assessment is the evaluation of lines of evidence for stressors being a potential cause of poor biological conditions, and can result in stressors being considered "likely" or "unlikely" causes. Using these tools in an iterative process can identify likely causes for potential remediation or follow-up study, as well as unlikely causes that may not need further investigation. The U.S. Environmental Protection Agency has outlined many of the steps in causal assessment as part of their Causal Analysis/Diagnosis Decision Information System (CADDIS, U.S. Environmental Protection Agency 2017). Although it may provide a relatively high level of certainty, CADDIS can be time consuming, and is unsuitable to large-scale application to many sites. Gillett and others (2023) standardized many of these steps to create rapid-screening causal assessment (RSCA) tools, which takes advantage of regional monitoring data sets and is well suited to large-scale applications at the cost of providing less certainty than traditional CADDIS. RSCA tools have some limitations, such as their inability to evaluate the relative contributions of different stressors. However, they provide a valuable starting point for more detailed investigations by narrowing the focus on a subset of likely stressors over those determined to be unlikely. Furthermore, their ability to analyze many sites at once allows helps managers prioritize sites for follow-up confirmatory studies.

Many lines of evidence in causal analysis are comparative in nature. For example, a spatial co-occurrence line of evidence looks at stress levels at the site in poor condition (i.e., the test site), compared to healthier comparator sites; higher stress levels at the test site are considered supporting evidence, whereas similar levels are considered indeterminate, and lower levels are considered weakening evidence. In this study, RSCA was applied to engineered channels in southern California in two ways. First, the standard application, in which modified test sites are compared to all appropriate comparator sites was conducted on all available sites with sufficient data. Second, RSCA was repeated, but comparator sites were limited to those that have similar channel engineering to the test site. Thus, modified RSCA identifies stressors that were potential causes of poor biological conditions, relative to similarly engineered channels exposed to different levels of stress.

This approach was applied at three spatial scales: First, a regional assessment was conducted to identify the most frequent likely causes in different watersheds of southern California, and in different classes of engineered channels. Second, the spatial distribution of outcomes was examined to identify geographic regions where similar patterns of stress were evident. Third, individual sites were evaluated in selected regions; local watershed managers reviewed results from both the standard and alternative approach in light of their understanding of the conditions of the channels they focused on.

Methods

Study area

Coastal southern California (i.e., the South Coast) is a semi-arid region with a Mediterranean climate, which experiences nearly all of its precipitation as rainfall during winter months. Lower elevations are characterized by chaparral, oak woodlands, grasslands, and coastal sage scrub. The region is bordered by the Transverse Ranges to the North, and the Peninsular Ranges to the East, and continues to the Mexican border to the South. Both Transverse and Peninsular ranges contain peaks that exceed 10,000 feet and regularly experience snow, although contributions to stream flow are limited. Much of the higher elevations are undeveloped and remain protected in a network of national, state, and county parks and forests. The lower elevations have been largely urbanized or converted to agriculture. Wildfires and drought are frequent in the region, with extensive fires occurring in 2009, 2013, 2017, and 2018 throughout much of the area. By area, the overall region is 59% undeveloped open space, 28% urban, and 13% agricultural (Jon Dewitz 2024).

Data collection and aggregation

The Stormwater Monitoring Coalition (SMC) has conducted bioassessment at approximately 90 sites per year since 2009 in southern California at a combination of probabilistic and targeted sampling locations. As part of this program, a diverse array of biological indicators (i.e., benthic macroinvertebrates and benthic algae), water chemistry (e.g., nutrients and major ions), and physical habitat measures are collected at 150-m reaches. Physical and biological indicators are measured following Ode et al. (2016), which are modified from protocols used by the National Rivers and Streams Assessment program of the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency 2022). In brief, benthic macroinvertebrates are collected in a systematic fashion from 11 equidistant transects at 25%, 50% or 75% along the transect width (or 0%, 50%, and 100% in streams with gradient below 1%). Benthic algae are sampled 0.5-m upstream from invertebrate sampling locations using tools appropriate for the substrate (i.e., ABS delimiters for soft substrates, rubber delimiters for hard mobile substrates, and syringe scrapers for bedrock or immobile hard substrates). Thus, biological samples are collected from different microhabitats (e.g., riffles and pools) in the proportion that they occur within the reach. Physical habitat sampling includes measures of bank width, substrate, riparian vegetation, flow microhabitats, and in-stream fish habitat cover, as well as measures of disturbance in the riparian zone.

Bioassessment data collected with comparable protocols that were available in the California Environmental Data Exchange Network (www.ceden.org) were also aggregated for this study. Data from a total of 2833 bioassessment sampling events from 1164 unique sites with channel modification information were aggregated for this study.

Data analysis

Channel classifications

Channels whose morphology or alignment have been deliberately altered were classified as engineered channels, while other channels (including those with degraded but not deliberately altered habitat) were classified as natural. Engineered channels were further categorized based primarily on bed and bank material following the process outlined in Mazor et al. (2024). Through site-visits, examination of photos, and interpretation of aerial images, sites were classified into one of five stream classes:

- Natural (NAT; 750 sites)
- Soft-bottom channels with unhardened banks (SB0; 64 sites)
- Soft-bottom channels with one hardened bank (SB1; 48 sites)
- Soft-bottom channels with two hardened banks (SB2; 80 sites)
- Hard-bottom channels (HB; 222 sites)

Hardening could result from concrete, rocks, sandbags, wood, or other resistant material, and needed to affect at least 25% of the reach-length to affect a classification. Sites lacking classification information were excluded from further analysis.

Rapid Screening Causal Assessment (RSCA)

As described in Gillett et al. (2023), RSCA evaluates the strength of evidence for a causal relationship between four stressors (i.e., eutrophication, salinization, habitat degradation, and temperature alteration) and poor biological conditions. Each stressor is organized into "modules" of standard indicators (Table 5). These indicators are evaluated with three standard lines of evidence (i.e., spatial co-occurrence, reference condition comparison, and stress-response). RSCA is summarized below, with additional detail provided in Supplement 3.

Table 5. Stressor modules and indicators used in rapid screening causal assessment. Abbreviations are shown in parentheses. Asterisks (*) designate indicators with a positive relationship with biological condition; all other indicators have negative relationships

Stressor module	Indicators
Eutrophication	Dissolved oxygen (DO) in mg/L* Total nitrogen (TN) in mg/L Total phosphorus (TP) in mg/L Benthic ash-free dry mass (AFDM) in g/m^2 Benthic chlorophyll a (chl-a) in mg/m^2
Altered habitat	Evenness of flow habitats (Ev_FlowHab)* Diversity of natural habitat cover types (H_AqHab)* Diversity of natural substrate (H_SubNat)* Percent sands and fines (PCT_SAFN)
Salinization	Chloride (Cl) in mg/L Sulfate (SO_4) in mg/L Specific conductivity (SpCond) in µS/cm Total dissolved solids (TDS) in mg/L
Altered temperature	Water temperature (Temp) in °C Percent riparian cover (XCMG)*

Three lines of evidence (LOEs) are derived for each indicator:

- Spatial co-occurrence (SC): For the spatial co-occurrence LOE, indicator values at the test site are compared to values at *healthier* samples from comparator sites (defined as those with CSCI scores greater than the test site's score) and interpreted as shown in Supplement 3: Table S - 6.
- Reference condition (RCC): For the reference condition LOE, indicator values at the test site are compared to values at samples *in reference condition* from comparator sites (defined as those with CSCI scores greater or equal to 0.79) and interpreted as shown in Supplement 3:Table S - 6.
- Stress-response (SR): For the stress-response LOE, a logistic regression model is calibrated using all comparator sites with stressor data (regardless of how the CSCI score compares to the test site's score). Probabilities of poor biological condition calculated by these models are interpreted as shown in Supplement 3: Table S - 6.

Although CADDIS includes other LOEs, such as temporal co-occurrence (U.S. Environmental Protection Agency 2017), only these three have so far been adapted for use in RSCA (Gillett et al. 2023).

The process for RSCA is described in Gillett et al. (2023). For each site, the first step is to identify "comparator" sites with similar environmental settings expected to support similar benthic macroinvertebrate assemblages under natural conditions as described in Gillett et al. (2019). This approach uses the models that underpin the CSCI, which calculates the probability of occurrence of numerous macroinvertebrate taxa in undisturbed environmental conditions based on watershed and climatic characteristics of a site.

Rapid screening causal assessment (RSCA) was to all samples in poor biological conditions. To characterize biological conditions, benthic macroinvertebrate samples were evaluated with the California Stream Condition Index (CSCI; Mazor et al. 2016). These scores were compared to the 10th percentile of scores at reference sites (i.e., 0.79). Samples with scores below this threshold were considered to be degraded, where RSCA was necessary.

Changes to the standard RSCA process for engineered channels

All lines of evidence were re-evaluated following the same protocol as with standard RSCA, but this time restricted comparators to just a subset of those with similar modifications (e.g., compare a hard-bottom test site to hard-bottom comparator sites). The overall percent of sites where stressors were identified as likely causes by each method was calculated, as was the frequency with which conclusions of the standard RSCA were confirmed by the modified RSCA.

Table 6. Assessment framework for integrating outcomes of standard RSCA and modified RSCA conducted with a subset of similarly engineered comparators.

Standard RSCA with all comparators	Modified RSCA with similarly engineered comparators	Conclusion
Likely	Likely	Likely cause confirmed. Stressor reduction likely to improve biology even if channel modification remains in place.
Likely	Indeterminate	Likely cause not confirmed. Unclear if stressor reduction likely to improve biology. Stressor reduction may not improve conditions if channel modification remains in place.
Likely	Unlikely	Likely cause not confirmed. Stressor may be less important than other factors. Stressor reduction may not improve conditions if channel modification remains in place.
Likely	Cannot be evaluated	Likely cause not confirmed. Need more data from modified comparators.
Indeterminate	Likely	Indeterminate but high priority for further investigation. Some evidence that stressor reduction may help.
Indeterminate	Indeterminate	Indeterminate.
Indeterminate	Unlikely	Indeterminate.
Indeterminate	Cannot be evaluated	Indeterminate.
Unlikely	Likely	Unlikely cause, but a high priority for further investigation.
Unlikely	Indeterminate	Unlikely cause.
Unlikely	Unlikely	Unlikely cause.

Standard RSCA with all comparators	Modified RSCA with similarly engineered comparators	Conclusion
Unlikely	Cannot be evaluated	Unlikely cause.

Application to engineered and natural channels in southern California

Both standard and modified RSCA were applied to 1024 sites in southern California. Outcomes from standard and modified RSCAs were compared to identify which classes and which stressors were more likely to have changes in outcomes. In addition, the number of times modified RSCA was unable to derive LOEs was calculated. Failures to derive LOEs are expected to be more frequent with modified RSCA due to the lower number of comparator sites used in analysis, as well as the overall lower scores modified comparators are likely to have. In addition to the regional analysis described above, the spatial distribution of outcomes was examined to identify areas within the region exhibiting consistent patterns, which potentially experience stress from the same set of sources.

Case studies

Local stormwater managers within the Stormwater Monitoring Coalition of southern California were asked to review RSCA results for sites in their region and provide feedback. Specifically, they were asked if the assessment framework (Table 6) was helpful, whether the conclusions made sense for sites in their region, if they had other information that could support or contradict conclusions, and what next steps they would consider for these sites.

Results

Data set

Of the 1164 assessment reaches in the dataset, 819 had at least one sample with a CSCI score below 0.79, indicating poor biological conditions where RSCA could be applied (Figure 7, Table 7). Of these sites, 36% were in engineered channels, most of which were hard-bottom. Engineered channels were found in every watershed, but they comprised over half of the sites within the Calleguas, Lower Santa Ana, San Gabriel, and Los Angeles River watersheds (84%, 73%, 65%, and 64%, respectively). They were comparatively rare in the Ventura River and Southern San Diego watersheds (10% and 5% respectively).

Table 7. Sites with channel engineering information used in the study. NAT: Natural channels. SB0: Soft-bottom channels with no hardened banks. SB1: Soft-bottom channels with one hardened bank. SB2: Soft-bottom channels with two hardened banks. HB: Hard-bottom channels, with or without hardened banks. RSCA Needed: Site had at least one sample with a CSCI score < 0.79, and RSCA was applied. RSCA Not needed: Site had no samples with a CSCI score < 0.79, and RSCA was not applied. South Coast: The entire SMC region, from Ventura to San Diego.

Region/Watershed	RSCA	NAT	SB0	SB1	SB2	HB	Total engineered
South Coast	Needed	427	61	35	75	221	392
South Coast	Not needed	323	3	13	5	1	22
Los Angeles Region	Needed	163	28	29	32	155	244
Los Angeles Region	Not needed	155	1	11	3	1	16
Ventura	Needed	25	0	3	0	0	3
Ventura	Not needed	36	0	4	0	0	4
Santa Clara	Needed	55	4	5	1	9	19
Santa Clara	Not needed	63	0	0	2	1	3
Calleguas	Needed	9	16	14	17	14	61
Calleguas	Not needed	3	0	2	0	0	2
Santa Monica Bay	Needed	37	2	3	5	17	27
Santa Monica Bay	Not needed	11	0	0	0	0	0
Los Angeles	Needed	23	1	3	3	67	74
Los Angeles	Not needed	21	1	1	1	0	3
San Gabriel	Needed	14	5	1	6	48	60
San Gabriel	Not needed	21	0	4	0	0	4
Santa Ana Region	Needed	79	17	5	31	42	95
Santa Ana Region	Not needed	48	1	2	0	0	3
Lower Santa Ana	Needed	13	8	2	23	17	50
Lower Santa Ana	Not needed	6	1	0	0	0	1
Middle Santa Ana	Needed	22	3	2	2	22	29
Middle Santa Ana	Not needed	10	0	1	0	0	1
Upper Santa Ana	Needed	28	5	1	0	3	9
Upper Santa Ana	Not needed	19	0	1	0	0	1
San Jacinto	Needed	16	1	0	6	0	7
San Jacinto	Not needed	13	0	0	0	0	0
San Diego Region	Needed	185	16	1	12	24	53
San Diego Region	Not needed	120	1	0	2	0	3
San Juan	Needed	23	3	1	7	6	17
San Juan	Not needed	17	0	0	0	0	0
Northern San Diego	Needed	38	4	0	5	0	9
Northern San Diego	Not needed	39	1	0	0	0	1

Central San Diego	Needed	51	3	0	0	8	11
Central San Diego	Not needed	8	0	0	0	0	0
Mission Bay and San Diego River	Needed	38	4	0	0	9	13
Mission Bay and San Diego River	Not needed	15	0	0	1	0	1
Southern San Diego	Needed	35	2	0	0	1	3
Southern San Diego	Not needed	41	0	0	1	0	1

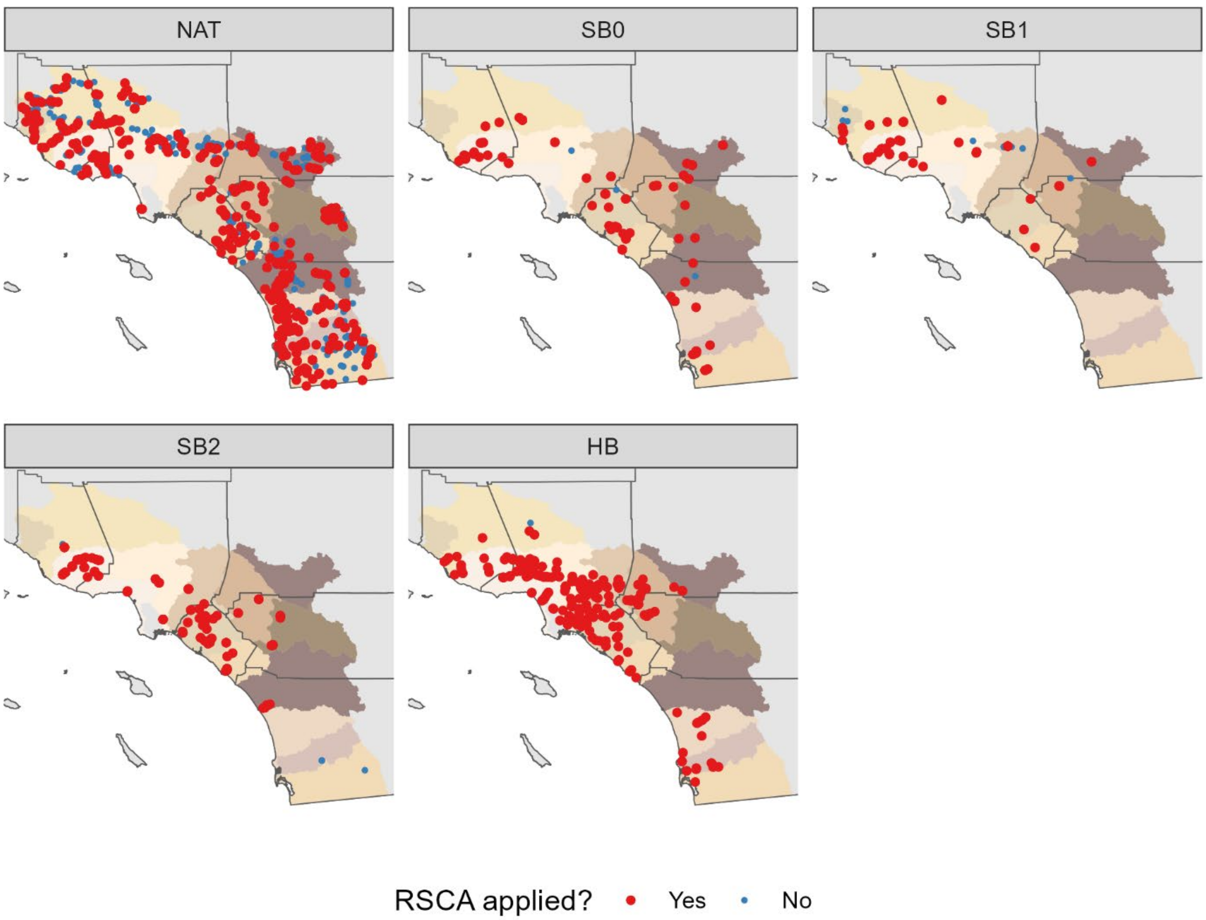


Figure 7. Location of sites in the study. NAT: Natural channels. SB0: Soft-bottom channels with no hardened banks. SB1: Soft-bottom channels with one hardened bank. SB2: Soft-bottom channels with two hardened banks. HB: Hard-bottom channels, with or without hardened banks. RSCA was applied to sites that had samples with CSCI scores < 0.79.

Comparison of modified and standard RSCA

Frequency of failures to derive evidence

As expected, constraining comparators to those with similar modifications severely reduced the number of comparators available for analysis, which reduced the ability to derive LOEs. Of the 5986 potential comparator sites in the SMC data set, channel engineering information was available at 1354 (including the 1024 in Table 7, plus additional sites outside of southern California). Restricting analyses to similarly engineered channels reduced the median number of comparators for HB streams by 88%, and all soft-bottom classes by over 95% (Table 8). Reductions were even greater when looking at healthier comparators, as required for evaluating the spatial co-occurrence LOE. When looking at streams in reference condition (for the reference condition comparison LOE), only a single site was typically available as a comparator for HB streams. Thus, constraining comparators to channels with similar engineering greatly reduces the data available to derive LOEs, and may prevent the analyses of some LOEs altogether (Table 9). HB and SB2 streams were the most severely affected, as no HB streams and only 4 SB2 streams had sufficient similarly engineered comparators to derive all three lines of evidence.

Sites where no LOEs could be derived were most common among natural channels (Table 9). This result is consistent with the fact that natural channels tend to span a much larger range of environmental settings, including some that are atypical for southern California (e.g., high elevations) and have relatively few comparators available (as documented in Gillett et al. 2019). Perhaps unsurprisingly, the RCC LOE was the most limiting due to the scarcity of engineered channels in reference condition.

Table 8. Median number of comparator sites for each class of channel. For natural , unmodified channels (NAT), "similarly engineered" comparators are also natural, unmodified channels.

Class	Comparators	Similarly engineered comparators	Healthier comparators	Healthier similarly engineered comparators	Comparators in reference condition	Similarly engineered comparators in reference condition
NAT	1131	444	436	224	468	230
HB	1310	160	910	82	474	1
SB0	1357	55	989	35	495	8
SB1	1395	43	649	27	473	16
SB2	1318	58	969	36	485	4

Table 9. Number of sites with sufficient numbers of comparator sites to derive LOEs. SC and RCC each require a minimum of 5 comparators. We assumed that 10 sites would be sufficient for the SR LOE.

Class	LOEs possible	Standard RSCA	Modified RSCA
NAT	0	0	24
NAT	1	1	3
NAT	2	3	6
NAT	3	653	624
HB	0	0	0
HB	1	0	3
HB	2	0	193
HB	3	196	0
SB0	0	0	2
SB0	1	0	1
SB0	2	0	2
SB0	3	56	51
SB1	0	0	3
SB1	2	0	2
SB1	3	48	43
SB2	0	0	1
SB2	1	0	2
SB2	2	0	60
SB2	3	67	4

Comparison of causal assessment conclusions from standard and modified RSCA

Across the data set, 46% of samples had CSCI scores > 0.79, and thus were excluded from further causal analysis. Among natural channels, 62% had passing CSCI scores, as did 45% of SB0 channels. At other engineered channels, the number was far lower—only 8% of other soft bottom channels, and only a single hard-bottom channel had CSCI scores > 0.79. Summaries of watersheds are provided in Supplement 4: Table S - 7.

The type of channel engineering was associated with the frequency that certain stressors were identified as likely causes. For example, at hard-bottom channels, altered temperature and habitat were identified as likely causes at nearly every site-visit, whereas the elevated conductivity was identified as likely at half of them, and eutrophication was likely at 69% (Figure 8, Table 10). In contrast, all four stressors were identified as likely causes with roughly similar frequencies in soft-bottom channels with 2 hardened sides.

Table 10. Percent of site-visits with each RSCA conclusion for each stressor and engineered channel class. Percent of site-visits that could not be evaluated due to insufficient data were excluded from analysis.

Stressor	Class	Conclusion	Standard	Modified	Difference
Conductivity	NAT	Unlikely Cause	39.7	48.5	8.8
Conductivity	NAT	Indeterminate Cause	6.0	4.8	-1.2
Conductivity	NAT	Likely Cause	54.3	46.8	-7.5
Conductivity	SB0	Unlikely Cause	30.9	16.9	-14.0
Conductivity	SB0	Indeterminate Cause	2.5	7.8	5.3
Conductivity	SB0	Likely Cause	66.7	75.3	8.7
Conductivity	SB1	Unlikely Cause	40.0	28.9	-11.1
Conductivity	SB1	Indeterminate Cause	13.3	4.4	-8.9
Conductivity	SB1	Likely Cause	46.7	66.7	20.0
Conductivity	SB2	Unlikely Cause	25.5	29.7	4.2
Conductivity	SB2	Indeterminate Cause	1.3	18.2	16.9
Conductivity	SB2	Likely Cause	73.2	52.0	-21.1
Conductivity	HB	Unlikely Cause	42.9	60.8	17.9
Conductivity	HB	Indeterminate Cause	7.3	6.8	-0.5
Conductivity	HB	Likely Cause	49.8	32.5	-17.4
Eutrophication	NAT	Unlikely Cause	33.5	42.5	9.1
Eutrophication	NAT	Indeterminate Cause	7.9	5.1	-2.8
Eutrophication	NAT	Likely Cause	58.6	52.4	-6.2
Eutrophication	SB0	Unlikely Cause	19.8	16.9	-2.9
Eutrophication	SB0	Indeterminate Cause	1.2	1.3	0.1
Eutrophication	SB0	Likely Cause	79.0	81.8	2.8
Eutrophication	SB1	Unlikely Cause	8.7	17.4	8.7
Eutrophication	SB1	Indeterminate Cause	0.0	4.3	4.3
Eutrophication	SB1	Likely Cause	91.3	78.3	-13.0
Eutrophication	SB2	Unlikely Cause	18.4	20.0	1.6
Eutrophication	SB2	Indeterminate Cause	2.0	2.7	0.7
Eutrophication	SB2	Likely Cause	79.6	77.3	-2.3
Eutrophication	HB	Unlikely Cause	26.9	39.5	12.6
Eutrophication	HB	Indeterminate Cause	4.3	3.3	-1.0
Eutrophication	HB	Likely Cause	68.8	57.2	-11.6
Habitat	NAT	Unlikely Cause	37.1	38.4	1.3
Habitat	NAT	Indeterminate Cause	2.0	8.1	6.1
Habitat	NAT	Likely Cause	60.9	53.5	-7.4
Habitat	SB0	Unlikely Cause	17.8	45.6	27.8
Habitat	SB0	Indeterminate Cause	0.0	16.2	16.2
Habitat	SB0	Likely Cause	82.2	38.2	-44.0
Habitat	SB1	Unlikely Cause	43.1	19.6	-23.5
Habitat	SB1	Indeterminate Cause	0.0	3.9	3.9

Stressor	Class	Conclusion	Standard	Modified	Difference
Habitat	SB1	Likely Cause	56.9	76.5	19.6
Habitat	SB2	Unlikely Cause	14.8	34.0	19.2
Habitat	SB2	Indeterminate Cause	2.0	13.6	11.6
Habitat	SB2	Likely Cause	83.2	52.4	-30.8
Habitat	HB	Unlikely Cause	0.7	54.8	54.1
Habitat	HB	Indeterminate Cause	0.0	2.2	2.2
Habitat	HB	Likely Cause	99.3	43.0	-56.3
Temperature	NAT	Unlikely Cause	55.8	57.7	1.9
Temperature	NAT	Indeterminate Cause	9.2	8.3	-0.9
Temperature	NAT	Likely Cause	35.0	34.0	-1.0
Temperature	SB0	Unlikely Cause	16.9	36.1	19.2
Temperature	SB0	Indeterminate Cause	10.4	13.9	3.5
Temperature	SB0	Likely Cause	72.7	50.0	-22.7
Temperature	SB1	Unlikely Cause	29.1	34.5	5.5
Temperature	SB1	Indeterminate Cause	30.9	25.5	-5.5
Temperature	SB1	Likely Cause	40.0	40.0	0.0
Temperature	SB2	Unlikely Cause	21.6	51.3	29.8
Temperature	SB2	Indeterminate Cause	7.8	10.7	2.8
Temperature	SB2	Likely Cause	70.6	38.0	-32.6
Temperature	HB	Unlikely Cause	3.0	23.0	20.0
Temperature	HB	Indeterminate Cause	1.6	31.0	29.4
Temperature	HB	Likely Cause	95.4	46.0	-49.4

When RSCA was repeated but comparator sites were limited to similarly modified sites, the same conclusion was reached 67% of the time when the standard RSCA resulted in a determination of likely, indeterminate, or unlikely (Table 6). The rate that likely causes were confirmed varied by channel type and stressor. In general, likely causes were more frequently confirmed in soft-bottom channels than hard-bottom, and for conductivity and eutrophication more than habitat or temperature (Table 12).

Table 11. Comparison of standard and modified RSCA (Mod RSCA) results at modified channels with CSCI scores < 0.79.

Standard RSCA	Mod RSCA Cannot be Evaluated	Mod RSCA Unlikely Cause	Mod RSCA Indeterminate Cause	Mod RSCA Likely Cause
Cannot be Evaluated	780	0	0	0
Unlikely Cause	12	334	10	33

Standard RSCA	Mod RSCA Cannot be Evaluated	Mod RSCA Unlikely Cause	Mod RSCA Indeterminate Cause	Mod RSCA Likely Cause
Indeterminate Cause	2	44	20	13
Likely Cause	38	347	190	957

Table 12. Percent of sites where likely causes identified by standard RSCA were confirmed by modified RSCA.

Class	Stressor	Likely (standard RSCA)	Likely (Mod RSCA)	Percent confirmed
SB0	Conductivity	47	41	87%
SB0	Eutrophication	54	48	89%
SB0	Habitat	53	23	43%
SB0	Temperature	46	27	59%
SB1	Conductivity	17	16	94%
SB1	Eutrophication	35	29	83%
SB1	Habitat	25	24	96%
SB1	Temperature	19	19	100%
SB2	Conductivity	94	64	68%
SB2	Eutrophication	105	93	89%
SB2	Habitat	110	69	63%
SB2	Temperature	96	51	53%
HB	Conductivity	124	78	63%
HB	Eutrophication	181	141	78%
HB	Habitat	258	105	41%
HB	Temperature	268	129	48%

When the RSCA conclusions differed, they tended to change in a consistent direction, with likely causes becoming indeterminate and indeterminate causes becoming unlikely. This shift was most pronounced with habitat and temperature (Figure 8, Table 12). For HB channels the percent of site-visits where habitat degradation was a likely stressor dropped from 99% to 43%, and temperature dropped nearly as much. SB0 and SB2 channels exhibited somewhat smaller drops, whereas the percent of NAT or SB1 channels did not change or even increased. Drops for conductivity were smaller still, whereas the effect on conclusions about eutrophication were relatively small (Table 10). These changes were clustered in the Los Angeles and San Gabriel river watersheds (Figure 9).

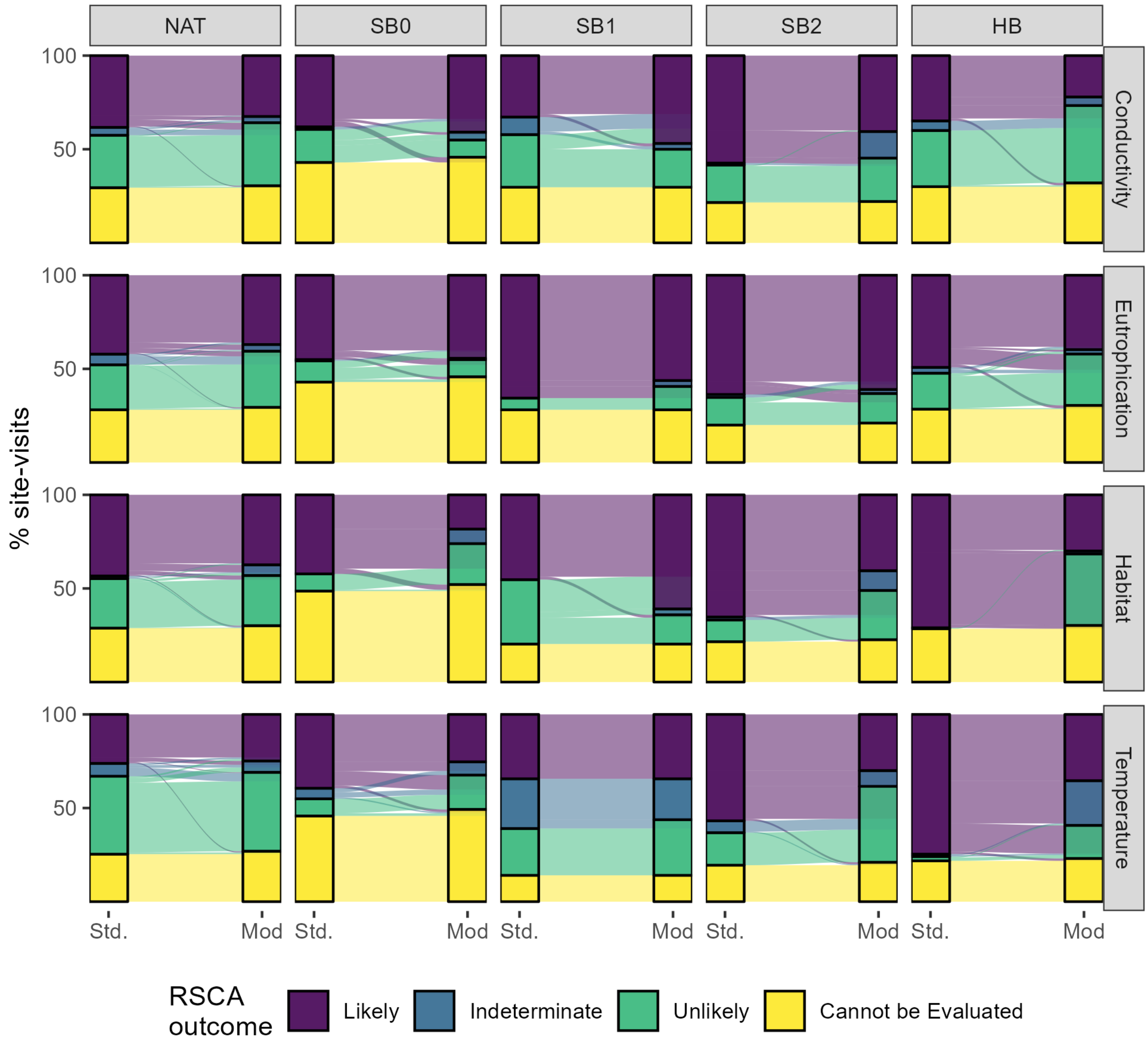


Figure 8. Comparison of standard and modified RSCA conclusions for each channel class. In each panel, the left bars indicate conclusions from the standard application of RSCA (Std.), whereas the right bars indicate conclusions from the modified application of RSCA (Mod.). The flowing lines connecting the left and right stacked bars are drawn with proportional thickness to indicate the number of site-visits with different conclusions from each application.

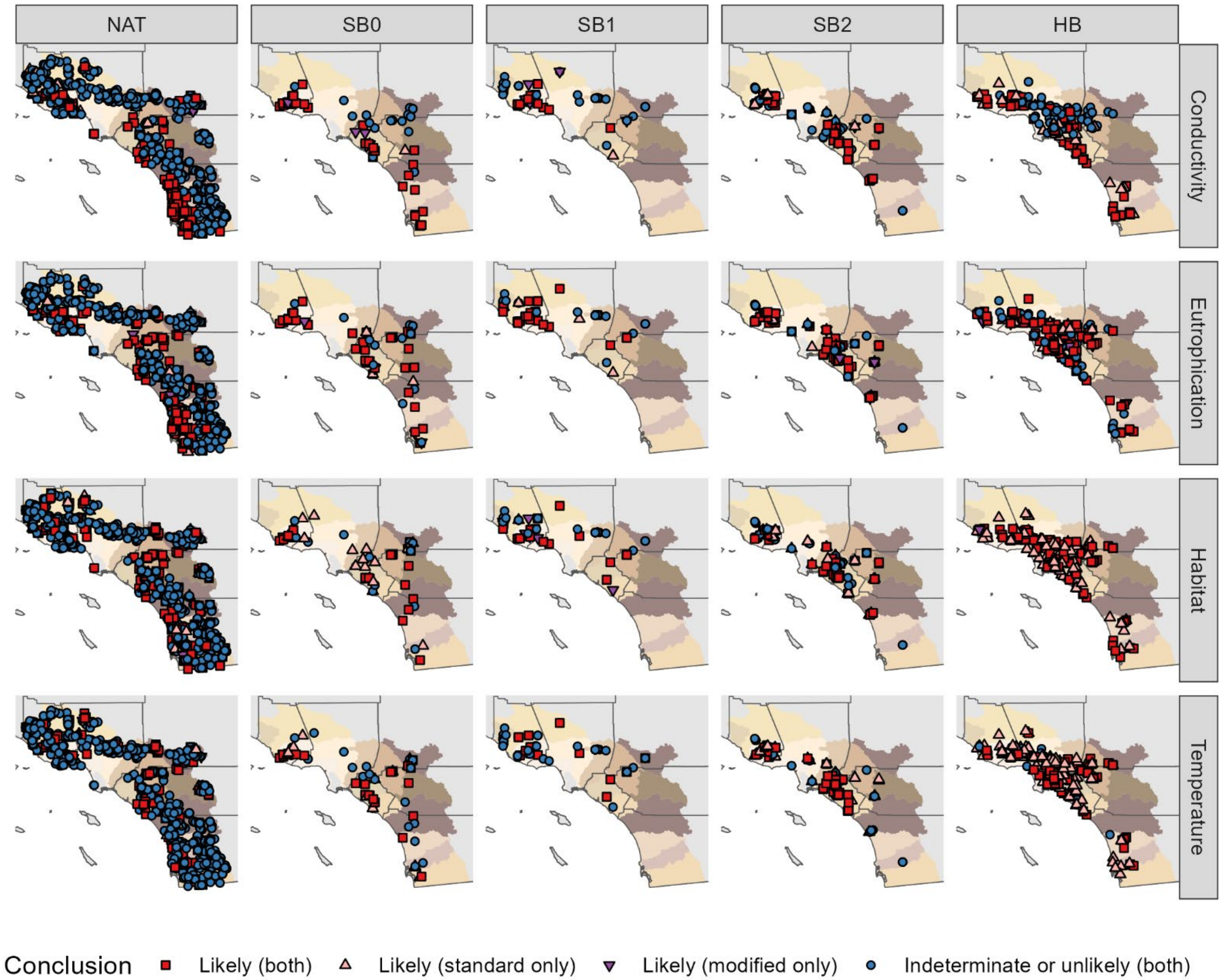


Figure 9. Map of sites showing where RSCA conclusions changed between the standard and modified application

Case studies

All of the practitioners who participated in case studies saw value in conducting both the modified RSCA in tandem with the standard approach. One stated, for example, that the results for the modified RSCA were more useful in hard-bottom channels because it could help identify factors other than habitat that could affect biological condition in these channels. Several practitioners believed that the modified RSCA results were more useful than those from the standard RSCA, or more credible when the two results disagreed.

Conejo Creek: Modified RSCA reinforces conclusions of standard RSCA

Conejo Creek provides an example of how watershed managers weighed information from both standard and modified RSCA. Conejo Creek is a soft-bottom channel with hardened banks (SB2) in Ventura County. Most sites along the creek received CSCI scores below 0.79, and hence RSCA was applied. At one site (SMC01860), both standard and modified RSCA consistently identified eutrophication as a likely cause. These conclusions were largely driven by high nutrient levels (total phosphorus ranged from 1.2 to 2.4 mg/L, and total nitrogen ranged from 5.8 to 7.8 mg/L), which were well above the ranges observed at healthier comparators (similarly modified or not) (Figure 10). Because both the standard and modified RSCA both pointed to eutrophication as a likely cause, reducing eutrophication stress could potentially improve CSCI scores relative to other SB2 channels. The heavy agricultural land use in the watershed was hypothesized as a potential source of nutrient inputs.

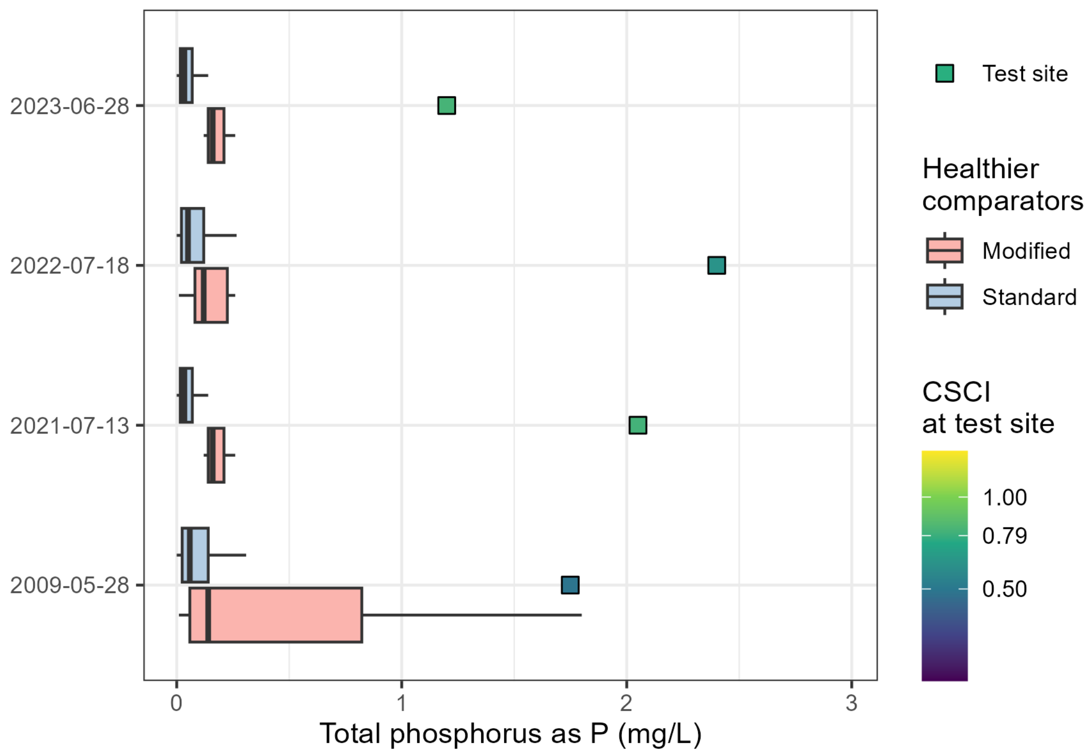


Figure 10. Levels of total phosphorus at a site on Conejo Creek, Ventura County (SMC01860) on different sampling dates compared to phosphorus levels at healthier comparators. Standard: All healthier comparators are included in the boxplot. Modified: Only similarly modified (i.e., SB2) healthier comparators are included in the boxplot.

San Jacinto River: Modified RSCA leads to a different conclusion from standard RSCA

Figure 11. A photo of the San Jacinto River site 802SJR116 taken in 2013. The armored banks are not visible in this photo.

Within Riverside county, a portion of the San Jacinto River (802SJR116) with armored banks and a natural bottom (SB2) was sampled on several occasions and had CSCI scores ranging from 0.34 to 0.63 (Figure 11). Specific conductivity ranged from 1740 to 2022 uS/cm—well above the levels seen at healthier comparators. However, these values were within typical ranges observed at healthier but similarly engineered comparators. Thus, reducing specific conductivity may not help this site attain better CSCI scores.

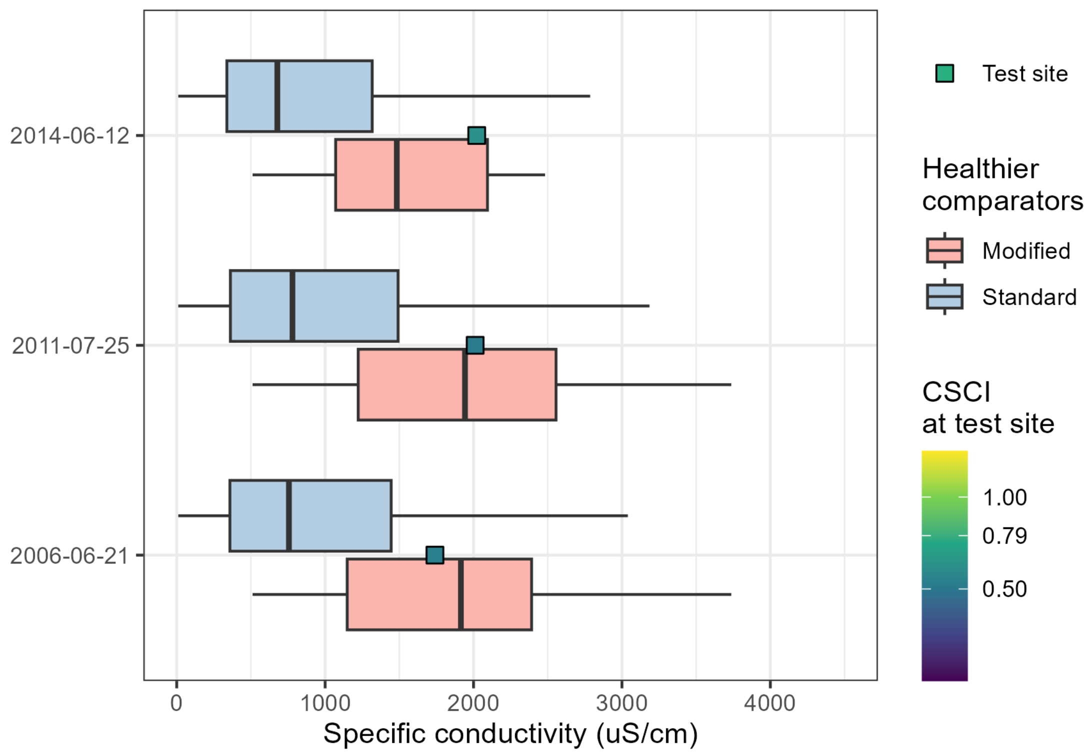


Figure 12. Levels of specific conductivity at a site on the San Jacinto River, Riverside County (802SJR116) on different sampling dates compared to specific conductivity at healthier comparators. Standard: All healthier comparators are included in the boxplot. Modified: Only similarly modified (i.e., SB2) healthier comparators are included in the boxplot

Murphy Canyon (907M23412): A relatively high-scoring modified channel where modified RSCA has less value

Figure 13. Murphy Canyon (907M23412) in 2020.

Murphy Canyon is a concrete-lined channel in San Diego County that had a CSCI score of 0.71, making it one of the highest-scoring HB channels in the dataset, yet still below the 0.79 threshold to trigger RSCA. Standard RSCA concluded that all four stressors were likely causes, although the modified RSCA only identified eutrophication and salinization as likely causes; habitat was indeterminate, whereas temperature was unlikely. The modified RSCA was severely hampered by the fact that so few similarly modified comparator sites were available to derive any LOEs. For example, there were no modified comparators in reference condition, meaning that neither the RCC nor the SR LOEs could be evaluated, and less than a dozen modified comparators had higher CSCI scores needed to derive the SC LOE. Thus, watershed managers believed that the standard RSCA provided more credible information about stress.

General feedback about RSCA

Some case study participants had feedback that was more generally applicable to the RSCA approach. For example, one indicated skepticism in some of the lines of evidence for dissolved oxygen due to its unimodal relationship with bioassessment index scores. Furthermore, dissolved oxygen was sometimes identified as supporting evidence of a eutrophication problem even when dissolved oxygen levels were relatively high—but not high enough to suggest hypersaturated conditions (e.g., site 801M15389, which had 11.5 mg/L dissolved oxygen). These outcomes could potentially reduce the overall credibility of RSCA results. Another case study participant recommended the inclusion of data on algal composition (e.g., California's algal stream condition indices, or ASCIs; Theroux et al. 2020) as a way to interpret stress from eutrophication. Algal communities have been shown to be more sensitive to water quality than habitat quality, and thus could be used to help disentangle the impacts of these two stressors (Charles et al. 2021, Poikane et al. 2022, Mazor et al. 2022).

Discussion

Protecting or improving biological integrity in modified channels remains a challenge, but the approach described in this study paves the way for identifying sites where stressor reductions are likely to produce benefits. Although modified channels tend to experience a similar set of stressors, our analyses suggest that different management strategies are needed for different sites. The key to the success of the proposed framework is that it complements the typical causal assessment approach with a modified approach that compares a test site to similarly modified comparator sites. Thus, the modified lines of evidence can provide insight into the potential effects of stressor reduction even when the channel modifications remain in place.

The caveats that apply to standard RSCA also apply to modified RSCA (Gillett et al. 2019, 2023). As a screening-level tool, RSCA is intended to quickly sort through large quantities of data at numerous sites, whereas more detailed analyses, supplemental sampling, and traditional causal assessments are needed to confidently prescribe fixes for specific sites. Thus, RSCA (in its standard or modified form) is best used as a prioritization tool and a springboard for more intensive investigation.

A major limitation of the modified RSCA is that the restriction of analyses to similarly modified comparators greatly reduces the amount of available data, particularly for the SR and RCC LOEs, which require at least some comparator sites in reference condition. LOEs could be adjusted for applications in modified channels (e.g., the SR response curve could be calibrated to predict the likelihood CSCI scores > the test site's CSCI score, rather than the likelihood of CSCI scores > 0.79). But these tweaks would not provide any insight for test sites that happen to have better CSCI scores than other similarly modified comparators (such as the Murphy Canyon case study site). In such cases, only the standard RSCA approach is applicable.

Recommendations and next steps

- Conduct standard and modified RSCA in parallel at all sites in modified channels where CSCI scores are low. Develop tools to facilitate the synthesis and incorporation of RSCA information into water quality monitoring reports.
- Conduct more detailed investigations and/or manipulative experiments at case study sites to validate conclusions of modified RSCA.
- Expand collection of channel engineering information (specifically, bed and bank material) at sites with existing bioassessment data, thus increasing the amount of data that could be used in modified RSCA.
- Explore modifications to LOEs that reduce the reliance on sites in reference condition.
- Incorporate new modules into RSCA to investigate flow modification and toxic pollutants as potential causes of poor biointegrity.
- Evaluate improvements to both standard and modified RSCA to address shortcomings identified in this study (such as its ability to handle unimodal stress responses to dissolved oxygen concentration).
- Identify and sample additional streams with physical modification but low levels of watershed development to expand the RCC pool.
- Incorporate additional biotic indices into causal assessment (e.g. ASCIs).

Part 3: The biological impacts of channel maintenance activities in modified channels

Stormwater agencies need to understand how channel maintenance might impact measures of biological integrity. Impacts could be negative due to the direct disturbance of habitat. However, impacts could also be positive, as the removal of excess fine sediments could generate suitable streambed substrate for benthic macroinvertebrates, fish, and algae. To investigate these potential impacts, the SMC conducted a pilot study at two sites in Riverside County. This pilot study was intended to identify the feasibility of evaluating biological conditions before and after channel maintenance activities occur.

Both sites were in soft-bottom modified channels, and it was initially thought that maintenance activities had previously occurred or could be scheduled in the future. One site was on upper Murrieta Creek (902UMC804), classified as SB0 (i.e., soft bottom with no hardened banks), and the other on the lower Temescal Channel (SMC18169), classified as SB2 (i.e., soft bottom with two hardened banks) (Figure 13). The Murrieta site is on a reach listed as impaired for toxicity (California State Water Resources Control Board 2022), as well as chlorpyrifos, copper, indicator bacteria, iron, manganese, nitrogen, and phosphorus. The Temescal site's reach (i.e., Temescal Creek Reach 1a) has listings for oil and grease, copper, iron, and malathion (California State Water Resources Control Board 2024).

Figure 14. Photos of the two pilot study sites.Top left: Murrieta Creek on 2/9/2023, after maintenance. Top right: Temescal Channel. Bottom left: Murrieta on 5/24/2023, prior to bioassessment.

On February 9, 2023 it was observed that mowing and potentially other maintenance activities had taken place along this reach of Murrieta Creek. Samples were collected from 902UMC804 on June 1, 2023 after field observations confirmed the creek appeared to have revegetated from the prior maintenance activities. It was then determined that this maintenance was not intended to be repeated in the foreseeable future and further post-maintenance samples were not collected. The Temescal Channel site SMC18169 was sampled on June 19, 2023 intended to be a pre-maintenance monitoring event. This site was in a soft bottom channel directly downstream from a fully hardened concrete flood control channel. It was thought maintenance was scheduled to be performed later that year however it was discovered regular maintenance activities are conducted only on the concrete lined portion of the channel, not within the soft bottomed portion of the channel where bioassessment had previously taken place and therefore post-maintenance samples were not collected.

Both sites were in poor condition, with CSCI and ASCI-D scores below the 10th percentile of reference (Table 13); however, the CSCI score at the Temescal site was much higher in 2023 (CSCI: 0.68) than at a previous sampling event in 2011 (CSCI: 0.45). Both sites had relatively limited fast-water habitat, although in-stream habitat complexity and riparian vegetation cover were substantially better at Upper Murrieta Creek. This difference is to be expected given the more extensive hardening within and upstream of the sampling location in Temescal Creek, as well as the greater extent of urbanization in its watershed compared to Murrieta Creek. Water column nitrogen concentrations were variable at both sites, with 10 mg/L in Murrieta and 2.3 mg/L at Temescal. Pyrethroids were detected in sediments at both sites.

Table 13. Pre-maintenance conditions at the two sites in the study sampled in 2023

Analyte	Upper Murrieta Creek 902UMC804	Lower Temescal Creek SMC18169
CSCI (threshold: 0.79)	0.56	0.68
ASCI (threshold: 0.86)	0.74	0.30
In-stream habitat complexity	63.1	11.7
% fast-water habitat*	3%	17%
Riparian vegetation cover**	18%	0%
Macroalgal cover	34%	64%
Macrophyte cover	28%	8%
Specific conductivity (uS/cm)	1625	1432
Total nitrogen (mg/L)	10	2.5
Total phosphorus (mg/L)	0.07	0.02
Total suspended solids (mg/L)	24	0.9

* % fast-water is the sum of the % area covered by fast-water habitats (that is, riffles, runs, rapids, and cascades), averaged across the 11 transects within the assessment reach. This is measured as a visual estimate at each transect.

** Riparian vegetation cover is the sum of upper canopy cover, averaged across each bank and 11 transects within the assessment reach. This is measured as binned visual estimate at each bank and transect: absent, sparse (<10%), moderate (10 to 40%), heavy (40 to 75%) and very heavy (>75%).

Conclusions

While conducting this study, Riverside County Flood Control and Water Conservation District staff determined that there is no system in place to allow for maintenance activities to be tracked at such a granular, 150-meter reach level. For example, although records documented which flood control facility had various maintenance activities performed, each facility can be several miles long and each activity might only affect a small portion of the channel. When initially begun, it was thought the information needed could be deduced from available information. However, as all systems are tied into specific project numbers designating specific facilities for maintenance schedules, payroll, accounting, and funding sources, at this time it is not possible to obtain the needed information to continue the study in this way.

Ultimately, pre- and post-maintenance activity samples could not be collected due to uncertainty about when and where maintenance activities occurred. At present, each agency within the SMC uses different methods of documenting past and planned channel maintenance activities. It may be helpful for the SMC to convene a workgroup that can develop an efficient and standardizable system of recording information about channel maintenance information that could support studies into the ecological impacts of these activities. However, agencies may face limitations in their ability to incorporate tracking and recordkeeping changes given historical information systems in place and resources needed to change how information is collected and maintained across departments.

PART 4: AN EVALUATION OF ENGINEERED CHANNELS WITH RELATIVELY GOOD BIOLOGICAL CONDITIONS

Summary

While most engineered stream channels in Southern California exhibit poor biological conditions, a few show unexpectedly high biological integrity, as indicated by California Stream Condition Index (CSCI) scores. To understand what sets these sites apart, the Stormwater Monitoring Coalition (SMC) resampled high- and low-scoring engineered channels across the region, focusing on hard-bottom and fully soft-bottom types. Additional data analyses on the top-performing sites were used to build a more robust dataset for comparison.

Results showed that CSCI scores in engineered channels can vary but are generally more stable than in natural streams, particularly in hard-bottom types. Environmental stressors like water quality and land use were less predictive of biological condition in engineered channels than in natural ones, although some patterns emerged: High-scoring sites often had more fast-water habitat, greater riparian vegetation, and were surrounded by less developed land. The muted response to environmental factors could indicate that physical modifications constrain biological conditions. Alternatively, this muted response could also indicate the impact of unmeasured or unevaluated stressors that co-occur with channel engineering, as only a handful of parameters were investigated in this study, and these were investigated one at a time. Common pollutants (such as metals or pesticides) were not measured at every site and not evaluated in this study. Thus, further investigation is recommended.

The findings suggest that habitat or water quality improvements could benefit engineered channels, but may not be sufficient to achieve reference-like conditions. Based on this study, we recommend increased sampling of high-scoring soft-bottom channels and leveraging restoration projects as natural experiments to better understand the potential for ecological improvement.

Introduction and background

Although the vast majority of streams in engineered channels have poor biological conditions, as indicated by low California Stream Condition Index (CSCI; Mazor et al. 2016) scores (Stormwater Monitoring Coalition 2017, Mazor et al. 2018a, 2024, Taniguchi-Quan et al. 2020), a small number have attained scores close to or even above thresholds indicating reference conditions. The Stormwater Monitoring Coalition undertook a study to investigate engineered channels with relatively high CSCI scores in order to identify environmental characteristics they share in common. These factors may provide insights into management strategies that promote better ecological health of engineered channels.

Approach

In 2023, a number of engineered channels where relatively high CSCI scores had been observed were identified and targeted for resampling. These sites included both hard- and soft-bottom channels (soft-bottom channels with one hardened side were excluded because previous analyses have shown that they tend to behave similar to unmodified channels). Although these sites had relatively high CSCI scores, these scores were often below 0.79 (i.e., the 10^{th} percentile of scores at reference sites); thus, these higher scoring sites may fall into the "likely" or "very likely altered" category with CSCI scores between 0.5 and 0.7. Lists of candidate sites were distributed to SMC participants, each of whom selected a site to sample in 2024; in some cases, backup sites were also identified.

Participants also selected one candidate lower-scoring site to sample in 2024. Candidate sites are shown in Table 14. In some regions, the highest scoring sites in engineered channels had very low CSCI scores (e.g., CSCI < 0.5), and thus no candidate sites were identified (e.g., the Santa Margarita portion of Riverside County); this lack of sites may reflect the low numbers of sites in engineered channels with sufficient flow for sampling in that region, and may not indicate that conditions of engineered channels there are particularly poor.

Table 14. High- and low-scoring engineered channels that were considered for sampling in 2024 and identified in the SMC workplan (Mazor 2024). HB: Hard-bottom engineered channels. SB0: Soft-bottom engineered channels with no hardened banks. SB1: Soft-bottom engineered channels with one hardened bank. SB2: Soft-bottom engineered channels with two hardened banks. The Max CSCI score was the highest CSCI score observed at the site prior to 2024.

Agency	Class	High-scoring site	Stream name	Max CSCI	Low-scoring paired site(s)	Stream name	Max CSCI
SGRRMP	HB	SMC00236	Big Dalton Wash	0.73	SMC02656 and	Walnut Creek	0.62
					SMC01260	Walnut Creek	0.55
R8	SB0	801STW258	San Timoteo Wash	0.87	801STW055	San Timoteo Wash	0.76
R4	SB2	403CE0188	Santa Paula Creek	0.93	404M07360	Medea Creek	0.71
VCWPD	SB2	403S00191	Santa Paula Creek	0.99	None		
		SMC01860	Conejo Creek	0.82			
LACFCD	SB2	404M07365	Rustic Creek	0.70	SGLT506 and	Walnut Creek	0.59
					LALT501		0.78
RCFC&WCD	SB2	SMC04749	Perris Valley Channel	0.61	SMC32897	Perris Valley Channel	0.40
San Diego	HB	SMC01606	Rose Canyon	0.71	SMC13062 and	Tecolote Creek	0.55
					906M21770	Soledad Canyon	0.62
San Diego	SB0	SMC06458	Sweetwater trib	0.54	None		
San Diego	SB2	SMC11430	Los Coches Creek	0.87	SMC00153	San Luis Rey	0.56
San Bernardino	SB0	801PLC469	Plunge Creek	0.98	None		
		801STW258	San Timoteo Wash	0.87			
Orange County	SB2	801SAR011	Santa Ana River	0.80	801STC532	Santiago Creek	0.71
	SB0	SMC01987	Aliso Creek	0.76	SMC00910	Aliso Creek	0.7

As described below in the results section, this approach was not successful in producing a data set which could be used to evaluate conditions contributing to relatively high CSCI scores in engineered channels. Therefore, an additional approach was implemented, focusing on the larger dataset of available bioassessment data in engineered channels. We screened data at other engineered channels with bioassessment data to identify sites where the maximum CSCI score was in the top 25th percentile of scores for that channel class within Southern California. That is, we established a "top quartile" dataset. Combined with the previous sites, we had a robust data set to evaluate key questions.

How consistent are good conditions in engineered channels?

Scores in engineered channels can be highly variable. For example, one of the sites identified as "low scoring" in Table 14 was sampled in 2024, and this new sample had a CSCI score that was nearly identical to its paired high-scoring site (Table 15). This increase in score could potentially be due to an increase in flow from rising groundwater, as 2023 and 2024 experienced higher than normal precipitation.

Table 15. Change in scores at a relatively high-scoring engineered channel and its paired low-scoring site. Both sites are in portions of the Perris Channel in Riverside County where the banks are hardened but the streambed remains soft.

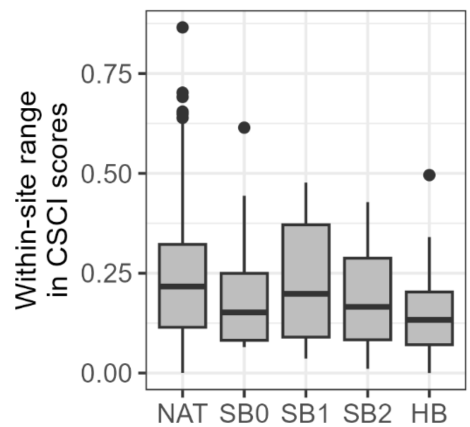
Type of site	Site code	Year of initial sample	Initial CSCI score	CSCI score in 2024	Change
High scoring	SMC04749	2009	0.61	0.64	+0.03
Low scoring	SMC32897	2014	0.40	0.62	+0.22

Among 437 sites with multiple samples, the typical site had CSCI scores that ranged 0.20 points. However, engineered channels typically exhibited *less* variation than NAT channels (Table 16, Figure 14). HB channels in particular had substantially smaller ranges in CSCI scores than other channel types, even compared to similarly low-scoring NAT channels. (Figure 15).

Table 16. Within-site ranges of CSCI scores by channel type.

Type	Number of sites	Median range in CSCI scores
NAT	295	0.22
SB0	22	0.15
SB1	16	0.20
SB2	38	0.17
HB	66	0.13

Figure 15. Within-site ranges of CSCI scores by channel type



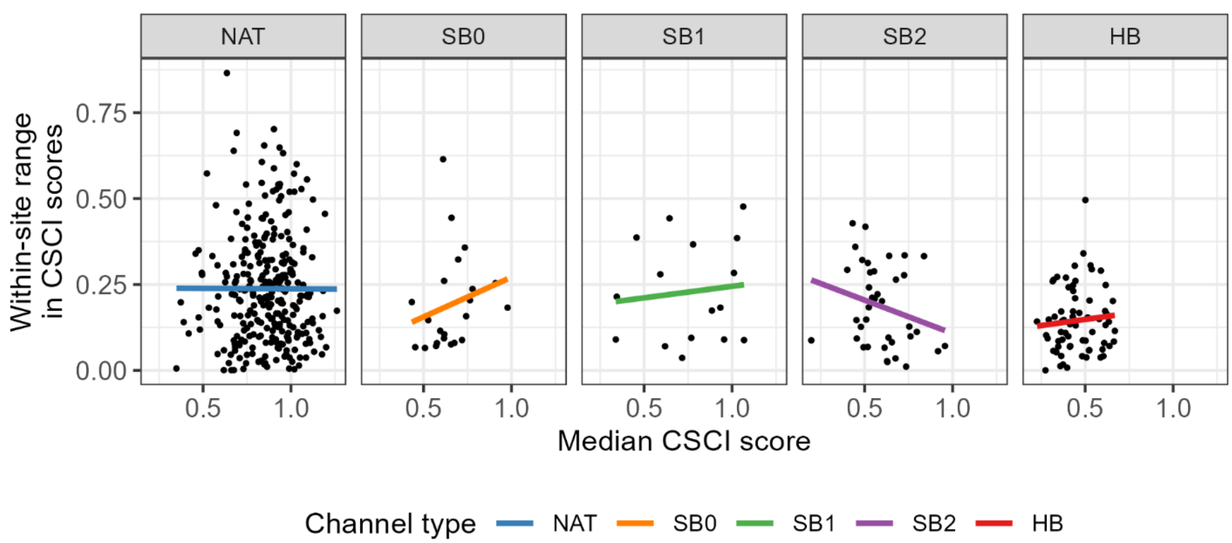


Figure 16. Relationship between the range and median CSCI score.

Do any environmental characteristics distinguish high-scoring engineered channels?

Environmental factors such as watershed alteration have the potential to impact CSCI scores, and they may explain why some engineered channels have better scores than others. To explore this question, sites in the top and bottom quartiles based on the site's maximum CSCI scores were identified (cutoff values are shown in Table 17). Stressor levels between the top and bottom groups were compared using t-tests. At least 5 sites in each group were necessary for there to be enough data for evaluation.

Table 17. Statistical distributions of maximum CSCI scores within classes of channels. The 25th and 75th quantiles were used to identify relatively low and high scoring sites, respectively.

Channel class	Total # sites	Total # sites with at least one CSCI score ≥ 0.79	10th	25th	50th	75th	90th
NAT	763	483	0.58	0.72	0.87	1.02	1.12
SB0	66	9	0.41	0.50	0.61	0.73	0.83
SB1	48	20	0.56	0.65	0.73	0.89	1.07
SB2	81	12	0.44	0.50	0.64	0.70	0.82
HB	228	1	0.32	0.39	0.49	0.60	0.68

At 54%, the most common class of engineered channel was HB, followed by SB2 (Table 18). Some channel classes were scarce or absent from certain watersheds; for example, there were no HB channels with bioassessment data in the San Jacinto, Northern San Diego, or Ventura watersheds. Overall, 26% of sites in the dataset were in engineered channels.

Table 18. Total number of sites with bioassessment data in each region and watershed

Watershed	NAT	SB0	SB1	SB2	HB	All engineered classes	Total # sites
South Coast	763	66	48	81	228	423	1186
Region 4	321	29	40	36	158	263	584
Ventura	61	0	7	0	0	7	68
Santa Clara	121	4	5	3	11	23	144
Calleguas	12	16	16	18	14	64	76
Santa Monica Bay	48	2	3	5	14	24	72
Los Angeles	44	2	4	4	70	80	124
San Gabriel	35	5	5	6	49	65	100

Region 8	131	18	7	31	45	101	232
Lower Santa Ana	20	9	2	23	19	53	73
Middle Santa Ana	33	3	3	2	23	31	64
Upper Santa Ana	49	5	2	0	3	10	59
San Jacinto	29	1	0	6	0	7	36
Region 9	311	19	1	14	25	59	370
San Juan	42	3	1	7	6	17	59
Northern San Diego	81	5	0	5	0	10	91
Central San Diego	59	4	0	0	9	13	72
Mission Bay and San Diego River	53	5	0	1	9	15	68
Southern San Diego	76	2	0	1	1	4	80

A total of 147 relatively high-scoring engineered channels were identified in all watersheds except for San Jacinto (Table 19). With 26 high-scoring engineered channels, the Los Angeles watershed was first, followed by the San Gabriel watershed. For HB channels, a clear spatial pattern could be discerned: high-scoring channels were more common away from the coast, in closer proximity to undeveloped areas within Regions 4 and 8, and along the lower San Diego river in Region 9 (Figure 16). The lower numbers of soft-bottom channels made it more difficult to observe a strong geographic pattern in their distribution; these sites occurred in both developed and undeveloped areas within the region. The one HB channel with a CSCI score above 0.79 was located in the upper Santa Clara watershed; this site (403M05800; 34.5291, -118.5224) drains the Drinkwater Reservoir and has an almost entirely undeveloped watershed.

Table 19. Number of high-scoring engineered and natural channels in each watershed.

Watershed	NAT	SB0	SB1	SB2	HB	All engineered classes
South Coast	306	29	14	30	74	147
Region 4	76	5	10	12	40	67
Ventura	7	0	2	0	0	2
Santa Clara	33	1	1	3	2	7
Calleguas	0	2	1	2	4	9
Santa Monica Bay	5	1	0	4	1	6
Los Angeles	13	1	1	2	22	26
San Gabriel	18	0	5	1	11	17
Region 8	32	6	2	4	8	20
Lower Santa Ana	0	1	0	2	2	5
Middle Santa Ana	6	1	0	2	4	7
Upper Santa Ana	21	4	2	0	2	8
San Jacinto	5	0	0	0	0	0
Region 9	83	6	0	5	9	20
San Juan	12	2	0	2	1	5

Northern San Diego	26	1	0	1	0	2
Central San Diego	8	1	0	0	3	4
Mission Bay and San Diego River	9	2	0	1	5	8
Southern San Diego	28	0	0	1	0	1

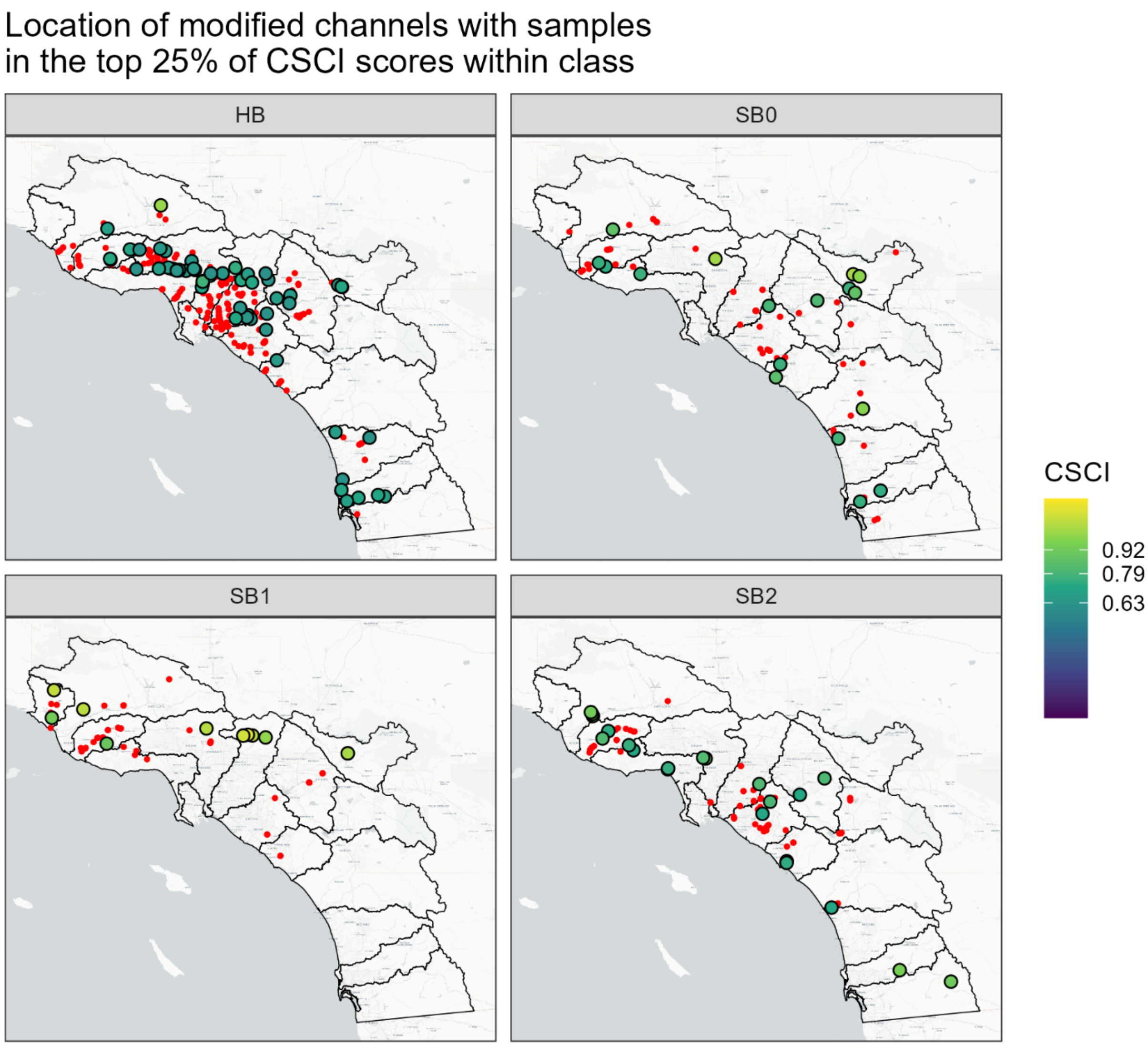


Figure 17. Location of high-scoring engineered channels in the South Coast region. Red dots indicate engineered channels with maximum CSCI scores below the class's 75th percentile (HB: 0.60; SB0: 0.73; SB1: 0.89; SB2: 0.70).

Outlier values for water quality were excluded from analysis based on the following criteria: pH > 14 or <3 ; alkalinity as $CaCO_3$ >2000 mg/L; temperature <4 or >40°C; salinity >10 ppt; total phosphorus > 10 mg/L; turbidity > 10 NTU; dissolved oxygen > 20 mg/L; and specific conductivity > 20,000 µS/cm. These values were selected because more extreme values likely indicated data entry errors or incorrect units, rather than true measurements in the authors' opinions.

In general, many stressors that had significant (p<0.01) relationships with CSCI scores within NAT channels had weaker or nonsignificant relationships in engineered channels (Table 20; mean values and t-statistics for more analytes are presented in supplemental material Table S - 8). For example, all water quality stressors (i.e., alkalinity, dissolved oxygen, salinity, specific conductivity, turbidity, water temperature, total nitrogen, total phosphorus, and pH) had significant relationships (p<0.01) with CSCI scores within NAT channels. In contrast, only dissolved oxygen had a significant relationship within HB channels, and even then it was in the opposite direction from expected (mean value in top vs. bottom groups: 10.1 vs 12.6 mg/L; Figure 17). Mean dissolved oxygen levels in both high- and low-scoring sites are well within ranges that support aquatic life, and the higher oxygenation of lower-scoring hard bottom channels may instead reflect the higher velocities commonly found in these channels, as well as eutrophication. Site elevation had a positive relationship with CSCI scores for several channel classes, which is expected given the fact that urbanization is typically more pervasive at elevations in the region.

Table 20. Summary of t-tests comparing environmental factors in high- vs. low-scoring sites. Positive: analyte measurements were significantly higher in high-scoring sites than in low-scoring sites (p<0.01). Negative: analyte measurements were significantly lower in high-scoring sites than in low-scoring sites (p<0.01). None: analyte measurements were not significantly different in high- vs. low-scoring sites. Need data: fewer than 5 sites with analyte measurements were available in either the high- or low-scoring group.

Type	Analyte	NAT	SB0	SB1	SB2	HB
Water quality	Alkalinity as CaCO3	Negative	None	Need data	None	None
Water quality	Dissolved oxygen	Positive	None	Need data	None	Negative
Water quality	Salinity	Negative	None	Need data	Need data	None
Water quality	Specific conductivity	Negative	None	Need data	None	None
Water quality	TN	Negative	None	None	None	None
Water quality	TP	Negative	None	None	None	None
Water quality	Temperature	Negative	None	Need data	None	None
Water quality	Turbidity	None	None	Need data	Need data	None
Water quality	pH	None	None	Need data	None	Negative
PHAB	Diversity of natural substrate types	Positive	None	Positive	None	None
PHAB	% fast-water habitats	Positive	None	Positive	None	Positive
PHAB	Riparian vegetation cover	None	Positive	None	None	Positive
PHAB	Mean in-stream fish habitat cover	None	None	None	None	None
PHAB	Sinuosity	None	None	None	None	None

Type	Analyte	NAT	SB0	SB1	SB2	HB
PHAB	Wetted width	Negative	None	None	None	None
PHAB	Bankfull channel width	Negative	None	None	None	None
Geospatial	Watershed area	Negative	None	None	None	None
Geospatial	% developed land cover (1 km)	Negative	None	Negative	None	Negative
Geospatial	% developed land cover (5 km)	Negative	None	Negative	Negative	Negative
Geospatial	% developed land cover (watershed)	Negative	None	Negative	None	Negative
Geospatial	Mean annual precipitation (2000 to 2009)	Positive	None	None	Positive	Positive
Geospatial	Mean air temperature (2000 to 2009)	Negative	None	None	None	Positive
Geospatial	Site elevation	Positive	None	Positive	None	Positive

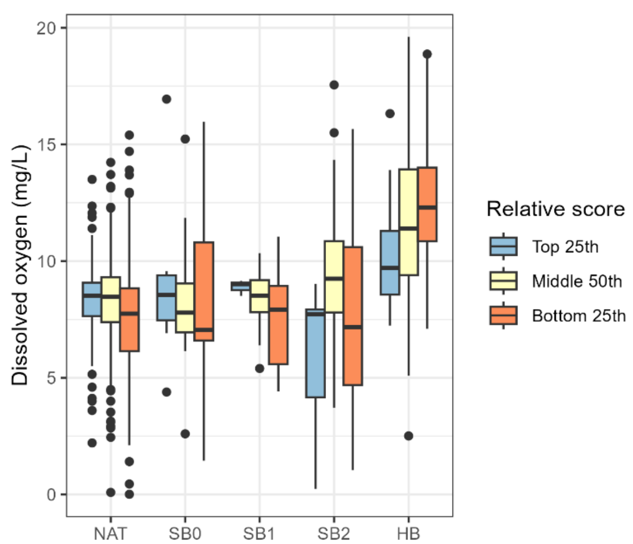


Figure 18. Dissolved oxygen levels in classes of engineered channels, stratified by maximum CSCI score.

Among physical habitat metrics, CSCI scores were related to several hydraulic and hydrologic metrics within HB channels. For example, the top scoring HB channels had on average over 50% fast-water habitats (such as riffles or runs); in contrast, the bottom-scoring HB channels had less than 25% fast-water habitats. Similarly, metrics related to riparian vegetation differentiated high- and low-scoring HB channels as well as soft bottom channels without hardened banks (SB0). For example, high-scoring channels had higher mean riparian vegetation cover than their low-scoring counterparts (HB: 17% vs 5%; SB0: 108% vs. 47%).

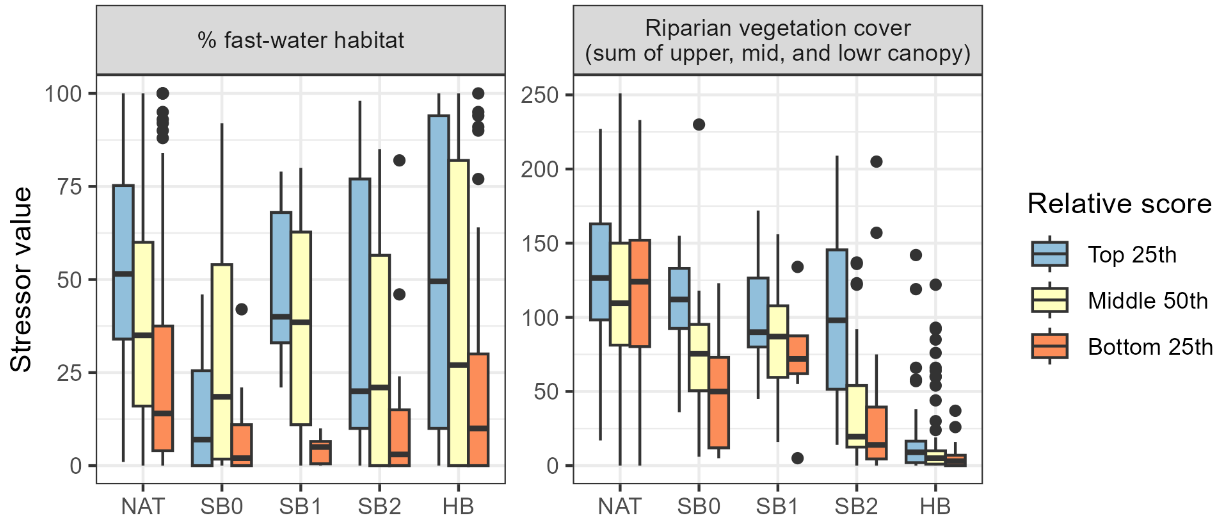


Figure 19. Physical habitat metrics in classes of engineered channels, stratified by maximum CSCI score

Among geospatial variables, those related to developed (urban or agricultural) land use differentiated high- and low-scoring sites. For example, high-scoring engineered channels had between 15% and 40% less developed land use within 5 km in the catchment compared to the low-scoring channels. Natural characteristics also differed, but to a smaller extent. For example, high-scoring HB channels drained watersheds that were only slightly smaller than those of low-scoring HB channels (mean area: 2496 km^2 vs. 2395 km^2), and for other engineered channel types, the difference was not significant ($p>0.01$).

Diminished responsiveness to water and habitat quality

In addition to comparing mean analyte values at high- and low-scoring sites, we also applied linear regression of CSCI scores against stressor values using the full data set (that is, including sites with intermediate CSCI scores), and visually examined the relationships in scatterplots (Figure 19). In general, relationships within this dataset between stressors and CSCI scores were strongest within NAT channels, and SB1 channels were essentially identical to NAT channels. SB0 showed weaker responses, and SB2 weaker still. HB channels only showed responses to a small number of stressors, such as total phosphorus (TP). Physical habitat metrics showed a muted response within engineered channels (Figure 20). Both hard- and soft-bottom channels showed a relatively strong positive response to vegetation cover (which is used as an indicator of shading and therefore temperature stress within RSCA). Note that linear models were used to explore relationships, which may be inappropriate for dissolved oxygen and pH, which appear to have nonlinear relationships with CSCI scores.

An important caveat in interpreting the graphs in Figure 19 and Figure 20 is that sites are examined for only a handful of environmental parameters, and these parameters are examined independently of each other; that is, their combined impact and the impact of unmeasured stressors were not analyzed. Therefore, stress levels may still be high even at sites that have low values of the stress indicator being plotted.

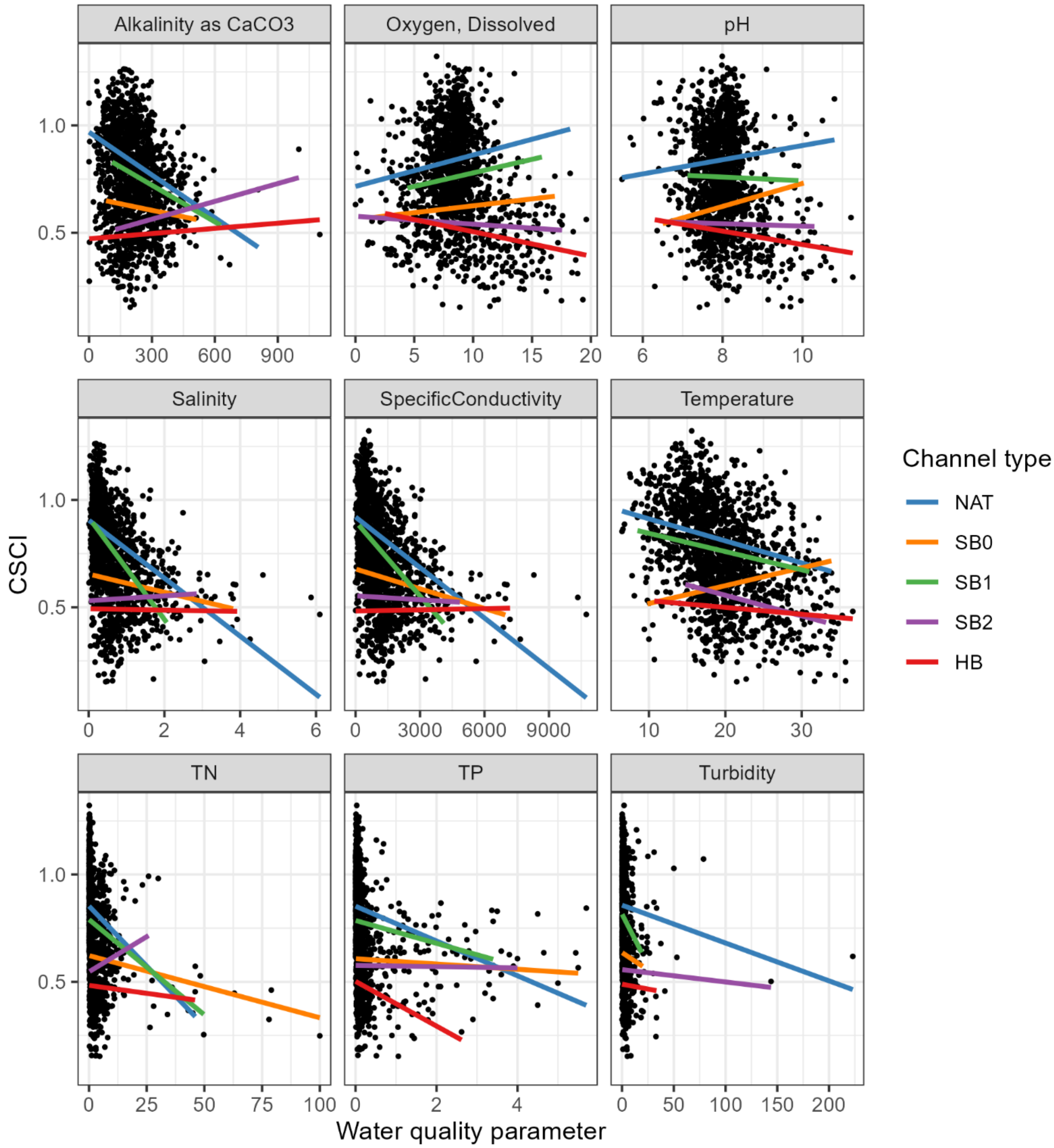


Figure 20. Relationship between CSCI scores and water quality stressors in different classes of engineered channels.

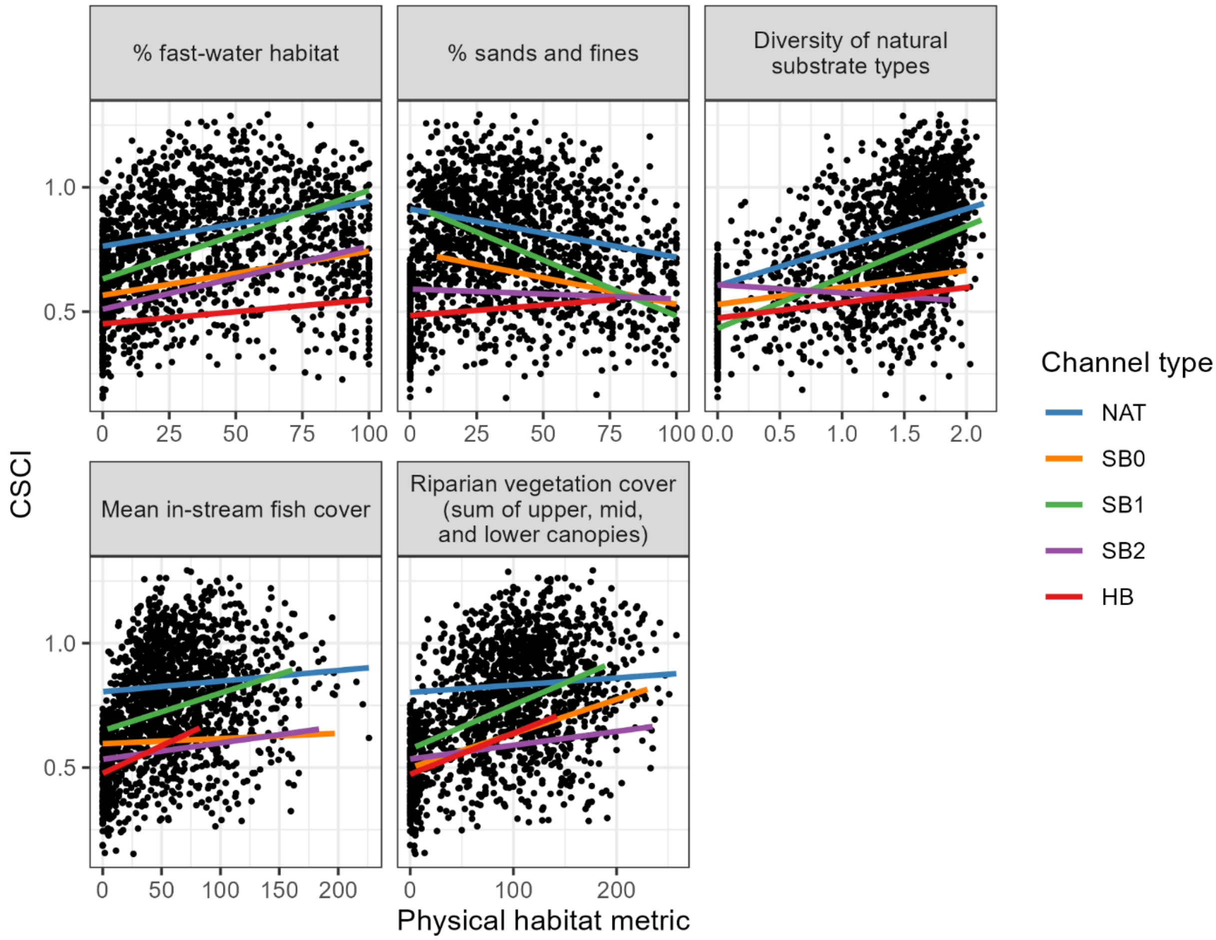


Figure 21. Relationship between CSCI scores and physical habitat metrics in different classes of engineered channels.

Conclusions and recommendations

These analyses provide some evidence that changing water quality or physical habitat conditions have the potential to improve biological conditions in engineered channels. The diminished responsiveness to stress in engineered channels could indicate that improving one water quality parameter alone may not be sufficient to achieve CSCI scores comparable to reference streams, or even to other natural channels. However, these analyses do not necessarily mean that channel engineering alone accounts for the diminished responsiveness; these models only considered one environmental factor at a time, and other factors could also account for low scores at sites where the examined water quality stress indicator is low. Because this study is based on observed associations rather than manipulative experiments, it is unclear if the better CSCI scores observed in some engineered channels are related to the water or habitat conditions at those sites, to developed land cover. In addition, this study did not attempt to address the question of whether restoration of engineered channels can increase CSCI scores.

The SMC workgroup recommends the following:

- Increase sampling at soft-bottom channels. Target previously unsampled sites (to increase the overall number of sites in the top quartile), as well as sites that have already been identified as high-scoring yet lack sufficient data for analysis (e.g., missing water chemistry data). Sampling could be supported through new studies or through a reallocation of existing sampling efforts within the SMC's stream survey as targeted sites. The goal of this sampling is to gain additional data from relatively high-scoring soft-bottom channels, rather than to gain additional data from soft-bottom channels in general. As with any site selected in a targeted fashion, these sites should not be used in assessments of overall ambient condition.
- Continue to revisit relatively high-scoring engineered channels in urban areas to confirm their conditions and identify factors contributing to their scores. Again, sampling could be supported through new studies or through a reallocation of existing sampling efforts within the SMC's stream survey as targeted sites.
- Take advantage of "natural experiments" where water quality or physical habitat is expected to change (e.g., due to restoration or installation of stormwater controls) to measure the impact in engineered channels. For example, collect bioassessment data before and after a channel restoration. To advance this goal, the SMC should develop a methodology to identify restorations and other projects that could be evaluated with a suitable study design.

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Supplement 1. Additional material for flow-ecology models

Table S - 1. Deviance explained, R squared (RSq), degrees of freedom (DF) and Akaike Information Criterion (AIC) for each flow-ecology mixed effects GAM with random intercept only.

Functional Flow Metric	*Deviance Explained*	*RSq*	*DF*	*AIC*
Spring recession magnitude	0.07	0.07	7.54	-106.01
Peak Flow Magnitude (Q99, cfs)	0.07	0.06	7.95	-101.50
Dry-season median baseflow	0.27	0.27	10.16	-299.40
Fall pulse magnitude	0.30	0.30	10.66	-333.32
10-year flood magnitude	0.17	0.16	10.53	-185.26
2-year flood magnitude	0.08	0.07	10.59	-102.38
5-year flood magnitude	0.13	0.12	10.76	-147.26
Wet-season low baseflow	0.17	0.16	10.68	-188.30
Wet-season median baseflow	0.09	0.08	10.85	-111.28

Table S - 2. Deviance explained, R squared (RSq), degrees of freedom (DF) and Akaike Information Criterion (AIC) for each flow-ecology mixed effects GAM with random slope only.

Functional Flow Metric	*Deviance Explained*	*RSq*	*DF*	*AIC*
Spring recession magnitude	0.39	0.39	7.98	-452.76
Peak Flow Magnitude (Q99, cfs)	0.39	0.39	7.77	-449.28
Dry-season median baseflow	0.42	0.41	10.60	-484.79
Fall pulse magnitude	0.42	0.41	10.79	-481.78
10-year flood magnitude	0.41	0.40	10.71	-466.56
2-year flood magnitude	0.43	0.42	10.23	-497.89
5-year flood magnitude	0.40	0.40	10.46	-463.67
Wet-season low baseflow	0.42	0.42	10.90	-487.61
Wet-season median baseflow	0.40	0.40	10.73	-460.02

Table S - 3. Sites with reference flows of zero. With mastered (site reference), COMID (NHD reach code), Flow Metric, Delta FFM, Channel Type, Category (defined through analysis), and median reference flows.

Masterid	*COMID*	*Flow Metric*	*Delta FFM*	*Channel Type*	*Category*	*Reference Flows (Median)*
904M21729	20341969	DS_Mag_50	0.28	NAT	Type X	0
SMC08094	22560942	DS_Mag_50	15.07	SB2	Type E	0
SMC08094	22560942	DS_Mag_50	15.07	SB2	Type C	0
SMC09118	22560942	DS_Mag_50	15.07	SB2	Type E	0
SMC09118	22560942	DS_Mag_50	15.07	SB2	Type C	0
904M21713	20342575	DS_Mag_50	0.76	HB	Type A	0
801M12625	22563212	DS_Mag_50	-8.69	HB	Type A	0
SMC02417	20342575	DS_Mag_50	0.76	HB	Type A	0
SMC13214	22560942	DS_Mag_50	15.07	SB2	Type E	0
SMC13214	22560942	DS_Mag_50	15.07	SB2	Type C	0
SMC01174	20329182	DS_Mag_50	9.02	NAT	Type A	0
801M12611	22560942	DS_Mag_50	15.07	SB2	Type E	0
801M12611	22560942	DS_Mag_50	15.07	SB2	Type C	0
SMC03737	20342575	DS_Mag_50	0.76	HB	Type A	0
910M24979	20333704	DS_Mag_50	5.68	NAT	Type A	0
902M18929	22548267	DS_Mag_50	2.32	NAT	Type X	0
903M20177	20341471	DS_Mag_50	1.82	NAT	Type A	0
SMC32718	20332828	DS_Mag_50	1.43	NAT	Type X	0
801M12675	22560942	DS_Mag_50	15.07	SB0	Type E	0
801M12675	22560942	DS_Mag_50	15.07	SB0	Type C	0
907CONECR	20332804	DS_Mag_50	0.37	NAT	Type A	0
904M21782	20342575	DS_Mag_50	0.76	HB	Type A	0
902S01097	22549067	DS_Mag_50	1.85	NAT	Type X	0
905SDYSA7	20330890	DS_Mag_50	0.05	NAT	Type X	0
907SDSVC3	20332430	DS_Mag_50	0.08	NAT	Type A	0
907SDSVC3	20332430	DS_Mag_50	0.08	NAT	Type X	0
904CBESC5	20341969	DS_Mag_50	0.28	NAT	Type A	0
907CONECR	20332804	DS_Mag_50	0.37	NAT	Type X	0
905BCN1xx	20330882	DS_Mag_50	0.17	NAT	Type X	0
901SJSMT2	20348717	DS_Mag_50	0.22	NAT	Type X	0
901SMCSMR	20350859	DS_Mag_50	0.05	NAT	Type X	0
905BCN1xx	20330882	DS_Mag_50	0.17	NAT	Type A	0
801M12625	22563212	Wet_BFL_Mag_10	-87.37	HB	Type E	0
SMC02206	22527369	Wet_BFL_Mag_10	0.65	SB2	Type A	0

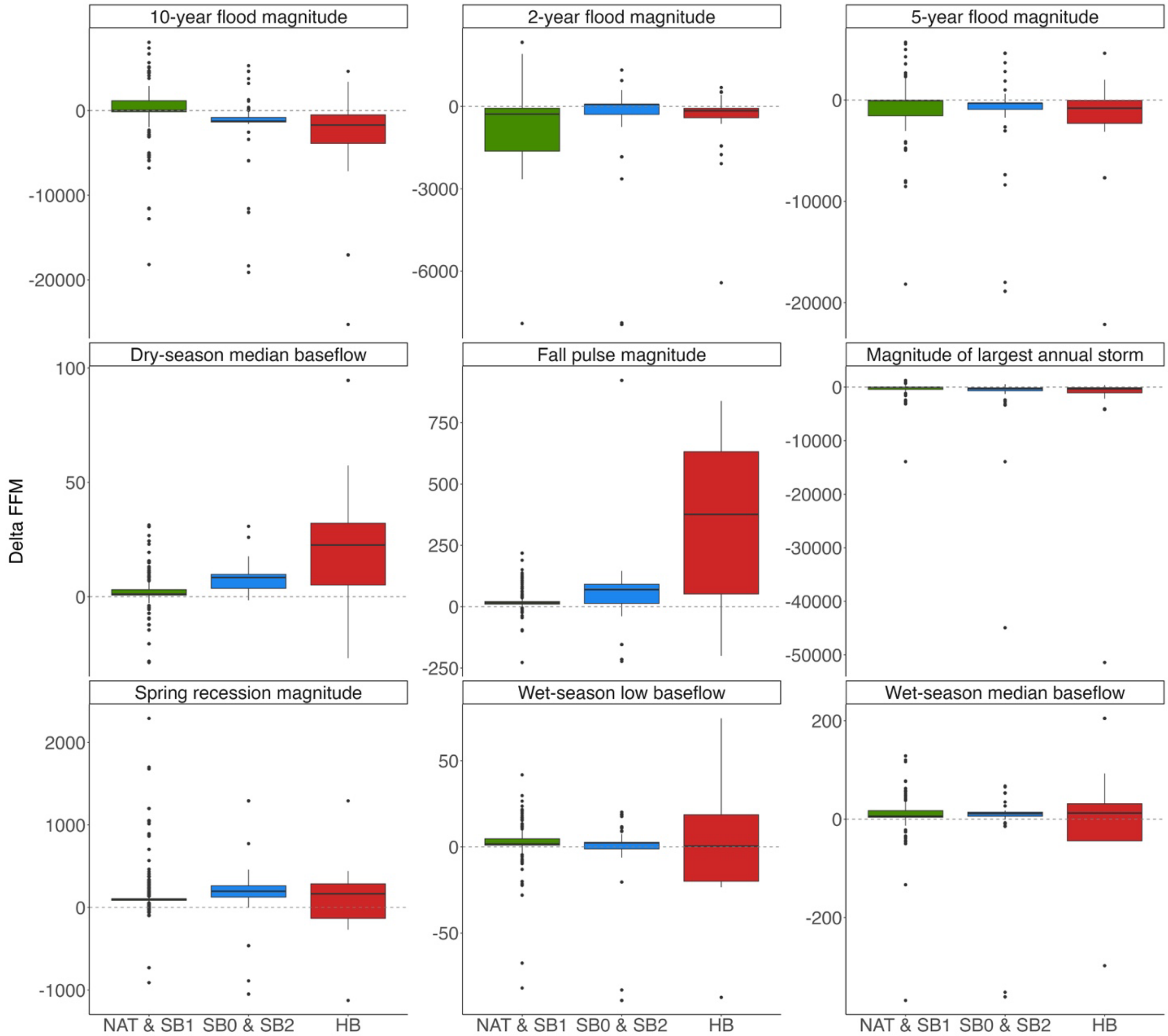

Figure S - 1. Boxplots of example ranges of all FFM and channel types. The horizontal bar is the median, the box represents the interquartile range, and the whiskers (vertical lines) represent 1.5 * the interquartile range. Zero delta on the y axis represents reference flow. NAT & SB1: Natural and soft bottom channels with one hard side channels, SB0 & SB2; Soft bottom channels with zero and two hard sides, HB; Hard bottom channels.

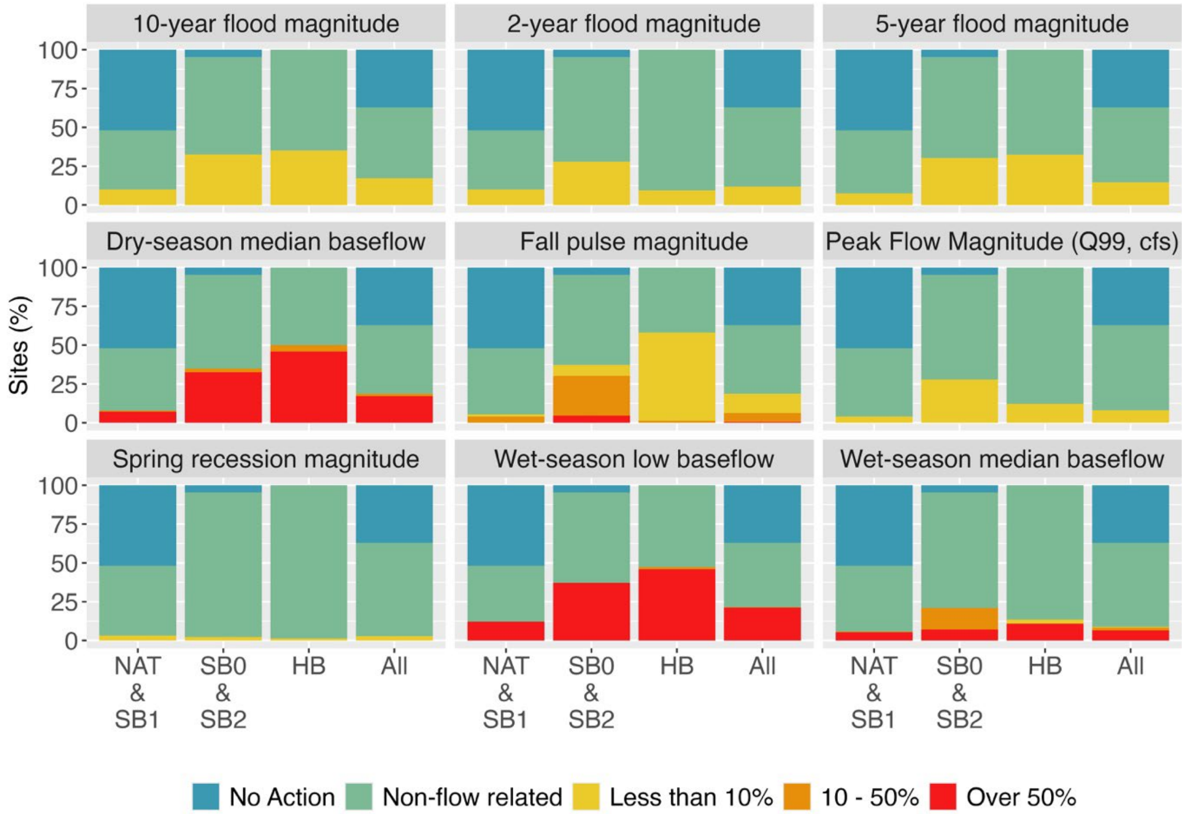

Figure S - 2. Improvements in delta FFM needed to achieve delta FFM associated with an incremental improvement (percent of sites). Categories based on Table 4. NAT & SB1; Natural and soft bottom channels with one hard side channels (n = 279), SB0 & SB2; Soft bottom channels with zero and two hard sides (n = 43), HB; Hard bottom channels (74), All; All channel types together (n = 396).

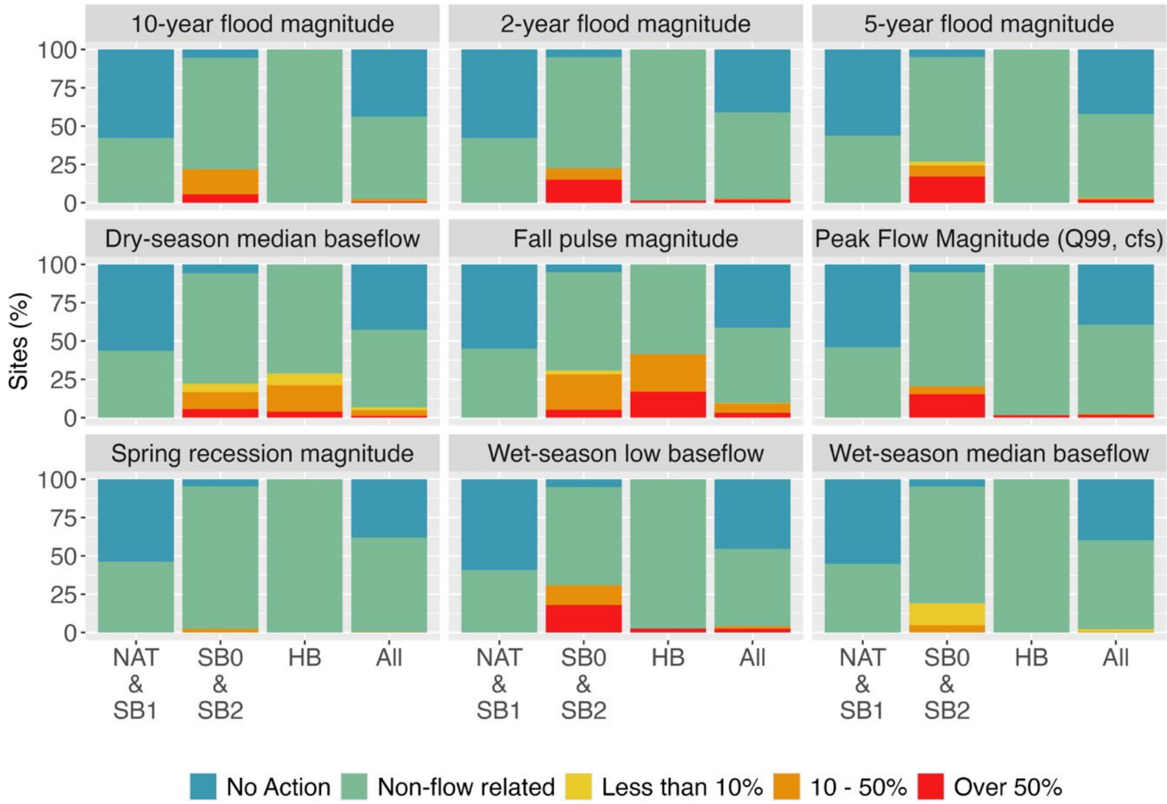

Figure S - 3. Improvements in delta FFM needed to achieve delta FFM associated with best observed condition (percent of sites). Categories based on Table 4. NAT & SB1; Natural and soft bottom channels with one hard side channels (n = 279), SB0 & SB2; Soft bottom channels with zero or two hard sides (n = 43), HB; Hard bottom channels (74), All; All channel types together (n = 396).

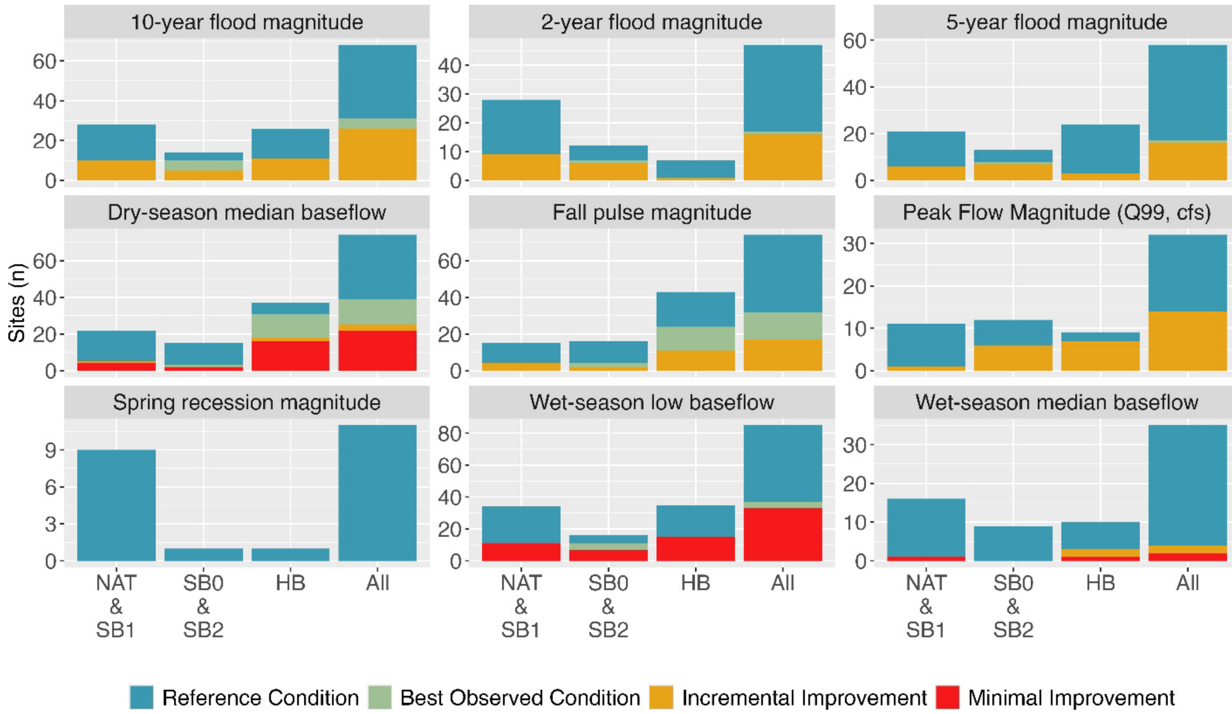

Figure S - 4. Number of sites that can reach target condition with 10-50% change in delta FFM: reference, best observed and incremental improvement for all FFMs and channel types.

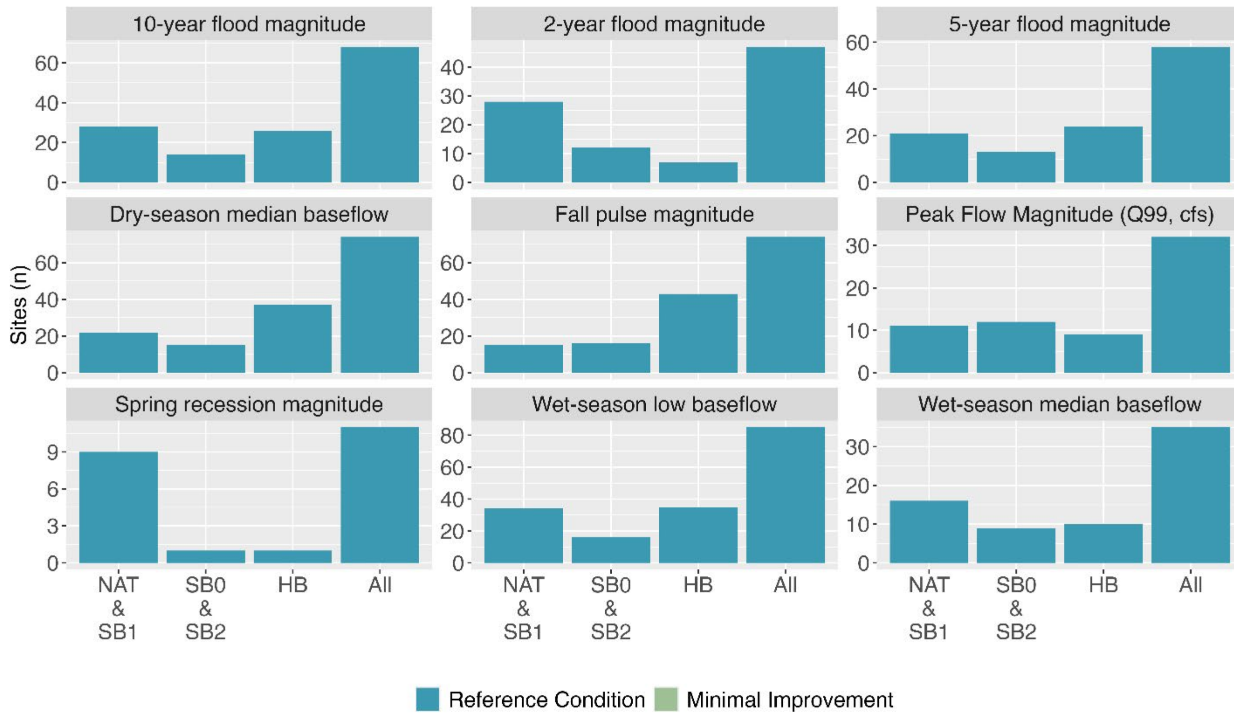

Figure S - 5. Number of sites that can reach target condition with over 50% change in delta FFM: reference, best observed and incremental improvement for all FFMs and channel types.

SUPPLEMENT 2. COMPARISON OF ESTIMATED FFM TO NATURAL FLOWS

We compared our calculated changes in delta FFM to California Environmental Flows Framework (CEFF; Stein et al. 2021) natural flows database to determine the number of sites requiring a return to "natural conditions" to improve their CSCI score. Modelled reference flows, available for all FFMs (except for Q99) and NHD reaches through the Natural Flows Database (rivers.codefornature.org, visited 01/21/2025), were used for this analysis.

First, we converted the delta FFM value needed for improvement into an absolute value by adding it to the median (p50) reference flow for each reach. We then counted the number of sites where the resulting absolute value fell within the range of natural conditions, defined as between the 10^{th} and 90^{th} percentile (as per CEFF). These site counts were subsequently converted to percentages based on FFM and channel type. Sites where delta FFM values were already within RC were removed from this analysis.

Additionally, we identified sites where achieving a CSCI improvement required reducing the flow to zero, i.e., creating dry stream conditions. Dry flows were defined as reaches with a median reference flow of zero. However, this measure is approximate, as it is based on modeled data where zero flow may not truly indicate zero flow an absence of flow due to uncertainty.

Overall, 26 sites were identified as dry reference flows (Table S - 4) for only dry-season baseflow and wet-season low baseflow. The majority of sites for dry season baseflow identified were NAT & SB1, with mixed soft and hard bottom channel types for the remaining sites.

Table S - 4. Number of sites where reference flows are dry (i.e., 0 flow), based on FFM and channel type. Total number of sites – 26. NAT & SB1; Natural and soft bottom channels with one hard side channels, SB0 & SB2; Soft bottom channels with zero and two hard sides, HB; Hard bottom channels, All; All channel types together.

Functional Flow Metric	Channel Type	Number of Sites
Dry-season median baseflow	NAT & SB1	14
Dry-season median baseflow	SB0 & SB2	5
Dry-season median baseflow	HB	5
Wet-season low baseflow	SB0 & SB2	2
Wet-season low baseflow	HB	1

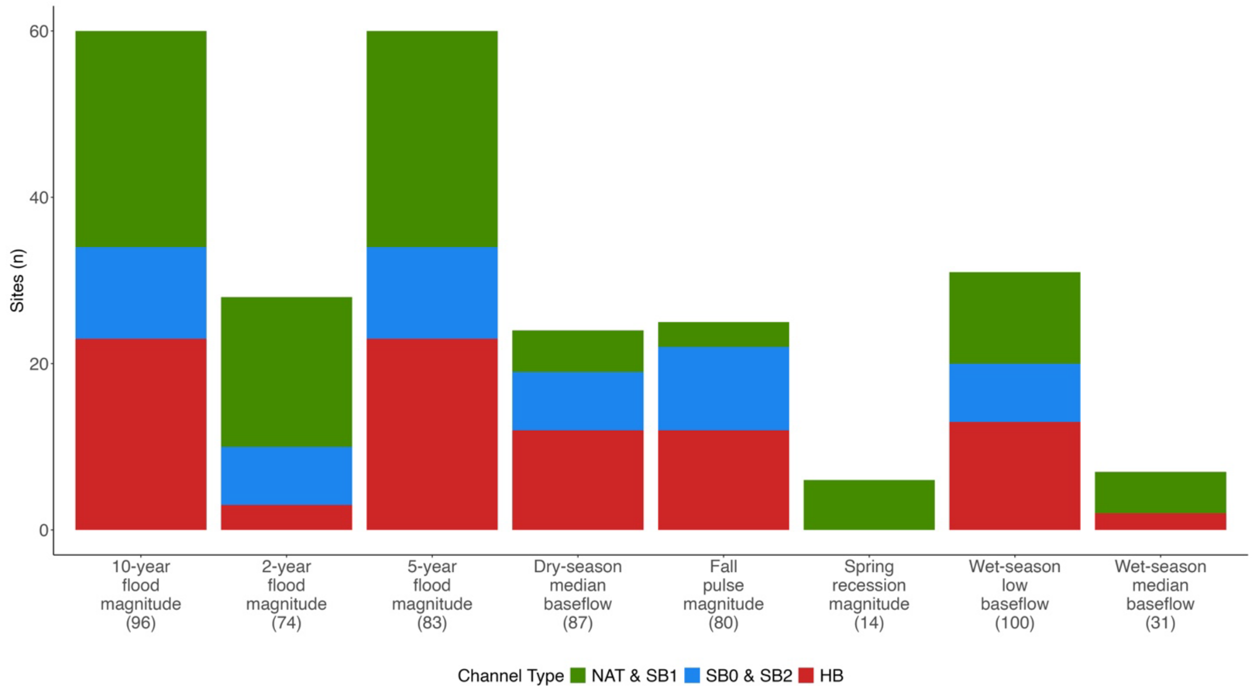

Figure S - 6. number of sites that require CEFF "natural flows" to reach reference condition flows for each FFM and channel type. Sites already within reference condition not included, brackets represent number of sites remaining.

The number of sites required to achieve CEFF 'natural flows' to reach reference conditions varied by FFM and channel type (Figure S - 6). Spring recession had the fewest sites needing CEFF flows (i.e., 6), suggesting that 8 sites could potentially reach reference conditions without achieving CEFF natural flows, the remaining sites were already within reference condition delta FFM, which is reflected on other results (Figure 5 and Figure 6). In contrast, 10-year & 5-year flood showed the highest numbers of sites requiring CEFF flows, which were similarly distributed between NAT & SB1 and HB channel types. Approximately two-thirds of sites not already within reference condition flows may achieve reference conditions by reaching CEFF natural flows, while the remaining one-third could reach reference conditions without attaining CEFF natural flows.

SUPPLEMENT 3. RAPID SCREENING CAUSAL ASSESSMENT (RSCA) INDICATORS AND LINES OF EVIDENCE

Gillett et al. (2023) describe a method for rapid screening causal assessment (RSCA), in the strength of evidence of a causal relationship between four stressors and poor biological conditions are evaluated. Each stressor is organized into a “module” with a standard set of indicators (Table S - 5).

Table S - 5. Stressor modules and indicators used in rapid screening causal assessment. Abbreviations are shown in parentheses. Asterisks (*) designate indicators with a positive relationship with biological condition; all other indicators have negative relationships

Stressor module	Indicators
Eutrophication	Dissolved oxygen (DO) in mg/L* Total nitrogen (TN) in mg/L Total phosphorus (TP) in mg/L Benthic ash-free dry mass (AFDM) in mg/cm^2 Benthic chlorophyll a (chl-a) in mg/m^2
Altered habitat	Evenness of flow habitats (Ev_FlowHab)* Diversity of natural habitat cover types (H_AqHab)* Diversity of natural substrate (H_SubNat)* Percent sands and fines (PCT_SAFN)
Salinization	Chloride (Cl) in mg/L Sulfate (SO_4) in mg/L Specific conductivity (SpCond) in µS/cm Total dissolved solids (TDS) in mg/L
Altered temperature	Water temperature (Temp) in °C Percent riparian cover (XCMG)*

Three lines of evidence (LOEs) are derived for each indicator as described below:

Spatial co-occurrence (SC): For the spatial co-occurrence LOE, indicator values at the test site are compared to values at *healthier* samples from comparator sites (defined as those with CSCI scores greater than the test site’s score) and interpreted as shown in Table S - 5.

Reference condition (RC): For the reference condition LOE, indicator values at the test site are compared to values at samples *in reference condition* from comparator sites (defined as those with CSCI scores greater or equal to 0.79) and interpreted as shown in Table S - 5.

Stress-response (SR): For the stress-response LOE, a logistic regression model is calibrated using all comparator sites with stressor data (regardless of how the CSCI score compares to the test site’s score). Probabilities of poor biological condition calculated by these models are interpreted as shown in Table S - 5.

Table S - 6. Lines of evidence in RSCA.

Line of evidence	Indicator direction	Supporting	Indeterminate	Weakening	No evidence
Spatial co-occurrence (SC)	Positive	Test site <25th percentile of healthier comparator sites	Test site ≥ 25th percentile and < 50th percentile of healthier comparator sites	Test site ≥ 50th percentile of healthier comparator sites	Data available at <5 healthier comparator sites
Spatial co-occurrence (SC)	Negative	Test site >75th percentile of healthier comparator sites	Test site ≤ 75th percentile and > 50th percentile of healthier comparator sites	Test site ≤ 50th percentile of healthier comparator sites	Data available at <5 healthier comparator sites
Reference condition comparison (RCC)	Positive	Test site < 10th percentile of comparator sites in reference condition	Test site ≥ 10th percentile and < 25th percentile of comparator sites in reference condition	Test site ≥ 25th percentile of comparator sites in reference condition	Data available at <5 comparator sites in reference condition
Reference condition comparison (RCC)	Negative	Test site > 90th percentile of comparator sites in reference condition	Test site ≤ 90th percentile and > 75th percentile of comparator sites in reference condition	Test site ≤ 75th percentile of comparator sites in reference condition	Data available at <5 comparator sites in reference condition
Stress-response (SR)	Positive or negative	Predicted probability of poor conditions ≥ 0.6	Predicted probability of poor conditions < 0.6 and > 0.4	Predicted probability of poor conditions ≤ 0.4	Model has p-value > 0.1, or model shows response in opposite direction.

Indicators are summarized to generate LOEs as follows:

- If any indicator within the module was scored as Supporting, then the line of evidence is scored as *Supporting*.
- If no indicator within the module was scored as Supporting and at least one indicator was scored as Weakening, then the line of evidence is scored as *Weakening.*
- If all indicators within the module were scored as Indeterminate, No Test Data, or No Evidence, then the line of evidence is scored as *Indeterminate.*
- If all indicators within the module were scored as No Evidence, then the line of evidence is scored as *No Evidence.*
- If all indicators within the module lack data at the test site, then the line of evidence is scored as *No Test Data.*

Modules are summarized by integrating LOEs as follows:

- If there are more Supporting LOEs than Weakening LOEs, the outcome is that the stressor is a *Likely cause.*

- If there are more Weakening LOEs than Supporting LOEs, the outcome is that the stressor is an *Unlikely cause.*
- If there is a balance of Supporting and Weakening LOEs, the outcome is that the stressor is an *Indeterminate cause.*
- If all LOEs are Indeterminate or a mix of Indeterminate and No Evidence, then the outcome is *Indeterminate cause.*
- If all LOEs are scored as No Evidence or No Test Data, then the outcome is *Cannot be Evaluated.*

SUPPLEMENT 4. REGIONAL AND WATERSHED SUMMARIES OF RSCA CONCLUSIONS

Table S - 7. Number of site-visits in the regions and watersheds within the South Coast. Only site-visits with CSCI scores < 0.79 are included.

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
South Coast	NAT	Conductivity	Cannot be Evaluated	757	223	231
South Coast	NAT	Conductivity	Indeterminate Cause	757	32	25
South Coast	NAT	Conductivity	Likely Cause	757	290	246
South Coast	NAT	Conductivity	Unlikely Cause	757	212	255
South Coast	NAT	Eutrophication	Cannot be Evaluated	757	213	223
South Coast	NAT	Eutrophication	Indeterminate Cause	757	43	27
South Coast	NAT	Eutrophication	Likely Cause	757	319	280
South Coast	NAT	Eutrophication	Unlikely Cause	757	182	227
South Coast	NAT	Habitat	Cannot be Evaluated	757	218	228
South Coast	NAT	Habitat	Indeterminate Cause	757	11	43
South Coast	NAT	Habitat	Likely Cause	757	328	283
South Coast	NAT	Habitat	Unlikely Cause	757	200	203
South Coast	NAT	Temperature	Cannot be Evaluated	757	192	204
South Coast	NAT	Temperature	Indeterminate Cause	757	52	46
South Coast	NAT	Temperature	Likely Cause	757	198	188
South Coast	NAT	Temperature	Unlikely Cause	757	315	319
South Coast	SB0	Conductivity	Cannot be Evaluated	142	61	65
South Coast	SB0	Conductivity	Indeterminate Cause	142	2	6
South Coast	SB0	Conductivity	Likely Cause	142	54	58
South Coast	SB0	Conductivity	Unlikely Cause	142	25	13
South Coast	SB0	Eutrophication	Cannot be Evaluated	142	61	65
South Coast	SB0	Eutrophication	Indeterminate Cause	142	1	1
South Coast	SB0	Eutrophication	Likely Cause	142	64	63
South Coast	SB0	Eutrophication	Unlikely Cause	142	16	13
South Coast	SB0	Habitat	Cannot be Evaluated	142	69	74

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
South Coast	SB0	Habitat	Indeterminate Cause	142	0	11
South Coast	SB0	Habitat	Likely Cause	142	60	26
South Coast	SB0	Habitat	Unlikely Cause	142	13	31
South Coast	SB0	Temperature	Cannot be Evaluated	142	65	70
South Coast	SB0	Temperature	Indeterminate Cause	142	8	10
South Coast	SB0	Temperature	Likely Cause	142	56	36
South Coast	SB0	Temperature	Unlikely Cause	142	13	26
South Coast	SB1	Conductivity	Cannot be Evaluated	64	19	19
South Coast	SB1	Conductivity	Indeterminate Cause	64	6	2
South Coast	SB1	Conductivity	Likely Cause	64	21	30
South Coast	SB1	Conductivity	Unlikely Cause	64	18	13
South Coast	SB1	Eutrophication	Cannot be Evaluated	64	18	18
South Coast	SB1	Eutrophication	Indeterminate Cause	64	0	2
South Coast	SB1	Eutrophication	Likely Cause	64	42	36
South Coast	SB1	Eutrophication	Unlikely Cause	64	4	8
South Coast	SB1	Habitat	Cannot be Evaluated	64	13	13
South Coast	SB1	Habitat	Indeterminate Cause	64	0	2
South Coast	SB1	Habitat	Likely Cause	64	29	39
South Coast	SB1	Habitat	Unlikely Cause	64	22	10
South Coast	SB1	Temperature	Cannot be Evaluated	64	9	9
South Coast	SB1	Temperature	Indeterminate Cause	64	17	14
South Coast	SB1	Temperature	Likely Cause	64	22	22
South Coast	SB1	Temperature	Unlikely Cause	64	16	19
South Coast	SB2	Conductivity	Cannot be Evaluated	190	41	42
South Coast	SB2	Conductivity	Indeterminate Cause	190	2	27
South Coast	SB2	Conductivity	Likely Cause	190	109	77
South Coast	SB2	Conductivity	Unlikely Cause	190	38	44
South Coast	SB2	Eutrophication	Cannot be Evaluated	190	38	40
South Coast	SB2	Eutrophication	Indeterminate Cause	190	3	4
South Coast	SB2	Eutrophication	Likely Cause	190	121	116
South Coast	SB2	Eutrophication	Unlikely Cause	190	28	30
South Coast	SB2	Habitat	Cannot be Evaluated	190	41	43

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
South Coast	SB2	Habitat	Indeterminate Cause	190	3	20
South Coast	SB2	Habitat	Likely Cause	190	124	77
South Coast	SB2	Habitat	Unlikely Cause	190	22	50
South Coast	SB2	Temperature	Cannot be Evaluated	190	37	40
South Coast	SB2	Temperature	Indeterminate Cause	190	12	16
South Coast	SB2	Temperature	Likely Cause	190	108	57
South Coast	SB2	Temperature	Unlikely Cause	190	33	77
South Coast	HB	Conductivity	Cannot be Evaluated	390	117	125
South Coast	HB	Conductivity	Indeterminate Cause	390	20	18
South Coast	HB	Conductivity	Likely Cause	390	136	86
South Coast	HB	Conductivity	Unlikely Cause	390	117	161
South Coast	HB	Eutrophication	Cannot be Evaluated	390	111	119
South Coast	HB	Eutrophication	Indeterminate Cause	390	12	9
South Coast	HB	Eutrophication	Likely Cause	390	192	155
South Coast	HB	Eutrophication	Unlikely Cause	390	75	107
South Coast	HB	Habitat	Cannot be Evaluated	390	111	118
South Coast	HB	Habitat	Indeterminate Cause	390	0	6
South Coast	HB	Habitat	Likely Cause	390	277	117
South Coast	HB	Habitat	Unlikely Cause	390	2	149
South Coast	HB	Temperature	Cannot be Evaluated	390	85	90
South Coast	HB	Temperature	Indeterminate Cause	390	5	93
South Coast	HB	Temperature	Likely Cause	390	291	138
South Coast	HB	Temperature	Unlikely Cause	390	9	69
R4	NAT	Conductivity	Cannot be Evaluated	259	60	61
R4	NAT	Conductivity	Indeterminate Cause	259	11	15
R4	NAT	Conductivity	Likely Cause	259	109	87
R4	NAT	Conductivity	Unlikely Cause	259	79	96
R4	NAT	Eutrophication	Cannot be Evaluated	259	57	58
R4	NAT	Eutrophication	Indeterminate Cause	259	7	16
R4	NAT	Eutrophication	Likely Cause	259	127	107
R4	NAT	Eutrophication	Unlikely Cause	259	68	78
R4	NAT	Habitat	Cannot be Evaluated	259	62	67

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
R4	NAT	Habitat	Indeterminate Cause	259	4	13
R4	NAT	Habitat	Likely Cause	259	121	102
R4	NAT	Habitat	Unlikely Cause	259	72	77
R4	NAT	Temperature	Cannot be Evaluated	259	49	54
R4	NAT	Temperature	Indeterminate Cause	259	26	18
R4	NAT	Temperature	Likely Cause	259	77	76
R4	NAT	Temperature	Unlikely Cause	259	107	111
R4	SB0	Conductivity	Cannot be Evaluated	52	17	18
R4	SB0	Conductivity	Indeterminate Cause	52	1	4
R4	SB0	Conductivity	Likely Cause	52	26	30
R4	SB0	Eutrophication	Cannot be Evaluated	52	17	18
R4	SB0	Eutrophication	Likely Cause	52	34	31
R4	SB0	Eutrophication	Unlikely Cause	52	1	3
R4	SB0	Habitat	Cannot be Evaluated	52	19	20
R4	SB0	Habitat	Indeterminate Cause	52	0	7
R4	SB0	Habitat	Likely Cause	52	27	8
R4	SB0	Habitat	Unlikely Cause	52	6	17
R4	SB0	Temperature	Cannot be Evaluated	52	19	20
R4	SB0	Temperature	Indeterminate Cause	52	8	6
R4	SB0	Temperature	Likely Cause	52	20	13
R4	SB0	Temperature	Unlikely Cause	52	5	13
R4	SB1	Conductivity	Cannot be Evaluated	54	17	17
R4	SB1	Conductivity	Indeterminate Cause	54	6	1
R4	SB1	Conductivity	Likely Cause	54	19	28
R4	SB1	Conductivity	Unlikely Cause	54	12	8
R4	SB1	Eutrophication	Cannot be Evaluated	54	16	16
R4	SB1	Eutrophication	Indeterminate Cause	54	0	1
R4	SB1	Eutrophication	Likely Cause	54	36	31
R4	SB1	Eutrophication	Unlikely Cause	54	2	6
R4	SB1	Habitat	Cannot be Evaluated	54	13	13
R4	SB1	Habitat	Indeterminate Cause	54	0	2
R4	SB1	Habitat	Likely Cause	54	21	30

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
R4	SB1	Habitat	Unlikely Cause	54	20	9
R4	SB1	Temperature	Cannot be Evaluated	54	9	9
R4	SB1	Temperature	Indeterminate Cause	54	16	13
R4	SB1	Temperature	Likely Cause	54	16	16
R4	SB1	Temperature	Unlikely Cause	54	13	16
R4	SB2	Conductivity	Cannot be Evaluated	106	17	17
R4	SB2	Conductivity	Indeterminate Cause	106	1	24
R4	SB2	Conductivity	Likely Cause	106	68	38
R4	SB2	Conductivity	Unlikely Cause	106	20	27
R4	SB2	Eutrophication	Cannot be Evaluated	106	17	17
R4	SB2	Eutrophication	Indeterminate Cause	106	0	2
R4	SB2	Eutrophication	Likely Cause	106	74	69
R4	SB2	Eutrophication	Unlikely Cause	106	15	18
R4	SB2	Habitat	Cannot be Evaluated	106	23	24
R4	SB2	Habitat	Indeterminate Cause	106	0	9
R4	SB2	Habitat	Likely Cause	106	69	37
R4	SB2	Habitat	Unlikely Cause	106	14	36
R4	SB2	Temperature	Cannot be Evaluated	106	19	20
R4	SB2	Temperature	Indeterminate Cause	106	11	12
R4	SB2	Temperature	Likely Cause	106	54	23
R4	SB2	Temperature	Unlikely Cause	106	22	51
R4	HB	Conductivity	Cannot be Evaluated	289	105	113
R4	HB	Conductivity	Indeterminate Cause	289	17	10
R4	HB	Conductivity	Likely Cause	289	85	54
R4	HB	Conductivity	Unlikely Cause	289	82	112
R4	HB	Eutrophication	Cannot be Evaluated	289	101	109
R4	HB	Eutrophication	Indeterminate Cause	289	4	6
R4	HB	Eutrophication	Likely Cause	289	140	106
R4	HB	Eutrophication	Unlikely Cause	289	44	68
R4	HB	Habitat	Cannot be Evaluated	289	99	106
R4	HB	Habitat	Indeterminate Cause	289	0	5
R4	HB	Habitat	Likely Cause	289	188	73

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
R4	HB	Habitat	Unlikely Cause	289	2	105
R4	HB	Temperature	Cannot be Evaluated	289	73	78
R4	HB	Temperature	Indeterminate Cause	289	4	59
R4	HB	Temperature	Likely Cause	289	205	96
R4	HB	Temperature	Unlikely Cause	289	7	56
R4	SB0	Conductivity	Unlikely Cause	52	8	0
R8	NAT	Conductivity	Cannot be Evaluated	125	31	38
R8	NAT	Conductivity	Likely Cause	125	26	20
R8	NAT	Conductivity	Unlikely Cause	125	62	67
R8	NAT	Eutrophication	Cannot be Evaluated	125	22	31
R8	NAT	Eutrophication	Likely Cause	125	49	41
R8	NAT	Eutrophication	Unlikely Cause	125	44	53
R8	NAT	Habitat	Cannot be Evaluated	125	8	13
R8	NAT	Habitat	Indeterminate Cause	125	4	14
R8	NAT	Habitat	Likely Cause	125	82	76
R8	NAT	Habitat	Unlikely Cause	125	31	22
R8	NAT	Temperature	Cannot be Evaluated	125	10	17
R8	NAT	Temperature	Indeterminate Cause	125	7	8
R8	NAT	Temperature	Likely Cause	125	58	52
R8	NAT	Temperature	Unlikely Cause	125	50	48
R8	SB0	Conductivity	Cannot be Evaluated	33	8	10
R8	SB0	Conductivity	Indeterminate Cause	33	1	1
R8	SB0	Conductivity	Likely Cause	33	7	9
R8	SB0	Conductivity	Unlikely Cause	33	17	13
R8	SB0	Eutrophication	Cannot be Evaluated	33	8	10
R8	SB0	Eutrophication	Likely Cause	33	17	16
R8	SB0	Eutrophication	Unlikely Cause	33	8	7
R8	SB0	Habitat	Cannot be Evaluated	33	6	9
R8	SB0	Habitat	Indeterminate Cause	33	0	4
R8	SB0	Habitat	Likely Cause	33	26	13
R8	SB0	Habitat	Unlikely Cause	33	1	7
R8	SB0	Temperature	Cannot be Evaluated	33	6	9

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
R8	SB0	Temperature	Indeterminate Cause	33	0	3
R8	SB0	Temperature	Likely Cause	33	24	17
R8	SB0	Temperature	Unlikely Cause	33	3	4
R8	SB1	Conductivity	Cannot be Evaluated	9	2	2
R8	SB1	Conductivity	Likely Cause	9	1	2
R8	SB1	Conductivity	Unlikely Cause	9	6	5
R8	SB1	Eutrophication	Cannot be Evaluated	9	2	2
R8	SB1	Eutrophication	Likely Cause	9	5	5
R8	SB1	Eutrophication	Unlikely Cause	9	2	2
R8	SB1	Habitat	Likely Cause	9	8	8
R8	SB1	Habitat	Unlikely Cause	9	1	1
R8	SB1	Temperature	Indeterminate Cause	9	1	1
R8	SB1	Temperature	Likely Cause	9	6	6
R8	SB1	Temperature	Unlikely Cause	9	2	2
R8	SB2	Conductivity	Cannot be Evaluated	60	16	17
R8	SB2	Conductivity	Indeterminate Cause	60	1	3
R8	SB2	Conductivity	Likely Cause	60	26	24
R8	SB2	Conductivity	Unlikely Cause	60	17	16
R8	SB2	Eutrophication	Cannot be Evaluated	60	14	16
R8	SB2	Eutrophication	Indeterminate Cause	60	1	2
R8	SB2	Eutrophication	Likely Cause	60	35	34
R8	SB2	Eutrophication	Unlikely Cause	60	10	8
R8	SB2	Habitat	Cannot be Evaluated	60	11	12
R8	SB2	Habitat	Indeterminate Cause	60	3	8
R8	SB2	Habitat	Likely Cause	60	42	32
R8	SB2	Habitat	Unlikely Cause	60	4	8
R8	SB2	Temperature	Cannot be Evaluated	60	11	13
R8	SB2	Temperature	Indeterminate Cause	60	1	3
R8	SB2	Temperature	Likely Cause	60	45	27
R8	SB2	Temperature	Unlikely Cause	60	3	17
R8	HB	Conductivity	Cannot be Evaluated	69	11	11
R8	HB	Conductivity	Indeterminate Cause	69	3	2
R8	HB	Conductivity	Likely Cause	69	20	9

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
R8	HB	Conductivity	Unlikely Cause	69	35	47
R8	HB	Eutrophication	Cannot be Evaluated	69	9	9
R8	HB	Eutrophication	Indeterminate Cause	69	3	2
R8	HB	Eutrophication	Likely Cause	69	37	33
R8	HB	Eutrophication	Unlikely Cause	69	20	25
R8	HB	Habitat	Cannot be Evaluated	69	7	7
R8	HB	Habitat	Indeterminate Cause	69	0	1
R8	HB	Habitat	Likely Cause	69	62	29
R8	HB	Habitat	Unlikely Cause	69	0	32
R8	HB	Temperature	Cannot be Evaluated	69	7	7
R8	HB	Temperature	Indeterminate Cause	69	1	20
R8	HB	Temperature	Likely Cause	69	61	31
R8	HB	Temperature	Unlikely Cause	69	0	11
R8	NAT	Conductivity	Indeterminate Cause	125	6	0
R8	NAT	Eutrophication	Indeterminate Cause	125	10	0
R9	NAT	Conductivity	Cannot be Evaluated	373	132	132
R9	NAT	Conductivity	Indeterminate Cause	373	15	10
R9	NAT	Conductivity	Likely Cause	373	155	139
R9	NAT	Conductivity	Unlikely Cause	373	71	92
R9	NAT	Eutrophication	Cannot be Evaluated	373	134	134
R9	NAT	Eutrophication	Indeterminate Cause	373	26	11
R9	NAT	Eutrophication	Likely Cause	373	143	132
R9	NAT	Eutrophication	Unlikely Cause	373	70	96
R9	NAT	Habitat	Cannot be Evaluated	373	148	148
R9	NAT	Habitat	Indeterminate Cause	373	3	16
R9	NAT	Habitat	Likely Cause	373	125	105
R9	NAT	Habitat	Unlikely Cause	373	97	104
R9	NAT	Temperature	Cannot be Evaluated	373	133	133
R9	NAT	Temperature	Indeterminate Cause	373	19	20
R9	NAT	Temperature	Likely Cause	373	63	60
R9	NAT	Temperature	Unlikely Cause	373	158	160

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
R9	SB0	Conductivity	Cannot be Evaluated	57	36	37
R9	SB0	Conductivity	Indeterminate Cause	57	0	1
R9	SB0	Conductivity	Likely Cause	57	21	19
R9	SB0	Eutrophication	Cannot be Evaluated	57	36	37
R9	SB0	Eutrophication	Indeterminate Cause	57	1	1
R9	SB0	Eutrophication	Likely Cause	57	13	16
R9	SB0	Eutrophication	Unlikely Cause	57	7	3
R9	SB0	Habitat	Cannot be Evaluated	57	44	45
R9	SB0	Habitat	Likely Cause	57	7	5
R9	SB0	Habitat	Unlikely Cause	57	6	7
R9	SB0	Temperature	Cannot be Evaluated	57	40	41
R9	SB0	Temperature	Indeterminate Cause	57	0	1
R9	SB0	Temperature	Likely Cause	57	12	6
R9	SB0	Temperature	Unlikely Cause	57	5	9
R9	SB1	Conductivity	Indeterminate Cause	1	0	1
R9	SB1	Eutrophication	Indeterminate Cause	1	0	1
R9	SB1	Habitat	Likely Cause	1	0	1
R9	SB1	Temperature	Unlikely Cause	1	1	1
R9	SB2	Conductivity	Cannot be Evaluated	24	8	8
R9	SB2	Conductivity	Likely Cause	24	15	15
R9	SB2	Conductivity	Unlikely Cause	24	1	1
R9	SB2	Eutrophication	Cannot be Evaluated	24	7	7
R9	SB2	Eutrophication	Likely Cause	24	12	13
R9	SB2	Eutrophication	Unlikely Cause	24	3	4
R9	SB2	Habitat	Cannot be Evaluated	24	7	7
R9	SB2	Habitat	Indeterminate Cause	24	0	3
R9	SB2	Habitat	Likely Cause	24	13	8
R9	SB2	Habitat	Unlikely Cause	24	4	6
R9	SB2	Temperature	Cannot be Evaluated	24	7	7
R9	SB2	Temperature	Indeterminate Cause	24	0	1
R9	SB2	Temperature	Likely Cause	24	9	7
R9	SB2	Temperature	Unlikely Cause	24	8	9

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
R9	HB	Conductivity	Cannot be Evaluated	32	1	1
R9	HB	Conductivity	Indeterminate Cause	32	0	6
R9	HB	Conductivity	Likely Cause	32	31	23
R9	HB	Conductivity	Unlikely Cause	32	0	2
R9	HB	Eutrophication	Cannot be Evaluated	32	1	1
R9	HB	Eutrophication	Indeterminate Cause	32	5	1
R9	HB	Eutrophication	Likely Cause	32	15	16
R9	HB	Eutrophication	Unlikely Cause	32	11	14
R9	HB	Habitat	Cannot be Evaluated	32	5	5
R9	HB	Habitat	Likely Cause	32	27	15
R9	HB	Habitat	Unlikely Cause	32	0	12
R9	HB	Temperature	Cannot be Evaluated	32	5	5
R9	HB	Temperature	Indeterminate Cause	32	0	14
R9	HB	Temperature	Likely Cause	32	25	11
R9	HB	Temperature	Unlikely Cause	32	2	2
R9	SB1	Conductivity	Likely Cause	1	1	0
R9	SB1	Eutrophication	Likely Cause	1	1	0
R9	SB1	Habitat	Unlikely Cause	1	1	0
R9	SB2	Eutrophication	Indeterminate Cause	24	2	0
Calleguas	NAT	Conductivity	Cannot be Evaluated	10	2	2
Calleguas	NAT	Conductivity	Indeterminate Cause	10	0	2
Calleguas	NAT	Conductivity	Likely Cause	10	8	6
Calleguas	NAT	Eutrophication	Cannot be Evaluated	10	2	2
Calleguas	NAT	Eutrophication	Likely Cause	10	8	8
Calleguas	NAT	Habitat	Cannot be Evaluated	10	3	3
Calleguas	NAT	Habitat	Likely Cause	10	5	5
Calleguas	NAT	Habitat	Unlikely Cause	10	2	2
Calleguas	NAT	Temperature	Cannot be Evaluated	10	2	2
Calleguas	NAT	Temperature	Likely Cause	10	1	1
Calleguas	NAT	Temperature	Unlikely Cause	10	4	7
Calleguas	SB0	Conductivity	Cannot be Evaluated	27	5	5
Calleguas	SB0	Conductivity	Likely Cause	27	18	22

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Calleguas	SB0	Eutrophication	Cannot be Evaluated	27	5	5
Calleguas	SB0	Eutrophication	Likely Cause	27	22	21
Calleguas	SB0	Eutrophication	Unlikely Cause	27	0	1
Calleguas	SB0	Habitat	Cannot be Evaluated	27	6	6
Calleguas	SB0	Habitat	Indeterminate Cause	27	0	1
Calleguas	SB0	Habitat	Likely Cause	27	17	8
Calleguas	SB0	Habitat	Unlikely Cause	27	4	12
Calleguas	SB0	Temperature	Cannot be Evaluated	27	6	6
Calleguas	SB0	Temperature	Indeterminate Cause	27	3	5
Calleguas	SB0	Temperature	Likely Cause	27	17	11
Calleguas	SB0	Temperature	Unlikely Cause	27	1	5
Calleguas	SB1	Conductivity	Cannot be Evaluated	26	12	12
Calleguas	SB1	Conductivity	Likely Cause	26	10	13
Calleguas	SB1	Conductivity	Unlikely Cause	26	4	1
Calleguas	SB1	Eutrophication	Cannot be Evaluated	26	12	12
Calleguas	SB1	Eutrophication	Likely Cause	26	13	13
Calleguas	SB1	Eutrophication	Unlikely Cause	26	1	1
Calleguas	SB1	Habitat	Cannot be Evaluated	26	9	9
Calleguas	SB1	Habitat	Indeterminate Cause	26	0	1
Calleguas	SB1	Habitat	Likely Cause	26	12	16
Calleguas	SB1	Temperature	Cannot be Evaluated	26	5	5
Calleguas	SB1	Temperature	Indeterminate Cause	26	7	4
Calleguas	SB1	Temperature	Likely Cause	26	9	9
Calleguas	SB1	Temperature	Unlikely Cause	26	5	8
Calleguas	SB2	Conductivity	Cannot be Evaluated	55	2	2
Calleguas	SB2	Conductivity	Indeterminate Cause	55	0	23
Calleguas	SB2	Conductivity	Likely Cause	55	46	20
Calleguas	SB2	Conductivity	Unlikely Cause	55	7	10
Calleguas	SB2	Eutrophication	Cannot be Evaluated	55	2	2
Calleguas	SB2	Eutrophication	Likely Cause	55	48	49
Calleguas	SB2	Eutrophication	Unlikely Cause	55	5	4
Calleguas	SB2	Habitat	Cannot be Evaluated	55	8	8

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Calleguas	SB2	Habitat	Indeterminate Cause	55	0	4
Calleguas	SB2	Habitat	Likely Cause	55	43	27
Calleguas	SB2	Habitat	Unlikely Cause	55	4	16
Calleguas	SB2	Temperature	Cannot be Evaluated	55	7	7
Calleguas	SB2	Temperature	Indeterminate Cause	55	7	6
Calleguas	SB2	Temperature	Likely Cause	55	33	14
Calleguas	SB2	Temperature	Unlikely Cause	55	8	28
Calleguas	HB	Conductivity	Cannot be Evaluated	16	1	3
Calleguas	HB	Conductivity	Indeterminate Cause	16	0	2
Calleguas	HB	Conductivity	Likely Cause	16	14	10
Calleguas	HB	Conductivity	Unlikely Cause	16	1	1
Calleguas	HB	Eutrophication	Cannot be Evaluated	16	1	3
Calleguas	HB	Eutrophication	Likely Cause	16	10	8
Calleguas	HB	Eutrophication	Unlikely Cause	16	5	5
Calleguas	HB	Habitat	Cannot be Evaluated	16	2	3
Calleguas	HB	Habitat	Likely Cause	16	14	7
Calleguas	HB	Habitat	Unlikely Cause	16	0	6
Calleguas	HB	Temperature	Cannot be Evaluated	16	1	2
Calleguas	HB	Temperature	Indeterminate Cause	16	0	5
Calleguas	HB	Temperature	Likely Cause	16	14	5
Calleguas	HB	Temperature	Unlikely Cause	16	1	4
Calleguas	NAT	Temperature	Indeterminate Cause	10	3	0
Calleguas	SB0	Conductivity	Indeterminate Cause	27	1	0
Calleguas	SB0	Conductivity	Unlikely Cause	27	3	0
Calleguas	SB1	Habitat	Unlikely Cause	26	5	0
Central San Diego	NAT	Conductivity	Cannot be Evaluated	103	36	36
Central San Diego	NAT	Conductivity	Likely Cause	103	63	60
Central San Diego	NAT	Conductivity	Unlikely Cause	103	4	7
Central San Diego	NAT	Eutrophication	Cannot be Evaluated	103	36	36
Central San Diego	NAT	Eutrophication	Indeterminate Cause	103	5	5
Central San Diego	NAT	Eutrophication	Likely Cause	103	45	40

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Central San Diego	NAT	Eutrophication	Unlikely Cause	103	17	22
Central San Diego	NAT	Habitat	Cannot be Evaluated	103	47	47
Central San Diego	NAT	Habitat	Indeterminate Cause	103	1	3
Central San Diego	NAT	Habitat	Likely Cause	103	27	23
Central San Diego	NAT	Habitat	Unlikely Cause	103	28	30
Central San Diego	NAT	Temperature	Cannot be Evaluated	103	43	43
Central San Diego	NAT	Temperature	Indeterminate Cause	103	10	10
Central San Diego	NAT	Temperature	Likely Cause	103	10	8
Central San Diego	NAT	Temperature	Unlikely Cause	103	40	42
Central San Diego	SB0	Conductivity	Cannot be Evaluated	28	26	26
Central San Diego	SB0	Conductivity	Likely Cause	28	2	2
Central San Diego	SB0	Eutrophication	Cannot be Evaluated	28	26	26
Central San Diego	SB0	Eutrophication	Likely Cause	28	1	1
Central San Diego	SB0	Eutrophication	Unlikely Cause	28	1	1
Central San Diego	SB0	Habitat	Cannot be Evaluated	28	27	27
Central San Diego	SB0	Habitat	Likely Cause	28	1	1
Central San Diego	SB0	Temperature	Cannot be Evaluated	28	26	26
Central San Diego	SB0	Temperature	Likely Cause	28	1	1
Central San Diego	SB0	Temperature	Unlikely Cause	28	1	1
Central San Diego	HB	Conductivity	Indeterminate Cause	9	0	4
Central San Diego	HB	Conductivity	Likely Cause	9	9	4
Central San Diego	HB	Conductivity	Unlikely Cause	9	0	1
Central San Diego	HB	Eutrophication	Indeterminate Cause	9	4	1
Central San Diego	HB	Eutrophication	Likely Cause	9	3	5
Central San Diego	HB	Eutrophication	Unlikely Cause	9	2	3
Central San Diego	HB	Habitat	Likely Cause	9	9	4

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Central San Diego	HB	Habitat	Unlikely Cause	9	0	5
Central San Diego	HB	Temperature	Indeterminate Cause	9	0	3
Central San Diego	HB	Temperature	Likely Cause	9	8	5
Central San Diego	HB	Temperature	Unlikely Cause	9	1	1
Los Angeles	NAT	Conductivity	Cannot be Evaluated	38	18	18
Los Angeles	NAT	Conductivity	Indeterminate Cause	38	0	2
Los Angeles	NAT	Conductivity	Likely Cause	38	1	1
Los Angeles	NAT	Conductivity	Unlikely Cause	38	19	17
Los Angeles	NAT	Eutrophication	Cannot be Evaluated	38	18	18
Los Angeles	NAT	Eutrophication	Indeterminate Cause	38	1	2
Los Angeles	NAT	Eutrophication	Likely Cause	38	10	9
Los Angeles	NAT	Eutrophication	Unlikely Cause	38	9	9
Los Angeles	NAT	Habitat	Cannot be Evaluated	38	13	13
Los Angeles	NAT	Habitat	Indeterminate Cause	38	0	4
Los Angeles	NAT	Habitat	Likely Cause	38	13	9
Los Angeles	NAT	Habitat	Unlikely Cause	38	12	12
Los Angeles	NAT	Temperature	Cannot be Evaluated	38	9	9
Los Angeles	NAT	Temperature	Likely Cause	38	14	14
Los Angeles	NAT	Temperature	Unlikely Cause	38	9	15
Los Angeles	SB0	Conductivity	Cannot be Evaluated	2	2	2
Los Angeles	SB0	Eutrophication	Cannot be Evaluated	2	2	2
Los Angeles	SB0	Habitat	Cannot be Evaluated	2	2	2
Los Angeles	SB0	Temperature	Cannot be Evaluated	2	2	2
Los Angeles	SB1	Conductivity	Cannot be Evaluated	3	2	2
Los Angeles	SB1	Conductivity	Unlikely Cause	3	1	1
Los Angeles	SB1	Eutrophication	Cannot be Evaluated	3	2	2
Los Angeles	SB1	Eutrophication	Indeterminate Cause	3	0	1
Los Angeles	SB1	Habitat	Cannot be Evaluated	3	2	2
Los Angeles	SB1	Habitat	Likely Cause	3	1	1
Los Angeles	SB1	Temperature	Cannot be Evaluated	3	2	2

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Los Angeles	SB1	Temperature	Likely Cause	3	1	1
Los Angeles	SB2	Conductivity	Cannot be Evaluated	14	10	10
Los Angeles	SB2	Conductivity	Unlikely Cause	14	2	4
Los Angeles	SB2	Eutrophication	Cannot be Evaluated	14	10	10
Los Angeles	SB2	Eutrophication	Indeterminate Cause	14	0	1
Los Angeles	SB2	Eutrophication	Likely Cause	14	3	1
Los Angeles	SB2	Eutrophication	Unlikely Cause	14	1	2
Los Angeles	SB2	Habitat	Cannot be Evaluated	14	7	8
Los Angeles	SB2	Habitat	Indeterminate Cause	14	0	2
Los Angeles	SB2	Habitat	Likely Cause	14	6	1
Los Angeles	SB2	Habitat	Unlikely Cause	14	1	3
Los Angeles	SB2	Temperature	Cannot be Evaluated	14	6	7
Los Angeles	SB2	Temperature	Indeterminate Cause	14	1	3
Los Angeles	SB2	Temperature	Likely Cause	14	4	1
Los Angeles	SB2	Temperature	Unlikely Cause	14	3	3
Los Angeles	HB	Conductivity	Cannot be Evaluated	118	61	62
Los Angeles	HB	Conductivity	Indeterminate Cause	118	8	2
Los Angeles	HB	Conductivity	Likely Cause	118	12	7
Los Angeles	HB	Conductivity	Unlikely Cause	118	37	47
Los Angeles	HB	Eutrophication	Cannot be Evaluated	118	58	59
Los Angeles	HB	Eutrophication	Indeterminate Cause	118	1	1
Los Angeles	HB	Eutrophication	Likely Cause	118	44	35
Los Angeles	HB	Eutrophication	Unlikely Cause	118	15	23
Los Angeles	HB	Habitat	Cannot be Evaluated	118	33	36
Los Angeles	HB	Habitat	Indeterminate Cause	118	0	2
Los Angeles	HB	Habitat	Likely Cause	118	85	34
Los Angeles	HB	Habitat	Unlikely Cause	118	0	46
Los Angeles	HB	Temperature	Cannot be Evaluated	118	16	18
Los Angeles	HB	Temperature	Indeterminate Cause	118	3	28
Los Angeles	HB	Temperature	Likely Cause	118	96	47
Los Angeles	HB	Temperature	Unlikely Cause	118	3	25
Los Angeles	NAT	Temperature	Indeterminate Cause	38	6	0

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Los Angeles	SB1	Eutrophication	Likely Cause	3	1	0
Los Angeles	SB2	Conductivity	Indeterminate Cause	14	1	0
Los Angeles	SB2	Conductivity	Likely Cause	14	1	0
Lower Santa Ana	NAT	Conductivity	Cannot be Evaluated	18	2	2
Lower Santa Ana	NAT	Conductivity	Likely Cause	18	8	5
Lower Santa Ana	NAT	Conductivity	Unlikely Cause	18	8	11
Lower Santa Ana	NAT	Eutrophication	Likely Cause	18	8	4
Lower Santa Ana	NAT	Eutrophication	Unlikely Cause	18	8	14
Lower Santa Ana	NAT	Habitat	Cannot be Evaluated	18	1	1
Lower Santa Ana	NAT	Habitat	Indeterminate Cause	18	1	2
Lower Santa Ana	NAT	Habitat	Likely Cause	18	10	12
Lower Santa Ana	NAT	Habitat	Unlikely Cause	18	6	3
Lower Santa Ana	NAT	Temperature	Cannot be Evaluated	18	1	1
Lower Santa Ana	NAT	Temperature	Likely Cause	18	7	8
Lower Santa Ana	NAT	Temperature	Unlikely Cause	18	7	9
Lower Santa Ana	SB0	Conductivity	Cannot be Evaluated	13	1	1
Lower Santa Ana	SB0	Conductivity	Indeterminate Cause	13	1	1
Lower Santa Ana	SB0	Conductivity	Likely Cause	13	5	9
Lower Santa Ana	SB0	Conductivity	Unlikely Cause	13	6	2
Lower Santa Ana	SB0	Eutrophication	Cannot be Evaluated	13	1	1
Lower Santa Ana	SB0	Eutrophication	Likely Cause	13	9	9
Lower Santa Ana	SB0	Eutrophication	Unlikely Cause	13	3	3
Lower Santa Ana	SB0	Habitat	Cannot be Evaluated	13	1	1
Lower Santa Ana	SB0	Habitat	Indeterminate Cause	13	0	3
Lower Santa Ana	SB0	Habitat	Likely Cause	13	12	4
Lower Santa Ana	SB0	Habitat	Unlikely Cause	13	0	5
Lower Santa Ana	SB0	Temperature	Cannot be Evaluated	13	1	1

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Lower Santa Ana	SB0	Temperature	Indeterminate Cause	13	0	3
Lower Santa Ana	SB0	Temperature	Likely Cause	13	11	8
Lower Santa Ana	SB0	Temperature	Unlikely Cause	13	1	1
Lower Santa Ana	SB1	Conductivity	Cannot be Evaluated	3	1	1
Lower Santa Ana	SB1	Conductivity	Likely Cause	3	1	1
Lower Santa Ana	SB1	Conductivity	Unlikely Cause	3	1	1
Lower Santa Ana	SB1	Eutrophication	Cannot be Evaluated	3	1	1
Lower Santa Ana	SB1	Eutrophication	Likely Cause	3	1	1
Lower Santa Ana	SB1	Eutrophication	Unlikely Cause	3	1	1
Lower Santa Ana	SB1	Habitat	Likely Cause	3	3	3
Lower Santa Ana	SB1	Temperature	Likely Cause	3	3	3
Lower Santa Ana	SB2	Conductivity	Cannot be Evaluated	38	8	8
Lower Santa Ana	SB2	Conductivity	Indeterminate Cause	38	1	2
Lower Santa Ana	SB2	Conductivity	Likely Cause	38	18	16
Lower Santa Ana	SB2	Conductivity	Unlikely Cause	38	11	12
Lower Santa Ana	SB2	Eutrophication	Cannot be Evaluated	38	7	7
Lower Santa Ana	SB2	Eutrophication	Indeterminate Cause	38	1	1
Lower Santa Ana	SB2	Eutrophication	Likely Cause	38	25	24
Lower Santa Ana	SB2	Eutrophication	Unlikely Cause	38	5	6
Lower Santa Ana	SB2	Habitat	Cannot be Evaluated	38	4	4
Lower Santa Ana	SB2	Habitat	Indeterminate Cause	38	3	4
Lower Santa Ana	SB2	Habitat	Likely Cause	38	27	22
Lower Santa Ana	SB2	Habitat	Unlikely Cause	38	4	8
Lower Santa Ana	SB2	Temperature	Cannot be Evaluated	38	4	4
Lower Santa Ana	SB2	Temperature	Indeterminate Cause	38	0	3
Lower Santa Ana	SB2	Temperature	Likely Cause	38	34	27

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Lower Santa Ana	SB2	Temperature	Unlikely Cause	38	0	4
Lower Santa Ana	HB	Conductivity	Cannot be Evaluated	26	6	6
Lower Santa Ana	HB	Conductivity	Indeterminate Cause	26	2	2
Lower Santa Ana	HB	Conductivity	Likely Cause	26	13	9
Lower Santa Ana	HB	Conductivity	Unlikely Cause	26	5	9
Lower Santa Ana	HB	Eutrophication	Cannot be Evaluated	26	3	3
Lower Santa Ana	HB	Eutrophication	Indeterminate Cause	26	2	2
Lower Santa Ana	HB	Eutrophication	Likely Cause	26	12	11
Lower Santa Ana	HB	Eutrophication	Unlikely Cause	26	9	10
Lower Santa Ana	HB	Habitat	Cannot be Evaluated	26	1	1
Lower Santa Ana	HB	Habitat	Indeterminate Cause	26	0	1
Lower Santa Ana	HB	Habitat	Likely Cause	26	25	7
Lower Santa Ana	HB	Habitat	Unlikely Cause	26	0	17
Lower Santa Ana	HB	Temperature	Cannot be Evaluated	26	1	1
Lower Santa Ana	HB	Temperature	Indeterminate Cause	26	1	15
Lower Santa Ana	HB	Temperature	Likely Cause	26	24	5
Lower Santa Ana	HB	Temperature	Unlikely Cause	26	0	5
Lower Santa Ana	NAT	Eutrophication	Indeterminate Cause	18	2	0
Lower Santa Ana	NAT	Temperature	Indeterminate Cause	18	3	0
Middle Santa Ana	NAT	Conductivity	Cannot be Evaluated	44	15	17
Middle Santa Ana	NAT	Conductivity	Likely Cause	44	7	6
Middle Santa Ana	NAT	Conductivity	Unlikely Cause	44	16	21
Middle Santa Ana	NAT	Eutrophication	Cannot be Evaluated	44	11	13
Middle Santa Ana	NAT	Eutrophication	Likely Cause	44	23	23
Middle Santa Ana	NAT	Eutrophication	Unlikely Cause	44	9	8
Middle Santa Ana	NAT	Habitat	Cannot be Evaluated	44	3	5

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Middle Santa Ana	NAT	Habitat	Indeterminate Cause	44	1	2
Middle Santa Ana	NAT	Habitat	Likely Cause	44	33	32
Middle Santa Ana	NAT	Habitat	Unlikely Cause	44	7	5
Middle Santa Ana	NAT	Temperature	Cannot be Evaluated	44	3	5
Middle Santa Ana	NAT	Temperature	Indeterminate Cause	44	3	2
Middle Santa Ana	NAT	Temperature	Likely Cause	44	18	18
Middle Santa Ana	NAT	Temperature	Unlikely Cause	44	20	19
Middle Santa Ana	SB0	Conductivity	Cannot be Evaluated	5	1	1
Middle Santa Ana	SB0	Conductivity	Unlikely Cause	5	4	4
Middle Santa Ana	SB0	Eutrophication	Cannot be Evaluated	5	1	1
Middle Santa Ana	SB0	Eutrophication	Likely Cause	5	3	3
Middle Santa Ana	SB0	Eutrophication	Unlikely Cause	5	1	1
Middle Santa Ana	SB0	Habitat	Cannot be Evaluated	5	1	1
Middle Santa Ana	SB0	Habitat	Likely Cause	5	4	4
Middle Santa Ana	SB0	Temperature	Cannot be Evaluated	5	1	1
Middle Santa Ana	SB0	Temperature	Likely Cause	5	4	3
Middle Santa Ana	SB0	Temperature	Unlikely Cause	5	0	1
Middle Santa Ana	SB1	Conductivity	Cannot be Evaluated	5	1	1
Middle Santa Ana	SB1	Conductivity	Likely Cause	5	0	1
Middle Santa Ana	SB1	Conductivity	Unlikely Cause	5	4	3
Middle Santa Ana	SB1	Eutrophication	Cannot be Evaluated	5	1	1
Middle Santa Ana	SB1	Eutrophication	Likely Cause	5	4	4
Middle Santa Ana	SB1	Habitat	Likely Cause	5	5	5
Middle Santa Ana	SB1	Temperature	Indeterminate Cause	5	1	1
Middle Santa Ana	SB1	Temperature	Likely Cause	5	2	2
Middle Santa Ana	SB1	Temperature	Unlikely Cause	5	2	2

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Middle Santa Ana	SB2	Conductivity	Cannot be Evaluated	7	3	4
Middle Santa Ana	SB2	Conductivity	Indeterminate Cause	7	0	1
Middle Santa Ana	SB2	Conductivity	Likely Cause	7	1	1
Middle Santa Ana	SB2	Conductivity	Unlikely Cause	7	3	1
Middle Santa Ana	SB2	Eutrophication	Cannot be Evaluated	7	3	5
Middle Santa Ana	SB2	Eutrophication	Likely Cause	7	1	1
Middle Santa Ana	SB2	Eutrophication	Unlikely Cause	7	3	1
Middle Santa Ana	SB2	Habitat	Cannot be Evaluated	7	1	2
Middle Santa Ana	SB2	Habitat	Indeterminate Cause	7	0	2
Middle Santa Ana	SB2	Habitat	Likely Cause	7	6	3
Middle Santa Ana	SB2	Temperature	Cannot be Evaluated	7	1	3
Middle Santa Ana	SB2	Temperature	Unlikely Cause	7	0	4
Middle Santa Ana	HB	Conductivity	Cannot be Evaluated	37	2	2
Middle Santa Ana	HB	Conductivity	Unlikely Cause	37	27	35
Middle Santa Ana	HB	Eutrophication	Cannot be Evaluated	37	4	4
Middle Santa Ana	HB	Eutrophication	Likely Cause	37	23	20
Middle Santa Ana	HB	Eutrophication	Unlikely Cause	37	9	13
Middle Santa Ana	HB	Habitat	Cannot be Evaluated	37	5	5
Middle Santa Ana	HB	Habitat	Likely Cause	37	32	17
Middle Santa Ana	HB	Habitat	Unlikely Cause	37	0	15
Middle Santa Ana	HB	Temperature	Cannot be Evaluated	37	5	5
Middle Santa Ana	HB	Temperature	Indeterminate Cause	37	0	4
Middle Santa Ana	HB	Temperature	Likely Cause	37	32	22
Middle Santa Ana	HB	Temperature	Unlikely Cause	37	0	6
Middle Santa Ana	NAT	Conductivity	Indeterminate Cause	44	6	0
Middle Santa Ana	NAT	Eutrophication	Indeterminate Cause	44	1	0

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Middle Santa Ana	SB2	Temperature	Likely Cause	7	6	0
Middle Santa Ana	HB	Conductivity	Indeterminate Cause	37	1	0
Middle Santa Ana	HB	Conductivity	Likely Cause	37	7	0
Middle Santa Ana	HB	Eutrophication	Indeterminate Cause	37	1	0
Mission Bay and San Diego River	NAT	Conductivity	Cannot be Evaluated	70	27	27
Mission Bay and San Diego River	NAT	Conductivity	Likely Cause	70	34	35
Mission Bay and San Diego River	NAT	Conductivity	Unlikely Cause	70	8	8
Mission Bay and San Diego River	NAT	Eutrophication	Cannot be Evaluated	70	29	29
Mission Bay and San Diego River	NAT	Eutrophication	Indeterminate Cause	70	4	1
Mission Bay and San Diego River	NAT	Eutrophication	Likely Cause	70	30	31
Mission Bay and San Diego River	NAT	Eutrophication	Unlikely Cause	70	7	9
Mission Bay and San Diego River	NAT	Habitat	Cannot be Evaluated	70	27	27
Mission Bay and San Diego River	NAT	Habitat	Indeterminate Cause	70	1	3
Mission Bay and San Diego River	NAT	Habitat	Likely Cause	70	23	19
Mission Bay and San Diego River	NAT	Habitat	Unlikely Cause	70	19	21
Mission Bay and San Diego River	NAT	Temperature	Cannot be Evaluated	70	25	25
Mission Bay and San Diego River	NAT	Temperature	Indeterminate Cause	70	2	3
Mission Bay and San Diego River	NAT	Temperature	Likely Cause	70	18	18
Mission Bay and San Diego River	NAT	Temperature	Unlikely Cause	70	25	24

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Mission Bay and San Diego River	SB0	Conductivity	Cannot be Evaluated	8	4	4
Mission Bay and San Diego River	SB0	Conductivity	Likely Cause	8	4	4
Mission Bay and San Diego River	SB0	Eutrophication	Cannot be Evaluated	8	4	4
Mission Bay and San Diego River	SB0	Eutrophication	Likely Cause	8	3	4
Mission Bay and San Diego River	SB0	Habitat	Cannot be Evaluated	8	5	5
Mission Bay and San Diego River	SB0	Habitat	Unlikely Cause	8	2	3
Mission Bay and San Diego River	SB0	Temperature	Cannot be Evaluated	8	4	4
Mission Bay and San Diego River	SB0	Temperature	Unlikely Cause	8	2	4
Mission Bay and San Diego River	HB	Conductivity	Likely Cause	11	11	10
Mission Bay and San Diego River	HB	Conductivity	Unlikely Cause	11	0	1
Mission Bay and San Diego River	HB	Eutrophication	Likely Cause	11	7	6
Mission Bay and San Diego River	HB	Eutrophication	Unlikely Cause	11	3	5
Mission Bay and San Diego River	HB	Habitat	Cannot be Evaluated	11	4	4
Mission Bay and San Diego River	HB	Habitat	Likely Cause	11	7	4
Mission Bay and San Diego River	HB	Habitat	Unlikely Cause	11	0	3
Mission Bay and San Diego River	HB	Temperature	Cannot be Evaluated	11	4	4
Mission Bay and San Diego River	HB	Temperature	Indeterminate Cause	11	0	4

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Mission Bay and San Diego River	HB	Temperature	Likely Cause	11	7	3
Mission Bay and San Diego River	NAT	Conductivity	Indeterminate Cause	70	1	0
Mission Bay and San Diego River	SB0	Eutrophication	Indeterminate Cause	8	1	0
Mission Bay and San Diego River	SB0	Habitat	Likely Cause	8	1	0
Mission Bay and San Diego River	SB0	Temperature	Likely Cause	8	2	0
Mission Bay and San Diego River	HB	Eutrophication	Indeterminate Cause	11	1	0
Northern San Diego	NAT	Conductivity	Cannot be Evaluated	77	27	27
Northern San Diego	NAT	Conductivity	Indeterminate Cause	77	6	4
Northern San Diego	NAT	Conductivity	Likely Cause	77	23	18
Northern San Diego	NAT	Conductivity	Unlikely Cause	77	21	28
Northern San Diego	NAT	Eutrophication	Cannot be Evaluated	77	27	27
Northern San Diego	NAT	Eutrophication	Indeterminate Cause	77	5	2
Northern San Diego	NAT	Eutrophication	Likely Cause	77	31	26
Northern San Diego	NAT	Eutrophication	Unlikely Cause	77	14	22
Northern San Diego	NAT	Habitat	Cannot be Evaluated	77	27	27
Northern San Diego	NAT	Habitat	Indeterminate Cause	77	0	5
Northern San Diego	NAT	Habitat	Likely Cause	77	29	22
Northern San Diego	NAT	Habitat	Unlikely Cause	77	21	23
Northern San Diego	NAT	Temperature	Cannot be Evaluated	77	23	23
Northern San Diego	NAT	Temperature	Indeterminate Cause	77	4	4
Northern San Diego	NAT	Temperature	Likely Cause	77	10	10
Northern San Diego	NAT	Temperature	Unlikely Cause	77	40	40
Northern San Diego	SB0	Conductivity	Indeterminate Cause	4	0	1

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Northern San Diego	SB0	Conductivity	Likely Cause	4	4	3
Northern San Diego	SB0	Eutrophication	Indeterminate Cause	4	0	1
Northern San Diego	SB0	Eutrophication	Likely Cause	4	4	3
Northern San Diego	SB0	Habitat	Cannot be Evaluated	4	1	1
Northern San Diego	SB0	Habitat	Likely Cause	4	3	3
Northern San Diego	SB0	Temperature	Cannot be Evaluated	4	1	1
Northern San Diego	SB0	Temperature	Likely Cause	4	1	1
Northern San Diego	SB0	Temperature	Unlikely Cause	4	2	2
Northern San Diego	SB2	Conductivity	Cannot be Evaluated	11	3	3
Northern San Diego	SB2	Conductivity	Likely Cause	11	8	8
Northern San Diego	SB2	Eutrophication	Cannot be Evaluated	11	3	3
Northern San Diego	SB2	Eutrophication	Likely Cause	11	6	7
Northern San Diego	SB2	Eutrophication	Unlikely Cause	11	0	1
Northern San Diego	SB2	Habitat	Cannot be Evaluated	11	2	2
Northern San Diego	SB2	Habitat	Indeterminate Cause	11	0	2
Northern San Diego	SB2	Habitat	Likely Cause	11	9	7
Northern San Diego	SB2	Temperature	Cannot be Evaluated	11	2	2
Northern San Diego	SB2	Temperature	Indeterminate Cause	11	0	1
Northern San Diego	SB2	Temperature	Unlikely Cause	11	8	8
Northern San Diego	SB2	Eutrophication	Indeterminate Cause	11	2	0
Northern San Diego	SB2	Temperature	Likely Cause	11	1	0
San Gabriel	NAT	Conductivity	Cannot be Evaluated	33	7	7
San Gabriel	NAT	Conductivity	Likely Cause	33	5	3
San Gabriel	NAT	Conductivity	Unlikely Cause	33	20	23
San Gabriel	NAT	Eutrophication	Cannot be Evaluated	33	6	6
San Gabriel	NAT	Eutrophication	Indeterminate Cause	33	2	3
San Gabriel	NAT	Eutrophication	Likely Cause	33	12	10
San Gabriel	NAT	Eutrophication	Unlikely Cause	33	13	14

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
San Gabriel	NAT	Habitat	Cannot be Evaluated	33	19	19
San Gabriel	NAT	Habitat	Indeterminate Cause	33	0	1
San Gabriel	NAT	Habitat	Likely Cause	33	5	4
San Gabriel	NAT	Habitat	Unlikely Cause	33	9	9
San Gabriel	NAT	Temperature	Cannot be Evaluated	33	18	18
San Gabriel	NAT	Temperature	Indeterminate Cause	33	4	7
San Gabriel	NAT	Temperature	Likely Cause	33	7	3
San Gabriel	NAT	Temperature	Unlikely Cause	33	4	5
San Gabriel	SB0	Conductivity	Cannot be Evaluated	9	0	1
San Gabriel	SB0	Conductivity	Indeterminate Cause	9	0	4
San Gabriel	SB0	Conductivity	Likely Cause	9	4	4
San Gabriel	SB0	Eutrophication	Cannot be Evaluated	9	0	1
San Gabriel	SB0	Eutrophication	Likely Cause	9	9	6
San Gabriel	SB0	Eutrophication	Unlikely Cause	9	0	2
San Gabriel	SB0	Habitat	Cannot be Evaluated	9	2	3
San Gabriel	SB0	Habitat	Indeterminate Cause	9	0	4
San Gabriel	SB0	Habitat	Unlikely Cause	9	0	2
San Gabriel	SB0	Temperature	Cannot be Evaluated	9	2	3
San Gabriel	SB0	Temperature	Likely Cause	9	1	1
San Gabriel	SB0	Temperature	Unlikely Cause	9	2	5
San Gabriel	SB1	Conductivity	Unlikely Cause	1	1	1
San Gabriel	SB1	Eutrophication	Likely Cause	1	1	1
San Gabriel	SB1	Habitat	Unlikely Cause	1	1	1
San Gabriel	SB1	Temperature	Unlikely Cause	1	1	1
San Gabriel	SB2	Conductivity	Cannot be Evaluated	20	4	4
San Gabriel	SB2	Conductivity	Indeterminate Cause	20	0	1
San Gabriel	SB2	Conductivity	Likely Cause	20	8	5
San Gabriel	SB2	Conductivity	Unlikely Cause	20	8	10
San Gabriel	SB2	Eutrophication	Cannot be Evaluated	20	4	4
San Gabriel	SB2	Eutrophication	Indeterminate Cause	20	0	1
San Gabriel	SB2	Eutrophication	Likely Cause	20	10	9
San Gabriel	SB2	Eutrophication	Unlikely Cause	20	6	6

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
San Gabriel	SB2	Habitat	Cannot be Evaluated	20	4	4
San Gabriel	SB2	Habitat	Indeterminate Cause	20	0	1
San Gabriel	SB2	Habitat	Likely Cause	20	13	7
San Gabriel	SB2	Habitat	Unlikely Cause	20	3	8
San Gabriel	SB2	Temperature	Cannot be Evaluated	20	4	4
San Gabriel	SB2	Temperature	Indeterminate Cause	20	2	3
San Gabriel	SB2	Temperature	Likely Cause	20	14	7
San Gabriel	SB2	Temperature	Unlikely Cause	20	0	6
San Gabriel	HB	Conductivity	Cannot be Evaluated	110	29	34
San Gabriel	HB	Conductivity	Indeterminate Cause	110	6	5
San Gabriel	HB	Conductivity	Likely Cause	110	35	20
San Gabriel	HB	Conductivity	Unlikely Cause	110	40	51
San Gabriel	HB	Eutrophication	Cannot be Evaluated	110	28	33
San Gabriel	HB	Eutrophication	Indeterminate Cause	110	2	3
San Gabriel	HB	Eutrophication	Likely Cause	110	63	45
San Gabriel	HB	Eutrophication	Unlikely Cause	110	17	29
San Gabriel	HB	Habitat	Cannot be Evaluated	110	53	56
San Gabriel	HB	Habitat	Indeterminate Cause	110	0	2
San Gabriel	HB	Habitat	Likely Cause	110	57	17
San Gabriel	HB	Habitat	Unlikely Cause	110	0	35
San Gabriel	HB	Temperature	Cannot be Evaluated	110	50	52
San Gabriel	HB	Temperature	Indeterminate Cause	110	0	14
San Gabriel	HB	Temperature	Likely Cause	110	60	36
San Gabriel	HB	Temperature	Unlikely Cause	110	0	8
San Gabriel	NAT	Conductivity	Indeterminate Cause	33	1	0
San Gabriel	SB0	Conductivity	Unlikely Cause	9	5	0
San Gabriel	SB0	Habitat	Likely Cause	9	7	0
San Gabriel	SB0	Temperature	Indeterminate Cause	9	4	0
San Jacinto	NAT	Conductivity	Cannot be Evaluated	21	4	5
San Jacinto	NAT	Conductivity	Likely Cause	21	2	1
San Jacinto	NAT	Conductivity	Unlikely Cause	21	15	15
San Jacinto	NAT	Eutrophication	Cannot be Evaluated	21	3	4

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
San Jacinto	NAT	Eutrophication	Likely Cause	21	8	8
San Jacinto	NAT	Eutrophication	Unlikely Cause	21	5	9
San Jacinto	NAT	Habitat	Cannot be Evaluated	21	0	1
San Jacinto	NAT	Habitat	Indeterminate Cause	21	0	2
San Jacinto	NAT	Habitat	Likely Cause	21	13	10
San Jacinto	NAT	Habitat	Unlikely Cause	21	8	8
San Jacinto	NAT	Temperature	Cannot be Evaluated	21	2	3
San Jacinto	NAT	Temperature	Indeterminate Cause	21	0	1
San Jacinto	NAT	Temperature	Likely Cause	21	9	7
San Jacinto	NAT	Temperature	Unlikely Cause	21	10	10
San Jacinto	SB0	Conductivity	Unlikely Cause	1	1	1
San Jacinto	SB0	Eutrophication	Likely Cause	1	1	1
San Jacinto	SB0	Habitat	Likely Cause	1	1	1
San Jacinto	SB0	Temperature	Likely Cause	1	1	1
San Jacinto	SB2	Conductivity	Cannot be Evaluated	15	5	5
San Jacinto	SB2	Conductivity	Likely Cause	15	7	7
San Jacinto	SB2	Conductivity	Unlikely Cause	15	3	3
San Jacinto	SB2	Eutrophication	Cannot be Evaluated	15	4	4
San Jacinto	SB2	Eutrophication	Indeterminate Cause	15	0	1
San Jacinto	SB2	Eutrophication	Likely Cause	15	9	9
San Jacinto	SB2	Eutrophication	Unlikely Cause	15	2	1
San Jacinto	SB2	Habitat	Cannot be Evaluated	15	6	6
San Jacinto	SB2	Habitat	Indeterminate Cause	15	0	2
San Jacinto	SB2	Habitat	Likely Cause	15	9	7
San Jacinto	SB2	Temperature	Cannot be Evaluated	15	6	6
San Jacinto	SB2	Temperature	Unlikely Cause	15	3	9
San Jacinto	NAT	Eutrophication	Indeterminate Cause	21	5	0
San Jacinto	SB2	Temperature	Indeterminate Cause	15	1	0
San Jacinto	SB2	Temperature	Likely Cause	15	5	0
San Juan	NAT	Conductivity	Cannot be Evaluated	56	23	23
San Juan	NAT	Conductivity	Indeterminate Cause	56	4	2
San Juan	NAT	Conductivity	Likely Cause	56	16	9
San Juan	NAT	Conductivity	Unlikely Cause	56	13	22

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
San Juan	NAT	Eutrophication	Cannot be Evaluated	56	23	23
San Juan	NAT	Eutrophication	Likely Cause	56	13	14
San Juan	NAT	Eutrophication	Unlikely Cause	56	12	19
San Juan	NAT	Habitat	Cannot be Evaluated	56	21	21
San Juan	NAT	Habitat	Indeterminate Cause	56	0	3
San Juan	NAT	Habitat	Likely Cause	56	21	16
San Juan	NAT	Habitat	Unlikely Cause	56	14	16
San Juan	NAT	Temperature	Cannot be Evaluated	56	19	19
San Juan	NAT	Temperature	Indeterminate Cause	56	3	2
San Juan	NAT	Temperature	Likely Cause	56	17	16
San Juan	NAT	Temperature	Unlikely Cause	56	17	19
San Juan	SB0	Conductivity	Cannot be Evaluated	13	6	7
San Juan	SB0	Conductivity	Likely Cause	13	7	6
San Juan	SB0	Eutrophication	Cannot be Evaluated	13	6	7
San Juan	SB0	Eutrophication	Likely Cause	13	3	5
San Juan	SB0	Eutrophication	Unlikely Cause	13	4	1
San Juan	SB0	Habitat	Cannot be Evaluated	13	8	9
San Juan	SB0	Habitat	Unlikely Cause	13	4	4
San Juan	SB0	Temperature	Cannot be Evaluated	13	8	9
San Juan	SB0	Temperature	Indeterminate Cause	13	0	1
San Juan	SB0	Temperature	Likely Cause	13	5	3
San Juan	SB1	Conductivity	Indeterminate Cause	1	0	1
San Juan	SB1	Eutrophication	Indeterminate Cause	1	0	1
San Juan	SB1	Habitat	Likely Cause	1	0	1
San Juan	SB1	Temperature	Unlikely Cause	1	1	1
San Juan	SB2	Conductivity	Cannot be Evaluated	13	5	5
San Juan	SB2	Conductivity	Likely Cause	13	7	7
San Juan	SB2	Conductivity	Unlikely Cause	13	1	1
San Juan	SB2	Eutrophication	Cannot be Evaluated	13	4	4
San Juan	SB2	Eutrophication	Likely Cause	13	6	6
San Juan	SB2	Eutrophication	Unlikely Cause	13	3	3
San Juan	SB2	Habitat	Cannot be Evaluated	13	5	5

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
San Juan	SB2	Habitat	Indeterminate Cause	13	0	1
San Juan	SB2	Habitat	Likely Cause	13	4	1
San Juan	SB2	Habitat	Unlikely Cause	13	4	6
San Juan	SB2	Temperature	Cannot be Evaluated	13	5	5
San Juan	SB2	Temperature	Likely Cause	13	8	7
San Juan	SB2	Temperature	Unlikely Cause	13	0	1
San Juan	HB	Conductivity	Indeterminate Cause	11	0	2
San Juan	HB	Conductivity	Likely Cause	11	11	9
San Juan	HB	Eutrophication	Likely Cause	11	5	5
San Juan	HB	Eutrophication	Unlikely Cause	11	6	6
San Juan	HB	Habitat	Cannot be Evaluated	11	1	1
San Juan	HB	Habitat	Likely Cause	11	10	6
San Juan	HB	Habitat	Unlikely Cause	11	0	4
San Juan	HB	Temperature	Cannot be Evaluated	11	1	1
San Juan	HB	Temperature	Indeterminate Cause	11	0	6
San Juan	HB	Temperature	Likely Cause	11	9	3
San Juan	HB	Temperature	Unlikely Cause	11	1	1
San Juan	NAT	Eutrophication	Indeterminate Cause	56	8	0
San Juan	SB0	Habitat	Likely Cause	13	1	0
San Juan	SB1	Conductivity	Likely Cause	1	1	0
San Juan	SB1	Eutrophication	Likely Cause	1	1	0
San Juan	SB1	Habitat	Unlikely Cause	1	1	0
Santa Clara	NAT	Conductivity	Cannot be Evaluated	89	21	22
Santa Clara	NAT	Conductivity	Indeterminate Cause	89	5	7
Santa Clara	NAT	Conductivity	Likely Cause	89	39	28
Santa Clara	NAT	Conductivity	Unlikely Cause	89	24	32
Santa Clara	NAT	Eutrophication	Cannot be Evaluated	89	21	22
Santa Clara	NAT	Eutrophication	Indeterminate Cause	89	4	6
Santa Clara	NAT	Eutrophication	Likely Cause	89	35	26
Santa Clara	NAT	Eutrophication	Unlikely Cause	89	29	35
Santa Clara	NAT	Habitat	Cannot be Evaluated	89	18	23
Santa Clara	NAT	Habitat	Indeterminate Cause	89	4	3
Santa Clara	NAT	Habitat	Likely Cause	89	50	44

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Santa Clara	NAT	Habitat	Unlikely Cause	89	17	19
Santa Clara	NAT	Temperature	Cannot be Evaluated	89	13	18
Santa Clara	NAT	Temperature	Indeterminate Cause	89	7	6
Santa Clara	NAT	Temperature	Likely Cause	89	34	36
Santa Clara	NAT	Temperature	Unlikely Cause	89	35	29
Santa Clara	SB0	Conductivity	Cannot be Evaluated	11	10	10
Santa Clara	SB0	Conductivity	Likely Cause	11	1	1
Santa Clara	SB0	Eutrophication	Cannot be Evaluated	11	10	10
Santa Clara	SB0	Eutrophication	Likely Cause	11	1	1
Santa Clara	SB0	Habitat	Cannot be Evaluated	11	9	9
Santa Clara	SB0	Habitat	Indeterminate Cause	11	0	1
Santa Clara	SB0	Habitat	Unlikely Cause	11	0	1
Santa Clara	SB0	Temperature	Cannot be Evaluated	11	9	9
Santa Clara	SB0	Temperature	Indeterminate Cause	11	1	1
Santa Clara	SB0	Temperature	Unlikely Cause	11	0	1
Santa Clara	SB1	Conductivity	Cannot be Evaluated	10	2	2
Santa Clara	SB1	Conductivity	Likely Cause	10	5	7
Santa Clara	SB1	Conductivity	Unlikely Cause	10	2	1
Santa Clara	SB1	Eutrophication	Cannot be Evaluated	10	2	2
Santa Clara	SB1	Eutrophication	Likely Cause	10	8	7
Santa Clara	SB1	Eutrophication	Unlikely Cause	10	0	1
Santa Clara	SB1	Habitat	Cannot be Evaluated	10	1	1
Santa Clara	SB1	Habitat	Likely Cause	10	4	4
Santa Clara	SB1	Habitat	Unlikely Cause	10	5	5
Santa Clara	SB1	Temperature	Cannot be Evaluated	10	1	1
Santa Clara	SB1	Temperature	Likely Cause	10	4	4
Santa Clara	SB1	Temperature	Unlikely Cause	10	5	5
Santa Clara	SB2	Conductivity	Unlikely Cause	2	2	2
Santa Clara	SB2	Eutrophication	Unlikely Cause	2	2	2
Santa Clara	SB2	Habitat	Cannot be Evaluated	2	2	2
Santa Clara	SB2	Temperature	Unlikely Cause	2	2	2
Santa Clara	HB	Conductivity	Cannot be Evaluated	15	4	4

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Santa Clara	HB	Conductivity	Indeterminate Cause	15	0	1
Santa Clara	HB	Conductivity	Likely Cause	15	9	4
Santa Clara	HB	Conductivity	Unlikely Cause	15	2	6
Santa Clara	HB	Eutrophication	Cannot be Evaluated	15	4	4
Santa Clara	HB	Eutrophication	Indeterminate Cause	15	1	2
Santa Clara	HB	Eutrophication	Likely Cause	15	7	8
Santa Clara	HB	Eutrophication	Unlikely Cause	15	3	1
Santa Clara	HB	Habitat	Cannot be Evaluated	15	3	3
Santa Clara	HB	Habitat	Likely Cause	15	10	6
Santa Clara	HB	Habitat	Unlikely Cause	15	2	6
Santa Clara	HB	Temperature	Indeterminate Cause	15	0	5
Santa Clara	HB	Temperature	Likely Cause	15	13	1
Santa Clara	HB	Temperature	Unlikely Cause	15	2	9
Santa Clara	SB0	Habitat	Likely Cause	11	2	0
Santa Clara	SB0	Temperature	Likely Cause	11	1	0
Santa Clara	SB1	Conductivity	Indeterminate Cause	10	1	0
Santa Monica Bay	NAT	Conductivity	Cannot be Evaluated	60	11	11
Santa Monica Bay	NAT	Conductivity	Indeterminate Cause	60	0	1
Santa Monica Bay	NAT	Conductivity	Likely Cause	60	49	47
Santa Monica Bay	NAT	Conductivity	Unlikely Cause	60	0	1
Santa Monica Bay	NAT	Eutrophication	Cannot be Evaluated	60	9	9
Santa Monica Bay	NAT	Eutrophication	Indeterminate Cause	60	0	3
Santa Monica Bay	NAT	Eutrophication	Likely Cause	60	49	46
Santa Monica Bay	NAT	Eutrophication	Unlikely Cause	60	2	2
Santa Monica Bay	NAT	Habitat	Cannot be Evaluated	60	9	9
Santa Monica Bay	NAT	Habitat	Indeterminate Cause	60	0	3
Santa Monica Bay	NAT	Habitat	Likely Cause	60	31	26
Santa Monica Bay	NAT	Habitat	Unlikely Cause	60	20	22
Santa Monica Bay	NAT	Temperature	Cannot be Evaluated	60	7	7
Santa Monica Bay	NAT	Temperature	Indeterminate Cause	60	1	4

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Santa Monica Bay	NAT	Temperature	Likely Cause	60	4	5
Santa Monica Bay	NAT	Temperature	Unlikely Cause	60	48	44
Santa Monica Bay	SB0	Conductivity	Likely Cause	3	3	3
Santa Monica Bay	SB0	Eutrophication	Likely Cause	3	2	3
Santa Monica Bay	SB0	Habitat	Indeterminate Cause	3	0	1
Santa Monica Bay	SB0	Habitat	Unlikely Cause	3	2	2
Santa Monica Bay	SB0	Temperature	Likely Cause	3	1	1
Santa Monica Bay	SB0	Temperature	Unlikely Cause	3	2	2
Santa Monica Bay	SB1	Conductivity	Likely Cause	3	3	3
Santa Monica Bay	SB1	Eutrophication	Likely Cause	3	3	3
Santa Monica Bay	SB1	Habitat	Likely Cause	3	2	3
Santa Monica Bay	SB1	Temperature	Indeterminate Cause	3	1	1
Santa Monica Bay	SB1	Temperature	Likely Cause	3	1	1
Santa Monica Bay	SB1	Temperature	Unlikely Cause	3	1	1
Santa Monica Bay	SB2	Conductivity	Cannot be Evaluated	15	1	1
Santa Monica Bay	SB2	Conductivity	Likely Cause	15	13	13
Santa Monica Bay	SB2	Conductivity	Unlikely Cause	15	1	1
Santa Monica Bay	SB2	Eutrophication	Cannot be Evaluated	15	1	1
Santa Monica Bay	SB2	Eutrophication	Likely Cause	15	13	10
Santa Monica Bay	SB2	Eutrophication	Unlikely Cause	15	1	4
Santa Monica Bay	SB2	Habitat	Cannot be Evaluated	15	2	2
Santa Monica Bay	SB2	Habitat	Indeterminate Cause	15	0	2
Santa Monica Bay	SB2	Habitat	Likely Cause	15	7	2
Santa Monica Bay	SB2	Habitat	Unlikely Cause	15	6	9
Santa Monica Bay	SB2	Temperature	Cannot be Evaluated	15	2	2
Santa Monica Bay	SB2	Temperature	Likely Cause	15	3	1

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Santa Monica Bay	SB2	Temperature	Unlikely Cause	15	9	12
Santa Monica Bay	HB	Conductivity	Cannot be Evaluated	30	10	10
Santa Monica Bay	HB	Conductivity	Likely Cause	30	15	13
Santa Monica Bay	HB	Conductivity	Unlikely Cause	30	2	7
Santa Monica Bay	HB	Eutrophication	Cannot be Evaluated	30	10	10
Santa Monica Bay	HB	Eutrophication	Likely Cause	30	16	10
Santa Monica Bay	HB	Eutrophication	Unlikely Cause	30	4	10
Santa Monica Bay	HB	Habitat	Cannot be Evaluated	30	8	8
Santa Monica Bay	HB	Habitat	Indeterminate Cause	30	0	1
Santa Monica Bay	HB	Habitat	Likely Cause	30	22	9
Santa Monica Bay	HB	Habitat	Unlikely Cause	30	0	12
Santa Monica Bay	HB	Temperature	Cannot be Evaluated	30	6	6
Santa Monica Bay	HB	Temperature	Indeterminate Cause	30	1	7
Santa Monica Bay	HB	Temperature	Likely Cause	30	22	7
Santa Monica Bay	HB	Temperature	Unlikely Cause	30	1	10
Santa Monica Bay	SB0	Eutrophication	Unlikely Cause	3	1	0
Santa Monica Bay	SB0	Habitat	Likely Cause	3	1	0
Santa Monica Bay	SB1	Habitat	Unlikely Cause	3	1	0
Santa Monica Bay	SB2	Temperature	Indeterminate Cause	15	1	0
Santa Monica Bay	HB	Conductivity	Indeterminate Cause	30	3	0
Southern San Diego	NAT	Conductivity	Cannot be Evaluated	67	19	19
Southern San Diego	NAT	Conductivity	Indeterminate Cause	67	4	4
Southern San Diego	NAT	Conductivity	Likely Cause	67	19	17
Southern San Diego	NAT	Conductivity	Unlikely Cause	67	25	27
Southern San Diego	NAT	Eutrophication	Cannot be Evaluated	67	19	19
Southern San Diego	NAT	Eutrophication	Indeterminate Cause	67	4	3

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Southern San Diego	NAT	Eutrophication	Likely Cause	67	24	21
Southern San Diego	NAT	Eutrophication	Unlikely Cause	67	20	24
Southern San Diego	NAT	Habitat	Cannot be Evaluated	67	26	26
Southern San Diego	NAT	Habitat	Indeterminate Cause	67	1	2
Southern San Diego	NAT	Habitat	Likely Cause	67	25	25
Southern San Diego	NAT	Habitat	Unlikely Cause	67	15	14
Southern San Diego	NAT	Temperature	Cannot be Evaluated	67	23	23
Southern San Diego	NAT	Temperature	Indeterminate Cause	67	0	1
Southern San Diego	NAT	Temperature	Likely Cause	67	8	8
Southern San Diego	NAT	Temperature	Unlikely Cause	67	36	35
Southern San Diego	SB0	Conductivity	Likely Cause	4	4	4
Southern San Diego	SB0	Eutrophication	Likely Cause	4	2	3
Southern San Diego	SB0	Eutrophication	Unlikely Cause	4	2	1
Southern San Diego	SB0	Habitat	Cannot be Evaluated	4	3	3
Southern San Diego	SB0	Habitat	Likely Cause	4	1	1
Southern San Diego	SB0	Temperature	Cannot be Evaluated	4	1	1
Southern San Diego	SB0	Temperature	Likely Cause	4	3	1
Southern San Diego	SB0	Temperature	Unlikely Cause	4	0	2
Southern San Diego	HB	Conductivity	Cannot be Evaluated	1	1	1
Southern San Diego	HB	Eutrophication	Cannot be Evaluated	1	1	1
Southern San Diego	HB	Habitat	Likely Cause	1	1	1
Southern San Diego	HB	Temperature	Indeterminate Cause	1	0	1
Southern San Diego	HB	Temperature	Likely Cause	1	1	0
Upper Santa Ana	NAT	Conductivity	Cannot be Evaluated	42	10	14
Upper Santa Ana	NAT	Conductivity	Likely Cause	42	9	8
Upper Santa Ana	NAT	Conductivity	Unlikely Cause	42	23	20

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Upper Santa Ana	NAT	Eutrophication	Cannot be Evaluated	42	8	14
Upper Santa Ana	NAT	Eutrophication	Likely Cause	42	10	6
Upper Santa Ana	NAT	Eutrophication	Unlikely Cause	42	22	22
Upper Santa Ana	NAT	Habitat	Cannot be Evaluated	42	4	6
Upper Santa Ana	NAT	Habitat	Indeterminate Cause	42	2	8
Upper Santa Ana	NAT	Habitat	Likely Cause	42	26	22
Upper Santa Ana	NAT	Habitat	Unlikely Cause	42	10	6
Upper Santa Ana	NAT	Temperature	Cannot be Evaluated	42	4	8
Upper Santa Ana	NAT	Temperature	Indeterminate Cause	42	1	5
Upper Santa Ana	NAT	Temperature	Likely Cause	42	24	19
Upper Santa Ana	NAT	Temperature	Unlikely Cause	42	13	10
Upper Santa Ana	SB0	Conductivity	Cannot be Evaluated	14	6	8
Upper Santa Ana	SB0	Conductivity	Unlikely Cause	14	6	6
Upper Santa Ana	SB0	Eutrophication	Cannot be Evaluated	14	6	8
Upper Santa Ana	SB0	Eutrophication	Likely Cause	14	4	3
Upper Santa Ana	SB0	Eutrophication	Unlikely Cause	14	4	3
Upper Santa Ana	SB0	Habitat	Cannot be Evaluated	14	4	7
Upper Santa Ana	SB0	Habitat	Indeterminate Cause	14	0	1
Upper Santa Ana	SB0	Habitat	Likely Cause	14	9	4
Upper Santa Ana	SB0	Habitat	Unlikely Cause	14	1	2
Upper Santa Ana	SB0	Temperature	Cannot be Evaluated	14	4	7
Upper Santa Ana	SB0	Temperature	Likely Cause	14	8	5
Upper Santa Ana	SB0	Temperature	Unlikely Cause	14	2	2
Upper Santa Ana	SB1	Conductivity	Unlikely Cause	1	1	1
Upper Santa Ana	SB1	Eutrophication	Unlikely Cause	1	1	1
Upper Santa Ana	SB1	Habitat	Unlikely Cause	1	1	1

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Upper Santa Ana	SB1	Temperature	Likely Cause	1	1	1
Upper Santa Ana	HB	Conductivity	Cannot be Evaluated	6	3	3
Upper Santa Ana	HB	Conductivity	Unlikely Cause	6	3	3
Upper Santa Ana	HB	Eutrophication	Cannot be Evaluated	6	2	2
Upper Santa Ana	HB	Eutrophication	Likely Cause	6	2	2
Upper Santa Ana	HB	Eutrophication	Unlikely Cause	6	2	2
Upper Santa Ana	HB	Habitat	Cannot be Evaluated	6	1	1
Upper Santa Ana	HB	Habitat	Likely Cause	6	5	5
Upper Santa Ana	HB	Temperature	Cannot be Evaluated	6	1	1
Upper Santa Ana	HB	Temperature	Indeterminate Cause	6	0	1
Upper Santa Ana	HB	Temperature	Likely Cause	6	5	4
Upper Santa Ana	NAT	Eutrophication	Indeterminate Cause	42	2	0
Upper Santa Ana	SB0	Conductivity	Likely Cause	14	2	0
Ventura	NAT	Conductivity	Cannot be Evaluated	29	1	1
Ventura	NAT	Conductivity	Indeterminate Cause	29	5	3
Ventura	NAT	Conductivity	Likely Cause	29	7	2
Ventura	NAT	Conductivity	Unlikely Cause	29	16	23
Ventura	NAT	Eutrophication	Cannot be Evaluated	29	1	1
Ventura	NAT	Eutrophication	Indeterminate Cause	29	0	2
Ventura	NAT	Eutrophication	Likely Cause	29	13	8
Ventura	NAT	Eutrophication	Unlikely Cause	29	15	18
Ventura	NAT	Habitat	Indeterminate Cause	29	0	2
Ventura	NAT	Habitat	Likely Cause	29	17	14
Ventura	NAT	Habitat	Unlikely Cause	29	12	13
Ventura	NAT	Temperature	Indeterminate Cause	29	5	1
Ventura	NAT	Temperature	Likely Cause	29	17	17
Ventura	NAT	Temperature	Unlikely Cause	29	7	11
Ventura	SB1	Conductivity	Cannot be Evaluated	11	1	1
Ventura	SB1	Conductivity	Indeterminate Cause	11	5	1

Region	Class	Stressor	Conclusion	Site-visits with CSCI < 0.79	Standard	Engineered
Ventura	SB1	Conductivity	Likely Cause	11	1	5
Ventura	SB1	Conductivity	Unlikely Cause	11	4	4
Ventura	SB1	Eutrophication	Likely Cause	11	10	7
Ventura	SB1	Eutrophication	Unlikely Cause	11	1	4
Ventura	SB1	Habitat	Cannot be Evaluated	11	1	1
Ventura	SB1	Habitat	Indeterminate Cause	11	0	1
Ventura	SB1	Habitat	Likely Cause	11	2	6
Ventura	SB1	Habitat	Unlikely Cause	11	8	3
Ventura	SB1	Temperature	Cannot be Evaluated	11	1	1
Ventura	SB1	Temperature	Indeterminate Cause	11	8	8
Ventura	SB1	Temperature	Likely Cause	11	1	1
Ventura	SB1	Temperature	Unlikely Cause	11	1	1

Supplement 5. Summaries of t-tests comparing scores in high- vs. low-scoring sites within each class of engineered channel.

Table S - 8. Mean values and t-statistics comparing water quality (WQ), physical habitat (PHAB), and geospatial (GIS) analytes in high- and low-scoring sites within each channel class. n_top: number of high-scoring sites with data. mean_top: mean analyte value at high-scoring sites. n_bot: number of low-scoring sites with data. mean_bot: mean analyte value at low-scoring sites. t_stat: Statistic from a t-test comparing mean values at high- and low-scoring sites. t_stat_p: p-value of the t-test. NA: Insufficient data for calculation.

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
WQ	Alkalinity as CaCO3	NAT	76	187	138	288	-8.18	0
WQ	Alkalinity as CaCO3	SB0	10	270	13	236	0.93	0.363
WQ	Alkalinity as CaCO3	SB1	2	221	5	278	NA	NA
WQ	Alkalinity as CaCO3	SB2	7	281	19	236	0.71	0.5
WQ	Alkalinity as CaCO3	HB	38	195	25	176	0.98	0.331
WQ	Oxygen, Dissolved	NAT	98	8.3	139	7.6	2.73	0.007
WQ	Oxygen, Dissolved	SB0	10	8.9	10	8.1	0.46	0.654
WQ	Oxygen, Dissolved	SB1	3	8.9	6	7.6	NA	NA
WQ	Oxygen, Dissolved	SB2	5	5.8	18	7.9	-1.11	0.301
WQ	Oxygen, Dissolved	HB	43	10.1	34	12.6	-4.36	0
WQ	Salinity	NAT	72	0.34	122	1.43	-10.5	0
WQ	Salinity	SB0	10	0.92	10	1.37	-1.41	0.18
WQ	Salinity	SB1	3	0.44	5	1.14	NA	NA
WQ	Salinity	SB2	4	1.00	18	1.06	NA	NA
WQ	Salinity	HB	45	0.73	36	0.72	0.14	0.887
WQ	SpecificConductivity	NAT	100	613	140	2427	-10.63	0
WQ	SpecificConductivity	SB0	10	1721	11	2418	-1.2	0.245
WQ	SpecificConductivity	SB1	3	802	6	2483	NA	NA
WQ	SpecificConductivity	SB2	5	1508	19	1937	-0.73	0.499
WQ	SpecificConductivity	HB	47	1431	39	1356	0.35	0.725
WQ	TN	NAT	94	0.8	119	2.6	-3.52	0.001
WQ	TN	SB0	12	4.9	15	25.5	-2.18	0.045
WQ	TN	SB1	5	1.2	6	11.2	-1.29	0.254
WQ	TN	SB2	10	6.4	17	3.4	1.18	0.264
WQ	TN	HB	39	3.3	29	5.7	-1.3	0.204
WQ	TP	NAT	97	0.054014	123	0.262513	-3.84	0
WQ	TP	SB0	12	0.5477	15	0.944627	-0.98	0.336
WQ	TP	SB1	6	0.052858	6	0.663833	-1.77	0.137

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
WQ	TP	SB2	10	0.457335	17	0.346625	0.45	0.658
WQ	TP	HB	38	0.130827	31	0.368221	-2.41	0.022
WQ	Temperature	NAT	100	16.0	143	19.6	-7.11	0
WQ	Temperature	SB0	10	23.4	11	22.2	0.62	0.545
WQ	Temperature	SB1	3	16.9	6	20.7	NA	NA
WQ	Temperature	SB2	5	20.9	19	20.6	0.25	0.809
WQ	Temperature	HB	46	23.5	40	25.1	-1.28	0.206
WQ	Turbidity	NAT	71	4.1	92	7.0	-1.05	0.297
WQ	Turbidity	SB0	8	4.9	5	4.8	0.04	0.972
WQ	Turbidity	SB1	0	NA	2	2.1	NA	NA
WQ	Turbidity	SB2	4	2.4	12	1.7	NA	NA
WQ	Turbidity	HB	25	4.7	19	5.2	-0.23	0.818
WQ	pH	NAT	96	7.9	143	7.8	1.72	0.087
WQ	pH	SB0	10	8.1	10	8.2	-0.4	0.696
WQ	pH	SB1	3	7.7	6	7.9	NA	NA
WQ	pH	SB2	5	8.1	19	7.9	0.95	0.373
WQ	pH	HB	45	8.4	38	9.0	-2.71	0.009
GIS	ag_1k_16	NAT	185	0.8	186	3.6	-3.75	0
GIS	ag_1k_16	SB0	17	7.2	17	34.5	-2.57	0.018
GIS	ag_1k_16	SB1	12	1.2	12	30.7	-2.57	0.026
GIS	ag_1k_16	SB2	21	4.5	20	9.0	-0.87	0.394
GIS	ag_1k_16	HB	57	2.1	57	4.8	-1.06	0.294
GIS	ag_5k_16	NAT	185	1.0	186	3.6	-3.22	0.001
GIS	ag_5k_16	SB0	17	5.1	17	23.8	-1.96	0.065
GIS	ag_5k_16	SB1	12	0.2	12	24.3	-2.42	0.034
GIS	ag_5k_16	SB2	21	3.7	20	4.9	-0.43	0.674
GIS	ag_5k_16	HB	57	1.9	57	4.1	-1.17	0.245
GIS	ag_ws_16	NAT	185	0.9	186	1.3	-1.16	0.246
GIS	ag_ws_16	SB0	17	3.4	17	22.9	-2.04	0.056
GIS	ag_ws_16	SB1	12	0.1	12	11.3	-1.92	0.081
GIS	ag_ws_16	SB2	21	1.4	20	3.3	-2.31	0.028
GIS	ag_ws_16	HB	57	0.4	57	3.4	-2.42	0.019
GIS	agur_1k_16	NAT	185	1.6	186	29.2	-14.23	0
GIS	agur_1k_16	SB0	17	46.6	17	74.3	-2.84	0.008
GIS	agur_1k_16	SB1	12	11.8	12	54.6	-3.96	0.001
GIS	agur_1k_16	SB2	21	53.7	20	81.9	-3.2	0.003
GIS	agur_1k_16	HB	57	71.8	57	88.6	-4.48	0
GIS	agur_5k_16	NAT	185	1.5	186	30.9	-14.54	0
GIS	agur_5k_16	SB0	17	35.1	17	59.9	-2.38	0.023
GIS	agur_5k_16	SB1	12	6.0	12	40.7	-3.33	0.004
GIS	agur_5k_16	SB2	21	40.7	20	72.1	-3.78	0.001
GIS	agur_5k_16	HB	57	56.6	57	77.3	-4.19	0

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
GIS	agur_ws_16	NAT	185	1.6	186	21.7	-11.76	0
GIS	agur_ws_16	SB0	17	26.7	17	52.9	-2.63	0.014
GIS	agur_ws_16	SB1	12	4.3	12	31.1	-3.44	0.003
GIS	agur_ws_16	SB2	21	20.9	20	42.2	-2.71	0.011
GIS	agur_ws_16	HB	57	38.2	57	55.4	-3.48	0.001
GIS	area_sqkm	NAT	185	85	186	409	-5.32	0
GIS	area_sqkm	SB0	17	442	17	473	-0.07	0.942
GIS	area_sqkm	SB1	12	157	12	211	-0.73	0.473
GIS	area_sqkm	SB2	21	593	20	1447	-1.59	0.124
GIS	area_sqkm	HB	57	221	57	396	-1.55	0.124
GIS	atmca	NAT	185	0.073351	186	0.071	1.25	0.212
GIS	atmca	SB0	17	0.066237	17	0.059667	1.85	0.078
GIS	atmca	SB1	12	0.056453	12	0.056938	-0.35	0.728
GIS	atmca	SB2	21	0.063376	20	0.061317	0.51	0.611
GIS	atmca	HB	57	0.059592	57	0.055149	2.51	0.014
GIS	atmmg	NAT	185	0.030573	186	0.030614	-0.34	0.735
GIS	atmmg	SB0	17	0.030914	17	0.030508	1.59	0.123
GIS	atmmg	SB1	12	0.03065	12	0.03035	0.58	0.572
GIS	atmmg	SB2	21	0.030781	20	0.031027	-1.02	0.315
GIS	atmmg	HB	57	0.031246	57	0.031384	-1.34	0.182
GIS	atmso4	NAT	185	0.399819	186	0.39722	0.84	0.4
GIS	atmso4	SB0	17	0.396343	17	0.381589	2.45	0.02
GIS	atmso4	SB1	12	0.377462	12	0.37407	0.73	0.474
GIS	atmso4	SB2	21	0.388121	20	0.390243	-0.35	0.729
GIS	atmso4	HB	57	0.387843	57	0.382767	2.15	0.035
GIS	bdh_ave	NAT	185	1.55328	186	1.566375	-3.42	0.001
GIS	bdh_ave	SB0	17	1.57856	17	1.573331	0.38	0.703
GIS	bdh_ave	SB1	12	1.544752	12	1.564492	-2.81	0.011
GIS	bdh_ave	SB2	21	1.56516	20	1.578646	-1.49	0.144
GIS	bdh_ave	HB	57	1.581998	57	1.581963	0.01	0.996
GIS	cao_mean	NAT	185	4.876626	186	6.043328	-3.47	0.001
GIS	cao_mean	SB0	17	6.969093	17	6.209645	0.43	0.67
GIS	cao_mean	SB1	12	5.043085	12	7.967616	-1.97	0.069
GIS	cao_mean	SB2	21	7.351016	20	4.743598	2.29	0.029
GIS	cao_mean	HB	57	6.158334	57	4.385047	2.4	0.018
GIS	cnl_pi_pct	NAT	185	0.5	186	4.7	-6.02	0
GIS	cnl_pi_pct	SB0	17	2.9	17	35.4	-3.04	0.008
GIS	cnl_pi_pct	SB1	12	0.4	12	3.6	-1.47	0.169
GIS	cnl_pi_pct	SB2	21	4.4	20	26.2	-2.47	0.022
GIS	cnl_pi_pct	HB	57	5.9	57	20.3	-3.14	0.003
GIS	code_21_1k_16	NAT	185	4.8	186	15.6	-10.74	0
GIS	code_21_1k_16	SB0	17	13.5	17	11.1	0.85	0.4

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
GIS	code_21_1k_16	SB1	12	9.8	12	14.0	-1.32	0.199
GIS	code_21_1k_16	SB2	21	17.1	20	6.6	3.15	0.004
GIS	code_21_1k_16	HB	57	15.7	57	7.7	3.94	0
GIS	code_21_5k_16	NAT	185	3.8	186	12.3	-11.23	0
GIS	code_21_5k_16	SB0	17	9.9	17	9.7	0.11	0.909
GIS	code_21_5k_16	SB1	12	4.3	12	8.7	-1.76	0.094
GIS	code_21_5k_16	SB2	21	12.5	20	8.1	2.64	0.012
GIS	code_21_5k_16	HB	57	14.8	57	9.6	3.67	0
GIS	code_21_ws_16	NAT	185	4.2	186	10.1	-8.66	0
GIS	code_21_ws_16	SB0	17	11.1	17	9.7	0.61	0.55
GIS	code_21_ws_16	SB1	12	3.9	12	10.5	-2.76	0.013
GIS	code_21_ws_16	SB2	21	10.0	20	8.6	0.86	0.396
GIS	code_21_ws_16	HB	57	12.4	57	9.5	2.99	0.003
GIS	condqr01	NAT	120	64.47023	97	108.8792	-4.75	0
GIS	condqr01	SB0	9	92.3732	7	106.8121	-0.38	0.709
GIS	condqr01	SB1	7	81.4733	3	143.9233	NA	NA
GIS	condqr01	SB2	14	135.0368	12	140.2924	-0.19	0.848
GIS	condqr01	HB	27	107.7304	26	90.57211	0.75	0.456
GIS	condqr10	NAT	120	182.2333	97	248.8844	-4.9	0
GIS	condqr10	SB0	9	224.6044	7	261.4857	-0.79	0.443
GIS	condqr10	SB1	7	237.8671	3	299.54	NA	NA
GIS	condqr10	SB2	14	296.3929	12	305.8167	-0.27	0.791
GIS	condqr10	HB	27	259.8111	26	244.9896	0.59	0.556
GIS	condqr50	NAT	120	373.2529	97	505.2381	-5.03	0
GIS	condqr50	SB0	9	434.6556	7	534.5429	-1.14	0.274
GIS	condqr50	SB1	7	425.4214	3	632.8667	NA	NA
GIS	condqr50	SB2	14	576.7643	12	609.7833	-0.46	0.647
GIS	condqr50	HB	27	509.5796	26	514.1673	-0.09	0.925
GIS	condqr90	NAT	120	555.2873	97	805.9327	-7.43	0
GIS	condqr90	SB0	9	726.7778	7	966.8571	-1.75	0.103
GIS	condqr90	SB1	7	613.2286	3	1078.833	NA	NA
GIS	condqr90	SB2	14	943.3857	12	943.9583	-0.01	0.996
GIS	condqr90	HB	27	862.3641	26	882.0115	-0.32	0.749
GIS	condqr99	NAT	120	837.0485	97	1031.16	-5.87	0
GIS	condqr99	SB0	9	986.6828	7	1108.157	-1.51	0.157
GIS	condqr99	SB1	7	828.16	3	1171	NA	NA
GIS	condqr99	SB2	14	1108.058	12	1110.293	-0.05	0.962
GIS	condqr99	HB	27	1124.158	26	1121.367	0.09	0.928
GIS	developed_1k_16	NAT	185	6.5	186	44.8	-16.36	0
GIS	developed_1k_16	SB0	17	60.1	17	85.3	-2.67	0.012
GIS	developed_1k_16	SB1	12	21.6	12	68.6	-4.27	0
GIS	developed_1k_16	SB2	21	70.8	20	88.5	-2.21	0.034

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
GIS	developed_1k_16	HB	57	87.4	57	96.2	-3.17	0.002
GIS	developed_5k_16	NAT	185	5.4	186	43.2	-16.15	0
GIS	developed_5k_16	SB0	17	45.0	17	69.6	-2.39	0.023
GIS	developed_5k_16	SB1	12	10.3	12	49.4	-3.59	0.002
GIS	developed_5k_16	SB2	21	53.2	20	80.2	-3.27	0.002
GIS	developed_5k_16	HB	57	71.3	57	86.9	-3.17	0.002
GIS	developed_ws_16	NAT	185	5.8	186	31.8	-12.47	0
GIS	developed_ws_16	SB0	17	37.8	17	62.5	-2.42	0.022
GIS	developed_ws_16	SB1	12	8.2	12	41.7	-3.6	0.002
GIS	developed_ws_16	SB2	21	30.9	20	50.8	-2.47	0.019
GIS	developed_ws_16	HB	57	50.6	57	64.8	-2.77	0.007
GIS	elev_range	NAT	185	1076	186	1056	0.28	0.78
GIS	elev_range	SB0	17	1253	17	622	1.98	0.057
GIS	elev_range	SB1	12	1662	12	938	3.32	0.003
GIS	elev_range	SB2	21	1390	20	1368	0.07	0.948
GIS	elev_range	HB	57	1073	57	1069	0.02	0.983
GIS	evi_maxave	NAT	185	3475.137	186	3213.532	4.67	0
GIS	evi_maxave	SB0	17	3456.488	17	3469.29	-0.05	0.964
GIS	evi_maxave	SB1	12	3657.734	12	3618.462	0.27	0.793
GIS	evi_maxave	SB2	21	3440.113	20	3158.309	1.97	0.058
GIS	evi_maxave	HB	57	3269.285	57	3038.393	2.48	0.015
GIS	grvl_dens	NAT	185	6.96E-04	186	0.004852	-3.31	0.001
GIS	grvl_dens	SB0	17	0.003229	17	0.015411	-0.77	0.45
GIS	grvl_dens	SB1	12	0.00347	12	0.004544	-0.19	0.853
GIS	grvl_dens	SB2	21	0.01765	20	0	1.46	0.159
GIS	grvl_dens	HB	57	0.008101	57	0.003256	1.06	0.292
GIS	grvl_mines	NAT	185	0.016216	186	0.107527	-3.27	0.001
GIS	grvl_mines	SB0	17	0.058824	17	0.058824	0	1
GIS	grvl_mines	SB1	12	0.083333	12	0.083333	0	1
GIS	grvl_mines	SB2	21	0.142857	20	0	1.83	0.083
GIS	grvl_mines	HB	57	0.122807	57	0.070175	0.8	0.426
GIS	kfct_ave	NAT	185	0.212344	186	0.245	-6.41	0
GIS	kfct_ave	SB0	17	0.236743	17	0.262738	-2.16	0.04
GIS	kfct_ave	SB1	12	0.191412	12	0.256491	-3.78	0.002
GIS	kfct_ave	SB2	21	0.267835	20	0.253836	1.32	0.194
GIS	kfct_ave	HB	57	0.258877	57	0.259701	-0.16	0.87
GIS	lprem_mean	NAT	185	-1.66389	186	-0.96003	-7.05	0
GIS	lprem_mean	SB0	17	-0.90138	17	0.300686	-2.73	0.011
GIS	lprem_mean	SB1	12	-1.32835	12	-0.25966	-3.08	0.006
GIS	lprem_mean	SB2	21	-0.73622	20	0.20987	-3.07	0.004
GIS	lprem_mean	HB	57	-0.10493	57	0.605061	-3.63	0
GIS	lst32ave	NAT	185	95.06234	186	59.89935	11.2	0

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
GIS	lst32ave	SB0	17	61.28699	17	52.74873	1.09	0.282
GIS	lst32ave	SB1	12	83.10877	12	58.43363	4.17	0
GIS	lst32ave	SB2	21	57.89717	20	49.81156	0.95	0.351
GIS	lst32ave	HB	57	49.22209	57	39.19318	2.44	0.017
GIS	max_elev	NAT	185	1897.222	186	1335.317	6.7	0
GIS	max_elev	SB0	17	1453.471	17	752	2.09	0.045
GIS	max_elev	SB1	12	2097.5	12	1072.167	4.06	0.001
GIS	max_elev	SB2	21	1559.286	20	1441.15	0.34	0.737
GIS	max_elev	HB	57	1252.772	57	1170.807	0.45	0.654
GIS	maxwd_ws	NAT	185	7.123532	186	6.296672	6.77	0
GIS	maxwd_ws	SB0	17	6.319156	17	5.323606	3.93	0
GIS	maxwd_ws	SB1	12	6.80166	12	5.285321	3.89	0.001
GIS	maxwd_ws	SB2	21	6.089979	20	5.790231	1.14	0.262
GIS	maxwd_ws	HB	57	5.920053	57	5.752368	1.15	0.254
GIS	meanp_ws	NAT	185	725.7002	186	516.3033	12.28	0
GIS	meanp_ws	SB0	17	507.9277	17	404.4876	3	0.006
GIS	meanp_ws	SB1	12	795.2149	12	495.4481	4.57	0
GIS	meanp_ws	SB2	21	511.9588	20	433.0011	2.9	0.006
GIS	meanp_ws	HB	57	504.9749	57	482.0004	0.97	0.334
GIS	mgo_mean	NAT	185	2.474246	186	2.70622	-1.85	0.065
GIS	mgo_mean	SB0	17	2.963693	17	2.685731	0.46	0.651
GIS	mgo_mean	SB1	12	2.31421	12	3.276107	-1.76	0.097
GIS	mgo_mean	SB2	21	3.15714	20	2.14747	2.61	0.014
GIS	mgo_mean	HB	57	2.662997	57	2.025165	2.35	0.021
GIS	mine_dens	NAT	185	0.011008	186	0.022532	-2.18	0.03
GIS	mine_dens	SB0	17	0.022964	17	0.020332	0.12	0.903
GIS	mine_dens	SB1	12	0.016213	12	0.013609	0.2	0.841
GIS	mine_dens	SB2	21	0.022639	20	0.016787	0.4	0.69
GIS	mine_dens	HB	57	0.013261	57	0.003918	1.76	0.083
GIS	mines	NAT	185	0.216216	186	0.360215	-1.8	0.073
GIS	mines	SB0	17	0.411765	17	0.235294	0.66	0.513
GIS	mines	SB1	12	0.416667	12	0.25	0.57	0.574
GIS	mines	SB2	21	0.238095	20	0.3	-0.35	0.726
GIS	mines	HB	57	0.22807	57	0.087719	1.6	0.113
GIS	minp_ws	NAT	185	2.170646	186	0.981973	5.84	0
GIS	minp_ws	SB0	17	1.453945	17	0.294971	2.45	0.024
GIS	minp_ws	SB1	12	1.049425	12	0.063776	2.46	0.031
GIS	minp_ws	SB2	21	0.730104	20	0.673841	0.15	0.882
GIS	minp_ws	HB	57	0.411607	57	0.184176	1.51	0.136
GIS	n_mean	NAT	185	0.032434	186	0.131145	-7.85	0
GIS	n_mean	SB0	17	0.151678	17	0.413462	-2.94	0.007
GIS	n_mean	SB1	12	0.051009	12	0.219236	-2.62	0.021

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
GIS	n_mean	SB2	21	0.168232	20	0.39966	-3.64	0.001
GIS	n_mean	HB	57	0.310195	57	0.479265	-3.76	0
GIS	nrst_dam	NAT	185	-8538.65	186	-5745.77	-6.24	0
GIS	nrst_dam	SB0	17	-6466.47	17	-5289.08	-0.68	0.501
GIS	nrst_dam	SB1	12	-2496.73	12	-4992.6	1.25	0.225
GIS	nrst_dam	SB2	21	-5232.46	20	-2492.02	-1.83	0.075
GIS	nrst_dam	HB	57	-4205.87	57	-4555.02	0.37	0.71
GIS	p_mean	NAT	185	0.153687	186	0.140764	5.46	0
GIS	p_mean	SB0	17	0.14904	17	0.138661	0.86	0.396
GIS	p_mean	SB1	12	0.152386	12	0.146742	0.55	0.59
GIS	p_mean	SB2	21	0.133381	20	0.13823	-0.64	0.529
GIS	p_mean	HB	57	0.131401	57	0.129901	0.63	0.533
GIS	paved_int_1k	NAT	185	1	186	2	-6.1	0
GIS	paved_int_1k	SB0	17	2	17	2	0.34	0.738
GIS	paved_int_1k	SB1	12	2	12	4	-1.07	0.299
GIS	paved_int_1k	SB2	21	3	20	4	-0.85	0.403
GIS	paved_int_1k	HB	57	4	57	3	0.73	0.464
GIS	paved_int_5k	NAT	185	5	186	25	-9.69	0
GIS	paved_int_5k	SB0	17	36	17	24	1.48	0.151
GIS	paved_int_5k	SB1	12	22	12	30	-0.49	0.63
GIS	paved_int_5k	SB2	21	27	20	32	-0.52	0.608
GIS	paved_int_5k	HB	57	25	57	22	0.8	0.425
GIS	paved_int_ws	NAT	185	29	186	268	-6.98	0
GIS	paved_int_ws	SB0	17	376	17	484	-0.3	0.766
GIS	paved_int_ws	SB1	12	66	12	280	-2.11	0.054
GIS	paved_int_ws	SB2	21	574	20	1438	-1.68	0.105
GIS	paved_int_ws	HB	57	229	57	354	-1.28	0.204
GIS	ppt_00_09	NAT	185	51570.57	186	36617.25	11.38	0
GIS	ppt_00_09	SB0	17	32900.78	17	33939.42	-0.45	0.658
GIS	ppt_00_09	SB1	12	53338.33	12	40068.62	2.85	0.012
GIS	ppt_00_09	SB2	21	36491.67	20	30015.39	3.16	0.003
GIS	ppt_00_09	HB	57	36520.55	57	32621.44	3.21	0.002
GIS	prmh_ave	NAT	185	5.837903	186	4.370698	4.8	0
GIS	prmh_ave	SB0	17	4.610209	17	4.323828	0.38	0.707
GIS	prmh_ave	SB1	12	5.133211	12	3.709346	1.97	0.072
GIS	prmh_ave	SB2	21	4.297298	20	5.462131	-1.9	0.065
GIS	prmh_ave	HB	57	4.127455	57	4.784129	-1.82	0.071
GIS	roaddens_1k	NAT	185	0.96981	186	5.068392	-13.7	0
GIS	roaddens_1k	SB0	17	6.404816	17	5.9648	0.25	0.807
GIS	roaddens_1k	SB1	12	2.794292	12	5.210264	-1.58	0.131
GIS	roaddens_1k	SB2	21	8.951365	20	10.10646	-0.79	0.437
GIS	roaddens_1k	HB	57	11.30954	57	11.66983	-0.4	0.693

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
GIS	roaddens_5k	NAT	185	0.823416	186	5.119205	-15.38	0
GIS	roaddens_5k	SB0	17	5.463279	17	5.835214	-0.26	0.795
GIS	roaddens_5k	SB1	12	1.627579	12	3.466785	-1.62	0.118
GIS	roaddens_5k	SB2	21	6.958305	20	9.922083	-2.34	0.025
GIS	roaddens_5k	HB	57	9.366548	57	11.61349	-2.82	0.006
GIS	roaddens_ws	NAT	185	0.919042	186	4.156533	-12.04	0
GIS	roaddens_ws	SB0	17	4.597369	17	5.095457	-0.4	0.69
GIS	roaddens_ws	SB1	12	1.090949	12	4.01968	-2.85	0.01
GIS	roaddens_ws	SB2	21	4.18309	20	6.714892	-2.3	0.029
GIS	roaddens_ws	HB	57	6.569739	57	8.737304	-2.87	0.005
GIS	s_mean	NAT	185	0.228014	186	0.403027	-4.08	0
GIS	s_mean	SB0	17	0.365128	17	0.366497	-0.01	0.993
GIS	s_mean	SB1	12	0.327002	12	0.548814	-1.24	0.227
GIS	s_mean	SB2	21	0.529211	20	0.353928	1.47	0.15
GIS	s_mean	HB	57	0.370212	57	0.311118	0.9	0.37
GIS	site_elev	NAT	185	821	186	279	11.92	0
GIS	site_elev	SB0	17	201	17	130	1.33	0.192
GIS	site_elev	SB1	12	436	12	134	4.29	0
GIS	site_elev	SB2	21	169	20	74	1.76	0.089
GIS	site_elev	HB	57	180	57	102	3.48	0.001
GIS	sumave_p	NAT	185	1707.852	186	883.4516	7.09	0
GIS	sumave_p	SB0	17	805.4905	17	488.0137	2.26	0.032
GIS	sumave_p	SB1	12	863.9725	12	396.9964	3.63	0.002
GIS	sumave_p	SB2	21	775.2813	20	745.3704	0.15	0.884
GIS	sumave_p	HB	57	592.6981	57	538.8744	1.15	0.253
GIS	temp_00_09	NAT	185	2224.791	186	2354.143	-5.67	0
GIS	temp_00_09	SB0	17	2472.4	17	2396.876	1.16	0.255
GIS	temp_00_09	SB1	12	2356.425	12	2369.833	-0.22	0.827
GIS	temp_00_09	SB2	21	2411.214	20	2372.92	0.76	0.454
GIS	temp_00_09	HB	57	2495.747	57	2395.24	3.48	0.001
GIS	tmax_ws	NAT	185	298.1701	186	307.5618	-3.85	0
GIS	tmax_ws	SB0	17	313.9891	17	300.0433	1.42	0.169
GIS	tmax_ws	SB1	12	307.1508	12	303.1515	0.59	0.566
GIS	tmax_ws	SB2	21	317.776	20	308.191	1.68	0.102
GIS	tmax_ws	HB	57	316.5356	57	303.8349	3.18	0.002
GIS	ucs_mean	NAT	185	129.9896	186	95.67976	9.11	0
GIS	ucs_mean	SB0	17	96.46365	17	52.82427	3.27	0.003
GIS	ucs_mean	SB1	12	122.3346	12	74.90658	2.72	0.013
GIS	ucs_mean	SB2	21	83.72048	20	57.7283	2.58	0.014
GIS	ucs_mean	HB	57	70.83739	57	48.81176	3.24	0.002
GIS	urban_1k_16	NAT	185	0.8	186	25.6	-12.86	0
GIS	urban_1k_16	SB0	17	39.4	17	39.8	-0.03	0.978

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
GIS	urban_1k_16	SB1	12	10.5	12	23.9	-1.54	0.139
GIS	urban_1k_16	SB2	21	49.2	20	72.9	-2.26	0.029
GIS	urban_1k_16	HB	57	69.6	57	83.8	-3.12	0.002
GIS	urban_5k_16	NAT	185	0.6	186	27.3	-13.68	0
GIS	urban_5k_16	SB0	17	30.0	17	36.2	-0.61	0.549
GIS	urban_5k_16	SB1	12	5.8	12	16.3	-1.58	0.129
GIS	urban_5k_16	SB2	21	37.0	20	67.2	-3.22	0.003
GIS	urban_5k_16	HB	57	54.7	57	73.2	-3.57	0.001
GIS	urban_ws_16	NAT	185	0.7	186	20.4	-11.66	0
GIS	urban_ws_16	SB0	17	23.3	17	30.0	-0.79	0.434
GIS	urban_ws_16	SB1	12	4.2	12	19.8	-2.67	0.014
GIS	urban_ws_16	SB2	21	19.5	20	38.9	-2.39	0.024
GIS	urban_ws_16	HB	57	37.8	57	52.0	-2.78	0.006
GIS	xwd_ws	NAT	185	42.20241	186	36.27393	7.45	0
GIS	xwd_ws	SB0	17	36.2601	17	29.19707	4.8	0
GIS	xwd_ws	SB1	12	39.85059	12	30.36694	4.06	0.001
GIS	xwd_ws	SB2	21	34.65563	20	32.49451	1.34	0.19
GIS	xwd_ws	HB	57	33.5796	57	31.64226	2.34	0.021
PHAB	CFC_ALG	NAT	111	6.621622	143	7.804196	-2.06	0.04
PHAB	CFC_ALG	SB0	11	8.090909	14	9.642857	-1.04	0.313
PHAB	CFC_ALG	SB1	7	9	7	10.85714	-1.19	0.279
PHAB	CFC_ALG	SB2	12	8.916667	19	10.26316	-1.3	0.212
PHAB	CFC_ALG	HB	50	9.68	37	8.324324	1.57	0.122
PHAB	CFC_ALL_EMAP	NAT	111	5.756757	143	5.538462	1.02	0.309
PHAB	CFC_ALL_EMAP	SB0	11	5.363636	14	5.285714	0.1	0.919
PHAB	CFC_ALL_EMAP	SB1	7	6	7	5.857143	0.19	0.856
PHAB	CFC_ALL_EMAP	SB2	12	5	19	5.157895	-0.24	0.815
PHAB	CFC_ALL_EMAP	HB	50	2.96	37	2.27027	2.17	0.033
PHAB	CFC_ALL_SWAMP	NAT	111	6.612613	143	6.363636	1.02	0.311
PHAB	CFC_ALL_SWAMP	SB0	11	6.090909	14	5.714286	0.44	0.667
PHAB	CFC_ALL_SWAMP	SB1	7	6.857143	7	6.571429	0.31	0.758
PHAB	CFC_ALL_SWAMP	SB2	12	5.666667	19	5.526316	0.17	0.864
PHAB	CFC_ALL_SWAMP	HB	50	3.06	37	2.297297	2.21	0.03
PHAB	CFC_AQM	NAT	111	6.702703	143	7.699301	-1.76	0.08
PHAB	CFC_AQM	SB0	11	8.545455	14	8.642857	-0.06	0.95
PHAB	CFC_AQM	SB1	7	7.857143	7	9.571429	-0.89	0.389
PHAB	CFC_AQM	SB2	12	7.75	19	8.736842	-0.7	0.491
PHAB	CFC_AQM	HB	50	2.72	37	1.810811	1.11	0.269
PHAB	CFC_BRS	NAT	111	8.810811	143	8.20979	1.3	0.196
PHAB	CFC_BRS	SB0	11	8	14	9.142857	-0.62	0.541
PHAB	CFC_BRS	SB1	7	7.857143	7	10.14286	-1.08	0.315
PHAB	CFC_BRS	SB2	12	6.666667	19	9.578947	-1.93	0.07

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PHAB	CFC_BRS	HB	50	5.46	37	4.891892	0.52	0.603
PHAB	CFC_HUM	NAT	111	0.198198	143	0.440559	-1.9	0.059
PHAB	CFC_HUM	SB0	11	0.909091	14	1	-0.1	0.922
PHAB	CFC_HUM	SB1	7	1	7	3	-1.07	0.322
PHAB	CFC_HUM	SB2	12	1.833333	19	0.052632	1.67	0.123
PHAB	CFC_HUM	HB	50	1.98	37	2.108108	-0.14	0.89
PHAB	CFC_LTR	NAT	111	6.675676	143	7.608392	-1.68	0.095
PHAB	CFC_LTR	SB0	11	7.545455	14	2.857143	2.42	0.025
PHAB	CFC_LTR	SB1	7	9.285714	7	7.857143	0.56	0.587
PHAB	CFC_LTR	SB2	12	5.583333	19	2	2.08	0.052
PHAB	CFC_LTR	HB	50	0.36	37	0.027027	1.78	0.08
PHAB	CFC_LWD	NAT	111	2.261261	143	1.79021	1.29	0.198
PHAB	CFC_LWD	SB0	11	1.181818	14	0.071429	1.53	0.157
PHAB	CFC_LWD	SB1	7	0.571429	7	0.142857	1.08	0.311
PHAB	CFC_LWD	SB2	12	0.583333	19	0.157895	1.37	0.19
PHAB	CFC_LWD	HB	50	0.32	37	0.027027	1.28	0.207
PHAB	CFC_OHV	NAT	111	8.954955	143	8.867133	0.2	0.84
PHAB	CFC_OHV	SB0	11	8.636364	14	8.714286	-0.05	0.958
PHAB	CFC_OHV	SB1	7	9.857143	7	10.57143	-0.93	0.377
PHAB	CFC_OHV	SB2	12	8.083333	19	7.684211	0.23	0.823
PHAB	CFC_OHV	HB	50	2.76	37	0.891892	2.73	0.008
PHAB	CFC_RCK	NAT	111	8.747748	143	4.79021	7.86	0
PHAB	CFC_RCK	SB0	11	3.454545	14	4.714286	-0.65	0.524
PHAB	CFC_RCK	SB1	7	9.428571	7	4.285714	2.36	0.044
PHAB	CFC_RCK	SB2	12	4	19	5.789474	-0.99	0.333
PHAB	CFC_RCK	HB	50	0.22	37	0.081081	0.8	0.425
PHAB	CFC_UCB	NAT	111	3.954955	143	4.20979	-0.49	0.624
PHAB	CFC_UCB	SB0	11	4.727273	14	6.214286	-0.8	0.433
PHAB	CFC_UCB	SB1	7	4	7	7	-1.14	0.277
PHAB	CFC_UCB	SB2	12	3.666667	19	3.210526	0.28	0.785
PHAB	CFC_UCB	HB	50	0.28	37	0.135135	0.66	0.509
PHAB	Ev_AqHab	NAT	111	0.73964	143	0.724126	0.57	0.57
PHAB	Ev_AqHab	SB0	11	0.763636	14	0.643571	1.15	0.265
PHAB	Ev_AqHab	SB1	7	0.835714	7	0.811429	0.46	0.655
PHAB	Ev_AqHab	SB2	12	0.675	19	0.714737	-0.47	0.644
PHAB	Ev_AqHab	HB	50	0.3376	37	0.316216	0.33	0.745
PHAB	Ev_FlowHab	NAT	111	0.616667	143	0.536643	2.41	0.017
PHAB	Ev_FlowHab	SB0	11	0.421818	14	0.356429	0.46	0.647
PHAB	Ev_FlowHab	SB1	7	0.737143	7	0.541429	1.5	0.172
PHAB	Ev_FlowHab	SB2	12	0.5275	19	0.370526	1.35	0.188
PHAB	Ev_FlowHab	HB	50	0.388	37	0.335946	0.71	0.477
PHAB	Ev_SubNat	NAT	111	0.825225	143	0.736224	5.41	0

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	Ev_SubNat	SB0	11	0.680909	14	0.520714	1.57	0.129
PHAB	Ev_SubNat	SB1	7	0.894286	7	0.735714	1.85	0.111
PHAB	Ev_SubNat	SB2	12	0.676667	19	0.694737	-0.25	0.807
PHAB	Ev_SubNat	HB	50	0.3414	37	0.230541	1.29	0.201
PHAB	H_AqHab	NAT	111	1.412072	143	1.357133	0.97	0.333
PHAB	H_AqHab	SB0	11	1.389091	14	1.147143	1.13	0.272
PHAB	H_AqHab	SB1	7	1.484286	7	1.468571	0.09	0.927
PHAB	H_AqHab	SB2	12	1.201667	19	1.184737	0.09	0.928
PHAB	H_AqHab	HB	50	0.4222	37	0.318108	1.33	0.188
PHAB	H_FlowHab	NAT	111	0.778018	143	0.553846	5.11	0
PHAB	H_FlowHab	SB0	11	0.409091	14	0.37	0.27	0.791
PHAB	H_FlowHab	SB1	7	0.954286	7	0.515714	2.81	0.016
PHAB	H_FlowHab	SB2	12	0.559167	19	0.275789	2.4	0.028
PHAB	H_FlowHab	HB	50	0.2824	37	0.232703	0.95	0.343
PHAB	H_SubNat	NAT	111	1.653153	143	1.36	6.88	0
PHAB	H_SubNat	SB0	11	1.238182	14	0.912143	1.51	0.145
PHAB	H_SubNat	SB1	7	1.971429	7	1.342857	4.03	0.006
PHAB	H_SubNat	SB2	12	1.21	19	1.233158	-0.15	0.881
PHAB	H_SubNat	HB	50	0.385	37	0.205405	1.82	0.073
PHAB	PBM_E	NAT	104	10.875	135	24.51852	-3.68	0
PHAB	PBM_E	SB0	11	31.72727	13	12.61538	1.43	0.179
PHAB	PBM_E	SB1	7	11	7	24.85714	-0.77	0.455
PHAB	PBM_E	SB2	11	18.63636	19	6.315789	1.13	0.277
PHAB	PBM_E	HB	50	1.26	37	0.648649	0.55	0.581
PHAB	PBM_S	NAT	104	49.40385	135	31.51111	3.46	0.001
PHAB	PBM_S	SB0	11	15.09091	13	34.92308	-1.33	0.198
PHAB	PBM_S	SB1	7	26.14286	7	18.14286	0.56	0.587
PHAB	PBM_S	SB2	11	36.36364	19	61.42105	-1.49	0.153
PHAB	PBM_S	HB	50	97.28	37	98.08108	-0.28	0.78
PHAB	PBM_V	NAT	104	39.73077	135	44.05185	-0.88	0.38
PHAB	PBM_V	SB0	11	53.18182	13	52.30769	0.05	0.958
PHAB	PBM_V	SB1	7	62.85714	7	57.14286	0.34	0.743
PHAB	PBM_V	SB2	11	45.09091	19	32.31579	0.84	0.412
PHAB	PBM_V	HB	50	1.46	37	1.297297	0.09	0.929
PHAB	PCT_BDRK	NAT	111	5.900901	143	2.167832	2.68	0.008
PHAB	PCT_BDRK	SB0	11	0	14	0	NA	NA
PHAB	PCT_BDRK	SB1	7	4.285714	7	0	2.48	0.048
PHAB	PCT_BDRK	SB2	12	0.083333	19	0.105263	-0.2	0.844
PHAB	PCT_BDRK	HB	50	0.02	37	0	1	0.322
PHAB	PCT_BIGR	NAT	111	52	143	32.26573	6.41	0
PHAB	PCT_BIGR	SB0	11	17.36364	14	13.85714	0.52	0.61
PHAB	PCT_BIGR	SB1	7	51.85714	7	19.14286	5.68	0

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	PCT_BIGR	SB2	12	23.33333	19	21.10526	0.25	0.805
PHAB	PCT_BIGR	HB	50	2.64	37	1.432432	0.7	0.486
PHAB	PCT_CB	NAT	111	16.46847	143	9.699301	5.03	0
PHAB	PCT_CB	SB0	11	3.636364	14	4.928571	-0.55	0.585
PHAB	PCT_CB	SB1	7	15.57143	7	3.285714	4.02	0.004
PHAB	PCT_CB	SB2	12	8.416667	19	5.421053	0.75	0.464
PHAB	PCT_CB	HB	50	0.72	37	0.054054	2.01	0.05
PHAB	PCT_CF	NAT	106	3.358491	135	0.681481	2.96	0.004
PHAB	PCT_CF	SB0	11	0	13	0.230769	-1	0.337
PHAB	PCT_CF	SB1	7	3	7	0	2.07	0.084
PHAB	PCT_CF	SB2	11	0.272727	19	0	1.4	0.192
PHAB	PCT_CF	HB	50	0.1	37	0	1	0.322
PHAB	PCT_CF_WT	NAT	106	3.235849	135	0.666667	2.95	0.004
PHAB	PCT_CF_WT	SB0	11	0	13	0.230769	-1	0.337
PHAB	PCT_CF_WT	SB1	7	3	7	0	2.07	0.084
PHAB	PCT_CF_WT	SB2	11	0.272727	19	0	1.4	0.192
PHAB	PCT_CF_WT	HB	50	0.1	37	0	1	0.322
PHAB	PCT_CPOM	NAT	106	39.08491	135	44.56296	-1.78	0.076
PHAB	PCT_CPOM	SB0	11	31.45455	13	30	0.15	0.883
PHAB	PCT_CPOM	SB1	7	44.14286	7	29.28571	1.17	0.268
PHAB	PCT_CPOM	SB2	11	43.63636	19	22.94737	2.17	0.043
PHAB	PCT_CPOM	HB	50	14.44	37	15.27027	-0.23	0.822
PHAB	PCT_DR	NAT	106	1.262055	135	1.215391	0.08	0.936
PHAB	PCT_DR	SB0	11	0.136364	13	0.230769	-0.35	0.729
PHAB	PCT_DR	SB1	7	1.814286	7	0	1.46	0.193
PHAB	PCT_DR	SB2	11	0.363636	19	0.631579	-0.57	0.575
PHAB	PCT_DR	HB	50	0.57	37	0.162162	1.02	0.313
PHAB	PCT_FAST	NAT	106	53.60377	135	26.07407	7.74	0
PHAB	PCT_FAST	SB0	11	13.36364	13	7.153846	1.07	0.296
PHAB	PCT_FAST	SB1	7	48.85714	7	4.142857	5.08	0.002
PHAB	PCT_FAST	SB2	11	40.18182	19	12.15789	2.27	0.04
PHAB	PCT_FAST	HB	50	50.7	37	24.27027	3.26	0.002
PHAB	PCT_FAST_WT	NAT	106	52.66038	135	25.54815	7.71	0
PHAB	PCT_FAST_WT	SB0	11	13	13	7	1.06	0.302
PHAB	PCT_FAST_WT	SB1	7	47.71429	7	4.142857	4.94	0.002
PHAB	PCT_FAST_WT	SB2	11	40	19	11.84211	2.29	0.039
PHAB	PCT_FAST_WT	HB	50	50.46	37	23.78378	3.33	0.001
PHAB	PCT_FN	NAT	111	5.918919	143	11.13287	-3.26	0.001
PHAB	PCT_FN	SB0	11	9.909091	14	50	-3.73	0.001
PHAB	PCT_FN	SB1	7	7.857143	7	6.714286	0.26	0.803
PHAB	PCT_FN	SB2	12	12.16667	19	11.94737	0.04	0.969
PHAB	PCT_FN	HB	50	4.3	37	2.783784	0.72	0.476

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	PCT_GC	NAT	111	14.74775	143	13.62937	0.73	0.466
PHAB	PCT_GC	SB0	11	12.18182	14	6.142857	1.36	0.193
PHAB	PCT_GC	SB1	7	11.71429	7	12.85714	-0.25	0.805
PHAB	PCT_GC	SB2	12	10.16667	19	12.68421	-0.49	0.626
PHAB	PCT_GC	HB	50	1.64	37	1.378378	0.17	0.862
PHAB	PCT_GF	NAT	111	11.13514	143	7.377622	3.34	0.001
PHAB	PCT_GF	SB0	11	11.63636	14	6.357143	1.56	0.136
PHAB	PCT_GF	SB1	7	8.142857	7	13.14286	-1.03	0.33
PHAB	PCT_GF	SB2	12	7.333333	19	10.68421	-0.82	0.425
PHAB	PCT_GF	HB	50	1.24	37	0.864865	0.6	0.55
PHAB	PCT_GL	NAT	106	39.48113	135	58.87407	-5.32	0
PHAB	PCT_GL	SB0	11	80.81818	13	80	0.09	0.925
PHAB	PCT_GL	SB1	7	32.14286	7	58.42857	-1.67	0.125
PHAB	PCT_GL	SB2	11	48	19	84.68421	-3.28	0.005
PHAB	PCT_GL	HB	50	48.6	37	73.08108	-2.98	0.004
PHAB	PCT_GL_WT	NAT	106	38.92453	135	58.0963	-5.27	0
PHAB	PCT_GL_WT	SB0	11	80.18182	13	79	0.13	0.895
PHAB	PCT_GL_WT	SB1	7	30.42857	7	58.42857	-1.84	0.096
PHAB	PCT_GL_WT	SB2	11	47.81818	19	84.10526	-3.23	0.006
PHAB	PCT_GL_WT	HB	50	47.9	37	72.78378	-3.05	0.003
PHAB	PCT_HP	NAT	111	0.099099	143	2.083916	-3.79	0
PHAB	PCT_HP	SB0	11	2.272727	14	0.357143	1.43	0.18
PHAB	PCT_HP	SB1	7	2.142857	7	0	1.08	0.321
PHAB	PCT_HP	SB2	12	0.583333	19	0.684211	-0.2	0.845
PHAB	PCT_HP	HB	50	0	37	0	NA	NA
PHAB	PCT_MAA	NAT	86	13.36047	120	25.46667	-4.28	0
PHAB	PCT_MAA	SB0	10	17	13	24.38462	-0.85	0.405
PHAB	PCT_MAA	SB1	6	18.66667	6	16.16667	0.27	0.791
PHAB	PCT_MAA	SB2	9	30.44444	18	26.22222	0.51	0.616
PHAB	PCT_MAA	HB	45	46.91111	31	33.12903	1.96	0.055
PHAB	PCT_MAP	NAT	86	15.0814	120	29.825	-4.77	0
PHAB	PCT_MAP	SB0	10	21.5	13	34.84615	-1.34	0.195
PHAB	PCT_MAP	SB1	6	19.83333	6	19.16667	0.07	0.948
PHAB	PCT_MAP	SB2	9	39.66667	18	37.66667	0.24	0.814
PHAB	PCT_MAP	HB	45	50.51111	31	41.19355	1.29	0.203
PHAB	PCT_MAU	NAT	86	2.116279	120	6.05	-3.24	0.001
PHAB	PCT_MAU	SB0	10	5.4	13	11.15385	-0.92	0.37
PHAB	PCT_MAU	SB1	6	1.5	6	4.166667	-0.78	0.461
PHAB	PCT_MAU	SB2	9	9.888889	18	14.94444	-0.83	0.419
PHAB	PCT_MAU	HB	45	5.377778	31	9.451613	-1.13	0.263
PHAB	PCT_MCP	NAT	86	12.03488	120	16.48333	-1.93	0.055
PHAB	PCT_MCP	SB0	10	17.9	13	19.53846	-0.18	0.857

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	PCT_MCP	SB1	6	7	6	20.33333	-1.08	0.32
PHAB	PCT_MCP	SB2	9	25.33333	18	16.33333	0.93	0.37
PHAB	PCT_MCP	HB	45	3.466667	31	0.548387	1.71	0.094
PHAB	PCT_MIAT1	NAT	86	3.895349	120	4.325	-0.34	0.733
PHAB	PCT_MIAT1	SB0	10	2.9	13	0.615385	1.17	0.268
PHAB	PCT_MIAT1	SB1	6	0.333333	6	0.5	-0.31	0.768
PHAB	PCT_MIAT1	SB2	9	1	18	0.166667	0.94	0.376
PHAB	PCT_MIAT1	HB	45	5.4	31	7.903226	-0.69	0.492
PHAB	PCT_MIAT1P	NAT	86	6.05814	120	6.116667	-0.03	0.975
PHAB	PCT_MIAT1P	SB0	10	8.2	13	1.538462	1.07	0.31
PHAB	PCT_MIAT1P	SB1	6	2.5	6	7.166667	-0.64	0.55
PHAB	PCT_MIAT1P	SB2	9	1.222222	18	0.833333	0.32	0.751
PHAB	PCT_MIAT1P	HB	45	9.8	31	8.83871	0.21	0.832
PHAB	PCT_MIATP	NAT	86	45.66279	120	50.84167	-1.02	0.311
PHAB	PCT_MIATP	SB0	10	15.7	13	17.69231	-0.21	0.837
PHAB	PCT_MIATP	SB1	6	5.666667	6	2.166667	1.15	0.289
PHAB	PCT_MIATP	SB2	9	32	18	20.94444	0.72	0.485
PHAB	PCT_MIATP	HB	45	42.02222	31	57.90323	-1.99	0.051
PHAB	PCT_NSA	NAT	86	16.73256	120	33.44167	-5.46	0
PHAB	PCT_NSA	SB0	10	23.2	13	35.07692	-1.18	0.252
PHAB	PCT_NSA	SB1	6	20.16667	6	19.66667	0.05	0.96
PHAB	PCT_NSA	SB2	9	40.22222	18	37.77778	0.29	0.778
PHAB	PCT_NSA	HB	45	53.04444	31	46.87097	0.98	0.329
PHAB	PCT_OT	NAT	111	3.954955	143	8.818182	-4.19	0
PHAB	PCT_OT	SB0	11	9.545455	14	2.785714	1.84	0.089
PHAB	PCT_OT	SB1	7	12.57143	7	9.714286	0.46	0.653
PHAB	PCT_OT	SB2	12	6.916667	19	6	0.19	0.853
PHAB	PCT_OT	HB	50	0.42	37	1.216216	-0.66	0.513
PHAB	PCT_POOL	NAT	106	5.59434	135	13.77778	-3.99	0
PHAB	PCT_POOL	SB0	11	5.181818	13	11	-0.98	0.338
PHAB	PCT_POOL	SB1	7	17.42857	7	37.42857	-1.27	0.231
PHAB	PCT_POOL	SB2	11	11.27273	19	2.210526	1.44	0.177
PHAB	PCT_POOL	HB	50	0.14	37	2.486486	-0.94	0.352
PHAB	PCT_POOL_WT	NAT	106	5.490566	135	13.6	-4.02	0
PHAB	PCT_POOL_WT	SB0	11	5.090909	13	10.69231	-0.95	0.352
PHAB	PCT_POOL_WT	SB1	7	17.28571	7	37.42857	-1.28	0.229
PHAB	PCT_POOL_WT	SB2	11	11.27273	19	2.210526	1.44	0.177
PHAB	PCT_POOL_WT	HB	50	0.14	37	2.486486	-0.94	0.352
PHAB	PCT_RA	NAT	106	1.292453	135	0.525926	1.28	0.202
PHAB	PCT_RA	SB0	11	0	13	0	NA	NA
PHAB	PCT_RA	SB1	7	0.142857	7	0	1	0.356
PHAB	PCT_RA	SB2	11	0	19	0	NA	NA

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	PCT_RA	HB	50	0	37	0	NA	NA
PHAB	PCT_RA_WT	NAT	106	1.264151	135	0.496296	1.33	0.185
PHAB	PCT_RA_WT	SB0	11	0	13	0	NA	NA
PHAB	PCT_RA_WT	SB1	7	0.142857	7	0	1	0.356
PHAB	PCT_RA_WT	SB2	11	0	19	0	NA	NA
PHAB	PCT_RA_WT	HB	50	0	37	0	NA	NA
PHAB	PCT_RC	NAT	111	0.027027	143	1.503497	-2.02	0.046
PHAB	PCT_RC	SB0	11	0.272727	14	1.285714	-1.51	0.15
PHAB	PCT_RC	SB1	7	0.857143	7	2.714286	-1.34	0.22
PHAB	PCT_RC	SB2	12	4.833333	19	6.631579	-0.38	0.707
PHAB	PCT_RC	HB	50	86.92	37	89.18919	-0.48	0.635
PHAB	PCT_RI	NAT	106	45.46226	135	21.62222	7.2	0
PHAB	PCT_RI	SB0	11	13.36364	13	6.307692	1.24	0.232
PHAB	PCT_RI	SB1	7	40.57143	7	3.285714	5.11	0.002
PHAB	PCT_RI	SB2	11	35.81818	19	12.15789	2.05	0.059
PHAB	PCT_RI	HB	50	46.6	37	22.91892	2.92	0.004
PHAB	PCT_RI_WT	NAT	106	44.68868	135	21.15556	7.19	0
PHAB	PCT_RI_WT	SB0	11	13	13	6.230769	1.21	0.242
PHAB	PCT_RI_WT	SB1	7	39.42857	7	3.285714	5.07	0.002
PHAB	PCT_RI_WT	SB2	11	35.63636	19	11.84211	2.07	0.057
PHAB	PCT_RI_WT	HB	50	46.36	37	22.43243	2.99	0.004
PHAB	PCT_RN	NAT	106	3.490566	135	3.244444	0.17	0.864
PHAB	PCT_RN	SB0	11	0	13	0.615385	-1.48	0.165
PHAB	PCT_RN	SB1	7	5.142857	7	0.857143	1.11	0.304
PHAB	PCT_RN	SB2	11	4.090909	19	0	1.6	0.141
PHAB	PCT_RN	HB	50	4	37	1.351351	0.88	0.382
PHAB	PCT_RN_WT	NAT	106	3.471698	135	3.22963	0.17	0.866
PHAB	PCT_RN_WT	SB0	11	0	13	0.538462	-1.46	0.17
PHAB	PCT_RN_WT	SB1	7	5.142857	7	0.857143	1.11	0.304
PHAB	PCT_RN_WT	SB2	11	4.090909	19	0	1.6	0.141
PHAB	PCT_RN_WT	HB	50	4	37	1.351351	0.88	0.382
PHAB	PCT_RR	NAT	111	1.567568	143	1.398601	0.26	0.792
PHAB	PCT_RR	SB0	11	0	14	0	NA	NA
PHAB	PCT_RR	SB1	7	4.285714	7	0	2.48	0.048
PHAB	PCT_RR	SB2	12	0	19	0.052632	-1	0.331
PHAB	PCT_RR	HB	50	0	37	0	NA	NA
PHAB	PCT_RS	NAT	111	4.342342	143	0.769231	2.85	0.005
PHAB	PCT_RS	SB0	11	0	14	0	NA	NA
PHAB	PCT_RS	SB1	7	0	7	0	NA	NA
PHAB	PCT_RS	SB2	12	0.083333	19	0.052632	0.31	0.759
PHAB	PCT_RS	HB	50	0.02	37	0	1	0.322
PHAB	PCT_SA	NAT	111	24.7027	143	34.30769	-3.78	0

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	PCT_SA	SB0	11	46	14	25.78571	1.73	0.097
PHAB	PCT_SA	SB1	7	12.85714	7	44.85714	-3.71	0.007
PHAB	PCT_SA	SB2	12	41.66667	19	41.89474	-0.03	0.978
PHAB	PCT_SA	HB	50	4.32	37	4.540541	-0.09	0.926
PHAB	PCT_SAFN	NAT	111	30.57658	143	45.38462	-5.2	0
PHAB	PCT_SAFN	SB0	11	55.90909	14	75.57143	-2	0.059
PHAB	PCT_SAFN	SB1	7	20.57143	7	51.57143	-3.75	0.004
PHAB	PCT_SAFN	SB2	12	53.91667	19	53.84211	0.01	0.994
PHAB	PCT_SAFN	HB	50	8.66	37	7.324324	0.39	0.701
PHAB	PCT_SB	NAT	111	11.7027	143	5.440559	5.89	0
PHAB	PCT_SB	SB0	11	1.636364	14	2.571429	-0.5	0.623
PHAB	PCT_SB	SB1	7	15.57143	7	2.571429	3.72	0.008
PHAB	PCT_SB	SB2	12	4.75	19	3.052632	0.62	0.544
PHAB	PCT_SB	HB	50	0.18	37	0	1.46	0.151
PHAB	PCT_SFGF	NAT	111	41.63063	143	52.6993	-3.77	0
PHAB	PCT_SFGF	SB0	11	67.45455	14	81.71429	-1.6	0.125
PHAB	PCT_SFGF	SB1	7	28.85714	7	64.85714	-5.17	0.001
PHAB	PCT_SFGF	SB2	12	61.16667	19	64.42105	-0.34	0.74
PHAB	PCT_SFGF	HB	50	9.9	37	8.162162	0.47	0.637
PHAB	PCT_SLOW	NAT	106	45.07547	135	72.65185	-7.67	0
PHAB	PCT_SLOW	SB0	11	86	13	91	-0.83	0.419
PHAB	PCT_SLOW	SB1	7	49.57143	7	95.85714	-5.06	0.002
PHAB	PCT_SLOW	SB2	11	59.27273	19	86.89474	-2.23	0.043
PHAB	PCT_SLOW	HB	50	48.74	37	75.56757	-3.34	0.001
PHAB	PCT_SLOW_WT	NAT	106	44.41509	135	71.6963	-7.6	0
PHAB	PCT_SLOW_WT	SB0	11	85.27273	13	89.69231	-0.69	0.498
PHAB	PCT_SLOW_WT	SB1	7	47.71429	7	95.85714	-5.67	0.001
PHAB	PCT_SLOW_WT	SB2	11	59.09091	19	86.31579	-2.19	0.046
PHAB	PCT_SLOW_WT	HB	50	48.04	37	75.27027	-3.4	0.001
PHAB	PCT_WD	NAT	111	2.243243	143	2.727273	-0.88	0.377
PHAB	PCT_WD	SB0	11	3.090909	14	0.142857	1.32	0.217
PHAB	PCT_WD	SB1	7	3.571429	7	3.714286	-0.04	0.966
PHAB	PCT_WD	SB2	12	3	19	1.052632	1.03	0.321
PHAB	PCT_WD	HB	50	0.14	37	0	2	0.051
PHAB	PCT_XB	NAT	111	3.387387	143	1.405594	3.57	0
PHAB	PCT_XB	SB0	11	0	14	0.142857	-1.47	0.165
PHAB	PCT_XB	SB1	7	5.142857	7	0.571429	4.01	0.005
PHAB	PCT_XB	SB2	12	0.166667	19	0.105263	0.31	0.759
PHAB	PCT_XB	HB	50	0.1	37	0	1	0.322
PHAB	SB_PP_D10	NAT	111	2.54955	143	1.825315	0.88	0.381
PHAB	SB_PP_D10	SB0	11	0.757273	14	0.244286	2.83	0.01
PHAB	SB_PP_D10	SB1	7	0.458571	7	0.744286	-1.04	0.317

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	SB_PP_D10	SB2	12	0.446667	19	0.608947	-0.86	0.399
PHAB	SB_PP_D10	HB	50	1811.76	37	3062.011	-2.08	0.041
PHAB	SB_PP_D25	NAT	111	7.842973	143	4.814545	2	0.046
PHAB	SB_PP_D25	SB0	11	0.848182	14	0.387143	2.56	0.018
PHAB	SB_PP_D25	SB1	7	6.441429	7	0.887143	2.87	0.028
PHAB	SB_PP_D25	SB2	12	4.525	19	1.344211	0.97	0.354
PHAB	SB_PP_D25	HB	50	1812.779	37	3062.092	-2.07	0.041
PHAB	SB_PP_D50	NAT	111	54.82631	143	27.43	2.72	0.007
PHAB	SB_PP_D50	SB0	11	6.564545	14	4.595	0.43	0.67
PHAB	SB_PP_D50	SB1	7	78.29	7	3.307143	2.58	0.042
PHAB	SB_PP_D50	SB2	12	25.2725	19	6.645789	1.22	0.247
PHAB	SB_PP_D50	HB	50	1815.956	37	3063.339	-2.07	0.042
PHAB	SB_PP_D75	NAT	111	223.425	143	98.92573	3.97	0
PHAB	SB_PP_D75	SB0	11	16.28091	14	20.95214	-0.3	0.769
PHAB	SB_PP_D75	SB1	7	283.5714	7	15.15143	3.68	0.01
PHAB	SB_PP_D75	SB2	12	47.84333	19	19.27579	1.1	0.292
PHAB	SB_PP_D75	HB	50	1828.655	37	3068.253	-2.06	0.042
PHAB	SB_PP_D90	NAT	111	564.8386	143	310.916	3.19	0.002
PHAB	SB_PP_D90	SB0	11	69.46	14	75.01286	-0.1	0.919
PHAB	SB_PP_D90	SB1	7	639.2857	7	130.8614	4.01	0.002
PHAB	SB_PP_D90	SB2	12	134.9217	19	69.48474	1.05	0.311
PHAB	SB_PP_D90	HB	50	1872.032	37	3068.442	-2	0.05
PHAB	SB_PT_D10	NAT	111	3.756486	143	41.49622	-0.95	0.342
PHAB	SB_PT_D10	SB0	11	0.757273	14	0.244286	2.83	0.01
PHAB	SB_PT_D10	SB1	7	0.458571	7	0.887143	-1.73	0.112
PHAB	SB_PT_D10	SB2	12	0.613333	19	0.608947	0.02	0.982
PHAB	SB_PT_D10	HB	50	3962.707	37	4436.572	-0.88	0.38
PHAB	SB_PT_D25	NAT	111	62.98126	143	84.82049	-0.29	0.773
PHAB	SB_PT_D25	SB0	11	0.848182	14	0.387143	2.56	0.018
PHAB	SB_PT_D25	SB1	7	8.865714	7	0.887143	3.12	0.02
PHAB	SB_PT_D25	SB2	12	4.525	19	1.816316	0.82	0.431
PHAB	SB_PT_D25	HB	50	4871.043	37	4742.301	0.29	0.774
PHAB	SB_PT_D50	NAT	111	177.8659	143	198.7179	-0.2	0.844
PHAB	SB_PT_D50	SB0	11	6.61	14	8.737857	-0.27	0.787
PHAB	SB_PT_D50	SB1	7	103.7143	7	3.307143	2.73	0.034
PHAB	SB_PT_D50	SB2	12	31.52	19	304.4089	-0.92	0.372
PHAB	SB_PT_D50	HB	50	5207.542	37	5355.163	-0.48	0.63
PHAB	SB_PT_D75	NAT	111	690.1728	143	600.4769	0.48	0.632
PHAB	SB_PT_D75	SB0	11	48.28091	14	52.23571	-0.07	0.942
PHAB	SB_PT_D75	SB1	7	442.8571	7	20.86571	3.71	0.01
PHAB	SB_PT_D75	SB2	12	528.5908	19	616.0637	-0.14	0.889
PHAB	SB_PT_D75	HB	50	5322.801	37	5355.163	-0.11	0.91

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	SB_PT_D90	NAT	111	1517.289	143	1282.817	0.88	0.378
PHAB	SB_PT_D90	SB0	11	581.3691	14	92.72714	0.96	0.361
PHAB	SB_PT_D90	SB1	7	3488.571	7	303.29	3.07	0.021
PHAB	SB_PT_D90	SB2	12	1509.255	19	983.6921	0.61	0.551
PHAB	SB_PT_D90	HB	50	5547.7	37	5660	-1	0.322
PHAB	SLOPE_0	NAT	95	4.894737	130	16.68828	-3.94	0
PHAB	SLOPE_0	SB0	10	13.53846	12	25	-1.18	0.252
PHAB	SLOPE_0	SB1	5	14.22222	6	26.66667	-0.63	0.543
PHAB	SLOPE_0	SB2	10	14	19	25.78947	-1.16	0.265
PHAB	SLOPE_0	HB	48	3.333333	36	3.888889	-0.25	0.807
PHAB	SLOPE_0_5	NAT	95	10.15789	130	46.77863	-9.21	0
PHAB	SLOPE_0_5	SB0	10	55.23077	12	70	-1.05	0.309
PHAB	SLOPE_0_5	SB1	5	20.44444	6	41.66667	-0.89	0.394
PHAB	SLOPE_0_5	SB2	10	49	19	81.57895	-2.33	0.041
PHAB	SLOPE_0_5	HB	48	29.58333	36	51.45062	-2.41	0.019
PHAB	SLOPE_1	NAT	95	22.68456	130	65.94423	-10.4	0
PHAB	SLOPE_1	SB0	10	82.69231	12	89.16667	-0.96	0.348
PHAB	SLOPE_1	SB1	5	32.44444	6	48.33333	-0.67	0.518
PHAB	SLOPE_1	SB2	10	64	19	94.73684	-2.6	0.027
PHAB	SLOPE_1	HB	48	63.81944	36	81.91358	-2.3	0.024
PHAB	SLOPE_2	NAT	95	41.84316	130	80.74247	-9.01	0
PHAB	SLOPE_2	SB0	10	98	12	96.66667	0.41	0.686
PHAB	SLOPE_2	SB1	5	48.66667	6	60	-0.47	0.652
PHAB	SLOPE_2	SB2	10	80	19	96.84211	-1.48	0.17
PHAB	SLOPE_2	HB	48	91.01852	36	93.61111	-0.53	0.597
PHAB	W1H_BLDG	NAT	111	0.013423	143	0.051958	-2.85	0.005
PHAB	W1H_BLDG	SB0	11	0.069091	14	0.156429	-1.09	0.287
PHAB	W1H_BLDG	SB1	7	0.014286	7	0.241429	-3.23	0.017
PHAB	W1H_BLDG	SB2	12	0.1625	19	0.193158	-0.34	0.738
PHAB	W1H_BLDG	HB	49	0.300408	37	0.334054	-0.53	0.597
PHAB	W1H_BRDG	NAT	106	0.009245	134	0.013806	-0.73	0.463
PHAB	W1H_BRDG	SB0	11	0.025455	13	0.020769	0.17	0.863
PHAB	W1H_BRDG	SB1	7	0.02	7	0	1	0.356
PHAB	W1H_BRDG	SB2	11	0	19	0.022105	-1	0.331
PHAB	W1H_BRDG	HB	50	0.0416	36	0.018056	1.01	0.314
PHAB	W1H_CROP	NAT	111	0	143	0.005315	-1.62	0.108
PHAB	W1H_CROP	SB0	11	0.08	14	0.236429	-1.37	0.186
PHAB	W1H_CROP	SB1	7	0.047143	7	0	1	0.356
PHAB	W1H_CROP	SB2	12	0	19	0	NA	NA
PHAB	W1H_CROP	HB	50	0.0054	37	0.045676	-1.48	0.146
PHAB	W1H_LDFL	NAT	111	0.226396	143	0.574126	-6.11	0
PHAB	W1H_LDFL	SB0	11	0.694545	14	1.073571	-2	0.058

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	W1H_LDFL	SB1	7	0.562857	7	0.672857	-0.31	0.765
PHAB	W1H_LDFL	SB2	12	0.866667	19	1.262632	-2.29	0.033
PHAB	W1H_LDFL	HB	50	0.9192	37	1.188108	-2.64	0.01
PHAB	W1H_LOG	NAT	111	0.003243	143	4.90E-04	0.91	0.364
PHAB	W1H_LOG	SB0	11	0	14	0	NA	NA
PHAB	W1H_LOG	SB1	7	0	7	0	NA	NA
PHAB	W1H_LOG	SB2	12	0	19	0	NA	NA
PHAB	W1H_LOG	HB	50	0	37	0	NA	NA
PHAB	W1H_MINE	NAT	111	0	143	0.004476	-1.55	0.123
PHAB	W1H_MINE	SB0	11	0	14	0	NA	NA
PHAB	W1H_MINE	SB1	7	0	7	0	NA	NA
PHAB	W1H_MINE	SB2	12	0	19	0	NA	NA
PHAB	W1H_MINE	HB	50	0	37	0	NA	NA
PHAB	W1H_ORVY	NAT	106	0.001132	134	0.004552	-0.73	0.467
PHAB	W1H_ORVY	SB0	11	0.008182	13	0.075385	-0.89	0.392
PHAB	W1H_ORVY	SB1	7	0	7	0	NA	NA
PHAB	W1H_ORVY	SB2	11	0.006364	19	0	1	0.341
PHAB	W1H_ORVY	HB	50	0.0066	36	0	1	0.322
PHAB	W1H_PARK	NAT	111	0.004595	143	0.049441	-2.86	0.005
PHAB	W1H_PARK	SB0	11	0.067273	14	0.110714	-0.35	0.727
PHAB	W1H_PARK	SB1	7	0	7	0.1	-1.05	0.333
PHAB	W1H_PARK	SB2	12	0.036667	19	0.115789	-1.2	0.241
PHAB	W1H_PARK	HB	50	0.2178	37	0.081892	2.25	0.027
PHAB	W1H_PIPE	NAT	111	0.012883	143	0.017692	-0.41	0.683
PHAB	W1H_PIPE	SB0	11	0.031818	14	0.050714	-0.73	0.472
PHAB	W1H_PIPE	SB1	7	0	7	0.02	-1	0.356
PHAB	W1H_PIPE	SB2	12	0.0275	19	0.211053	-1.99	0.061
PHAB	W1H_PIPE	HB	50	0.2452	37	0.364865	-1.11	0.27
PHAB	W1H_PSTR	NAT	111	0.03982	143	0.021608	0.79	0.432
PHAB	W1H_PSTR	SB0	11	0.002727	14	0.012857	-0.77	0.454
PHAB	W1H_PSTR	SB1	7	0	7	0	NA	NA
PHAB	W1H_PSTR	SB2	12	0	19	0	NA	NA
PHAB	W1H_PSTR	HB	50	0.0122	37	0	1	0.322
PHAB	W1H_PVMT	NAT	111	0.021081	143	0.053497	-2.22	0.027
PHAB	W1H_PVMT	SB0	11	0.066364	14	0.279286	-1.72	0.1
PHAB	W1H_PVMT	SB1	7	0.164286	7	0.08	0.82	0.43
PHAB	W1H_PVMT	SB2	12	0.178333	19	0.498947	-2.62	0.014
PHAB	W1H_PVMT	HB	50	0.2838	37	0.468919	-1.99	0.051
PHAB	W1H_ROAD	NAT	111	0.079009	143	0.123007	-1.76	0.08
PHAB	W1H_ROAD	SB0	11	0.126364	14	0.2	-0.77	0.452
PHAB	W1H_ROAD	SB1	7	0.111429	7	0.132857	-0.24	0.811
PHAB	W1H_ROAD	SB2	12	0.191667	19	0.142105	0.59	0.559

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	W1H_ROAD	HB	50	0.2588	37	0.218108	0.57	0.57
PHAB	W1H_VEGM	NAT	106	0.007736	134	0.046716	-2.32	0.021
PHAB	W1H_VEGM	SB0	11	0.03	13	0.11	-0.7	0.495
PHAB	W1H_VEGM	SB1	7	0	7	0	NA	NA
PHAB	W1H_VEGM	SB2	11	0.081818	19	0.078947	0.03	0.98
PHAB	W1H_VEGM	HB	50	0.076	36	0.027778	1.12	0.265
PHAB	W1H_WALL	NAT	111	0.016757	143	0.086084	-3.05	0.003
PHAB	W1H_WALL	SB0	11	0.296364	14	0.307857	-0.06	0.954
PHAB	W1H_WALL	SB1	7	0.368571	7	0.501429	-0.63	0.542
PHAB	W1H_WALL	SB2	12	0.7675	19	1.108947	-1.86	0.078
PHAB	W1H_WALL	HB	49	1.299592	37	1.010541	2.21	0.031
PHAB	W1_HALL_EMAP	NAT	111	0.417207	143	0.987692	-5.86	0
PHAB	W1_HALL_EMAP	SB0	11	1.434545	14	2.427857	-2.38	0.026
PHAB	W1_HALL_EMAP	SB1	7	1.268571	7	1.748571	-0.9	0.386
PHAB	W1_HALL_EMAP	SB2	12	2.230833	19	3.532632	-3.23	0.003
PHAB	W1_HALL_EMAP	HB	49	3.525306	37	3.712162	-0.69	0.494
PHAB	W1_HALL_SWAMP	NAT	106	0.403396	134	1.03694	-5.85	0
PHAB	W1_HALL_SWAMP	SB0	11	1.498182	13	2.77	-3.34	0.003
PHAB	W1_HALL_SWAMP	SB1	7	1.288571	7	1.748571	-0.87	0.404
PHAB	W1_HALL_SWAMP	SB2	11	2.232727	19	3.633684	-3.22	0.003
PHAB	W1_HALL_SWAMP	HB	49	3.652041	36	3.721111	-0.25	0.805
PHAB	XBEARING	NAT	95	198.7626	130	195.7345	0.31	0.756
PHAB	XBEARING	SB0	10	210.72	12	194.1917	0.46	0.657
PHAB	XBEARING	SB1	5	132.58	6	196.8333	-1.43	0.196
PHAB	XBEARING	SB2	10	227.43	19	201.2895	0.94	0.359
PHAB	XBEARING	HB	48	181.8896	36	158.525	1.33	0.187
PHAB	XBKF_H	NAT	103	0.820388	135	0.940741	-0.39	0.699
PHAB	XBKF_H	SB0	11	0.390909	13	0.630769	-2.4	0.027
PHAB	XBKF_H	SB1	7	0.571429	7	0.585714	-0.12	0.909
PHAB	XBKF_H	SB2	11	0.509091	19	0.542105	-0.23	0.82
PHAB	XBKF_H	HB	50	0.866	37	0.513514	1.44	0.157
PHAB	XBKF_W	NAT	103	7.876699	135	12.97185	-4.28	0
PHAB	XBKF_W	SB0	11	10.45455	13	7.592308	1.03	0.316
PHAB	XBKF_W	SB1	7	11.87143	7	12.74286	-0.24	0.812
PHAB	XBKF_W	SB2	11	19.87273	19	16.83158	0.51	0.614
PHAB	XBKF_W	HB	50	15.306	37	17.74865	-0.59	0.557
PHAB	XC	NAT	106	34.76415	134	26.79851	2.8	0.006
PHAB	XC	SB0	11	25.81818	13	4.153846	4.14	0.001
PHAB	XC	SB1	7	34.42857	7	23	0.91	0.381
PHAB	XC	SB2	11	18.45455	19	7.263158	1.54	0.139
PHAB	XC	HB	50	2.62	37	0.675676	2.76	0.008
PHAB	XCDENBK	NAT	4	31	4	46	NA	NA

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	XCDENBK	SB0	0	NA	1	0	NA	NA
PHAB	XCDENBK	SB2	2	64.5	1	0	NA	NA
PHAB	XCDENBK	HB	1	98	4	43.5	NA	NA
PHAB	XCDENMID	NAT	111	71.87387	143	56.84615	4.17	0
PHAB	XCDENMID	SB0	11	56.18182	14	23.07143	2.95	0.008
PHAB	XCDENMID	SB1	7	75.85714	7	35.28571	2.22	0.05
PHAB	XCDENMID	SB2	12	37.66667	19	23.94737	0.98	0.337
PHAB	XCDENMID	HB	50	15.82	37	6.324324	3.18	0.002
PHAB	XCM	NAT	106	73.48113	134	65.18657	2.03	0.043
PHAB	XCM	SB0	11	59.72727	13	21.61538	3.73	0.001
PHAB	XCM	SB1	7	72.71429	7	47.14286	1.43	0.179
PHAB	XCM	SB2	11	53.09091	19	22.68421	2.04	0.055
PHAB	XCM	HB	50	7.56	37	1.783784	2.93	0.005
PHAB	XCMG	NAT	106	128.3208	134	114.7388	2.12	0.035
PHAB	XCMG	SB0	11	108.4545	13	47.30769	4.2	0
PHAB	XCMG	SB1	7	102.8571	7	72.85714	1.39	0.19
PHAB	XCMG	SB2	11	99.45455	19	37.57895	2.72	0.014
PHAB	XCMG	HB	50	17.36	37	5.405405	2.87	0.006
PHAB	XEMBED	NAT	107	34.79439	110	32.23636	1.29	0.197
PHAB	XEMBED	SB0	8	23.25	9	38.44444	-1.74	0.104
PHAB	XEMBED	SB1	7	34.42857	5	60.2	-3.63	0.007
PHAB	XEMBED	SB2	8	45	12	41.33333	0.51	0.62
PHAB	XEMBED	HB	7	28.14286	1	0	NA	NA
PHAB	XFC_ALG	NAT	106	9.800943	135	21.00741	-4.48	0
PHAB	XFC_ALG	SB0	11	20.25455	13	29.56923	-1.01	0.325
PHAB	XFC_ALG	SB1	7	18.95714	7	21.61429	-0.26	0.797
PHAB	XFC_ALG	SB2	11	24.5	19	31.20526	-0.78	0.447
PHAB	XFC_ALG	HB	50	39.52	37	34.01892	0.82	0.414
PHAB	XFC_AQM	NAT	106	8.653774	135	17.25111	-4.97	0
PHAB	XFC_AQM	SB0	11	19.19091	13	16.41538	0.34	0.739
PHAB	XFC_AQM	SB1	7	10.64286	7	16.32857	-0.77	0.463
PHAB	XFC_AQM	SB2	11	20.67273	19	18.88421	0.19	0.852
PHAB	XFC_AQM	HB	50	4.396	37	1.624324	1.28	0.205
PHAB	XFC_BIG	NAT	106	32.45	135	18.6763	4.65	0
PHAB	XFC_BIG	SB0	11	10	13	16.79231	-0.92	0.374
PHAB	XFC_BIG	SB1	7	35.75714	7	12.97143	2.13	0.065
PHAB	XFC_BIG	SB2	11	12.83636	19	6.257895	1.53	0.152
PHAB	XFC_BIG	HB	50	15.846	37	16.88378	-0.14	0.888
PHAB	XFC_BRS	NAT	106	10.30472	135	8.051852	2.16	0.032
PHAB	XFC_BRS	SB0	11	9.081818	13	6.015385	1.05	0.311
PHAB	XFC_BRS	SB1	7	7.528571	7	9.542857	-0.45	0.664
PHAB	XFC_BRS	SB2	11	4.618182	19	5.142105	-0.36	0.723

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	XFC_BRS	HB	50	2.666	37	2.227027	0.84	0.404
PHAB	XFC_HUM	NAT	106	0.165094	135	1.163704	-1.49	0.137
PHAB	XFC_HUM	SB0	11	2.054545	13	4.284615	-0.52	0.613
PHAB	XFC_HUM	SB1	7	1.228571	7	1.371429	-0.14	0.895
PHAB	XFC_HUM	SB2	11	3.7	19	0.026316	1.36	0.203
PHAB	XFC_HUM	HB	50	15.226	37	16.77027	-0.21	0.834
PHAB	XFC_LTR	NAT	106	6.346226	135	7.162963	-0.94	0.348
PHAB	XFC_LTR	SB0	11	11.73636	13	4.161538	1.46	0.161
PHAB	XFC_LTR	SB1	7	14.31429	7	9.185714	0.71	0.496
PHAB	XFC_LTR	SB2	11	11.34545	19	1.110526	1.46	0.175
PHAB	XFC_LTR	HB	50	0.2	37	0.013514	1.69	0.097
PHAB	XFC_LWD	NAT	106	2.354717	135	1.888889	0.91	0.365
PHAB	XFC_LWD	SB0	11	1.363636	13	0.038462	1.35	0.206
PHAB	XFC_LWD	SB1	7	0.514286	7	0.071429	1.13	0.299
PHAB	XFC_LWD	SB2	11	0.3	19	0.073684	1.48	0.164
PHAB	XFC_LWD	HB	50	0.242	37	0.013514	1.46	0.151
PHAB	XFC_NAT_EMAP	NAT	106	59.95377	135	44.20667	4.05	0
PHAB	XFC_NAT_EMAP	SB0	11	36.5	13	36.91538	-0.04	0.969
PHAB	XFC_NAT_EMAP	SB1	7	60.01429	7	36.82857	1.45	0.173
PHAB	XFC_NAT_EMAP	SB2	11	33.01818	19	23.92105	1.1	0.288
PHAB	XFC_NAT_EMAP	HB	50	5.23	37	2.762162	2.28	0.026
PHAB	XFC_NAT_SWAMP	NAT	106	74.95377	135	68.62074	1.37	0.171
PHAB	XFC_NAT_SWAMP	SB0	11	67.42727	13	57.49231	0.5	0.622
PHAB	XFC_NAT_SWAMP	SB1	7	84.97143	7	62.34286	0.97	0.354
PHAB	XFC_NAT_SWAMP	SB2	11	65.03636	19	43.91579	1.17	0.259
PHAB	XFC_NAT_SWAMP	HB	50	9.826	37	4.4	2.12	0.038
PHAB	XFC_OHV	NAT	106	17.36415	135	18.64222	-0.64	0.522
PHAB	XFC_OHV	SB0	11	19.47273	13	18.39231	0.15	0.881
PHAB	XFC_OHV	SB1	7	17.95714	7	15.68571	0.26	0.801
PHAB	XFC_OHV	SB2	11	19.26364	19	12.54737	0.79	0.439
PHAB	XFC_OHV	HB	50	1.944	37	0.421622	2.34	0.023
PHAB	XFC_RCK	NAT	106	26.7	135	11.97407	5.56	0
PHAB	XFC_RCK	SB0	11	3.109091	13	7.661538	-1.2	0.247
PHAB	XFC_RCK	SB1	7	31.14286	7	7.057143	2.29	0.051
PHAB	XFC_RCK	SB2	11	5.427273	19	4.673684	0.24	0.812
PHAB	XFC_RCK	HB	50	0.176	37	0.037838	0.93	0.358
PHAB	XFC_UCB	NAT	106	3.230189	135	3.64963	-0.58	0.561
PHAB	XFC_UCB	SB0	11	3.472727	13	4.807692	-0.59	0.558
PHAB	XFC_UCB	SB1	7	2.871429	7	4.471429	-0.76	0.463
PHAB	XFC_UCB	SB2	11	3.409091	19	1.484211	1.42	0.179
PHAB	XFC_UCB	HB	50	0.202	37	0.062162	0.98	0.33
PHAB	XG	NAT	106	54.83962	135	49.66667	1.48	0.139

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	XG	SB0	11	48.72727	13	25.69231	2.73	0.012
PHAB	XG	SB1	7	30.14286	7	25.71429	0.39	0.705
PHAB	XG	SB2	11	46.36364	19	14.89474	3.11	0.007
PHAB	XG	HB	50	9.8	37	3.621622	2.55	0.013
PHAB	XGB	NAT	106	35.60377	135	38.59259	-0.82	0.414
PHAB	XGB	SB0	11	42.54545	13	70.07692	-2.62	0.017
PHAB	XGB	SB1	7	60	7	70	-0.65	0.528
PHAB	XGB	SB2	11	54.18182	19	72.05263	-1.5	0.147
PHAB	XGB	HB	50	75.04	37	71.37838	0.54	0.588
PHAB	XGH	NAT	106	25.39623	135	24.67407	0.32	0.748
PHAB	XGH	SB0	11	25.45455	13	21.84615	0.5	0.622
PHAB	XGH	SB1	7	12.57143	7	18.57143	-0.88	0.406
PHAB	XGH	SB2	11	19.72727	19	7.421053	2.67	0.021
PHAB	XGH	HB	50	5.74	37	2.945946	2.1	0.039
PHAB	XGW	NAT	106	29.4434	135	24.99259	1.83	0.069
PHAB	XGW	SB0	11	23.27273	13	3.846154	3.52	0.005
PHAB	XGW	SB1	7	17.57143	7	7.142857	1.62	0.141
PHAB	XGW	SB2	11	26.63636	19	7.473684	1.82	0.091
PHAB	XGW	HB	50	4.06	37	0.675676	2.09	0.041
PHAB	XM	NAT	106	38.71698	135	38.28148	0.18	0.855
PHAB	XM	SB0	11	33.90909	13	17.46154	2.36	0.029
PHAB	XM	SB1	7	38.28571	7	24.14286	1.59	0.14
PHAB	XM	SB2	11	34.63636	19	15.42105	1.98	0.064
PHAB	XM	HB	50	4.94	37	1.108108	2.38	0.021
PHAB	XMIAT	NAT	86	0.319767	120	0.380833	-0.77	0.443
PHAB	XMIAT	SB0	10	0.16	13	0.084615	0.79	0.445
PHAB	XMIAT	SB1	6	0.033333	6	0.016667	0.62	0.55
PHAB	XMIAT	SB2	9	0.155556	18	0.077778	0.93	0.373
PHAB	XMIAT	HB	45	0.3	31	0.593548	-1.57	0.124
PHAB	XMIATP	NAT	86	0.530233	120	0.571667	-0.41	0.682
PHAB	XMIATP	SB0	10	0.54	13	0.246154	1.2	0.255
PHAB	XMIATP	SB1	6	0.233333	6	0.4	-0.61	0.559
PHAB	XMIATP	SB2	9	0.288889	18	0.283333	0.06	0.953
PHAB	XMIATP	HB	45	0.573333	31	0.716129	-0.72	0.475
PHAB	XPCAN	NAT	106	0.848585	134	0.764851	2.29	0.023
PHAB	XPCAN	SB0	11	0.78	13	0.232308	4.67	0
PHAB	XPCAN	SB1	7	0.864286	7	0.5	1.9	0.089
PHAB	XPCAN	SB2	11	0.586364	19	0.244737	2.22	0.038
PHAB	XPCAN	HB	50	0.2338	37	0.13027	1.95	0.055
PHAB	XPCM	NAT	106	0.841792	135	0.748593	2.49	0.014
PHAB	XPCM	SB0	11	0.765455	13	0.197692	4.85	0
PHAB	XPCM	SB1	7	0.844286	7	0.474286	1.91	0.087

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	XPCM	SB2	11	0.582727	19	0.227895	2.28	0.034
PHAB	XPCM	HB	50	0.1704	37	0.062432	2.55	0.013
PHAB	XPCMG	NAT	106	0.841415	134	0.75209	2.4	0.017
PHAB	XPCMG	SB0	11	0.76	13	0.193846	4.85	0
PHAB	XPCMG	SB1	7	0.831429	7	0.415714	2.22	0.051
PHAB	XPCMG	SB2	11	0.582727	19	0.228421	2.27	0.035
PHAB	XPCMG	HB	50	0.165	37	0.055946	2.59	0.011
PHAB	XPGVEG	NAT	104	0.997692	133	0.960902	2.79	0.006
PHAB	XPGVEG	SB0	11	0.975455	12	0.984167	-0.33	0.744
PHAB	XPGVEG	SB1	7	0.972857	7	0.935714	0.56	0.591
PHAB	XPGVEG	SB2	11	0.954545	19	0.795789	2.18	0.039
PHAB	XPGVEG	HB	50	0.6166	36	0.459444	1.71	0.091
PHAB	XPMGVEG	NAT	106	0.827925	135	0.74163	2.17	0.031
PHAB	XPMGVEG	SB0	11	0.814545	13	0.479231	2.34	0.029
PHAB	XPMGVEG	SB1	7	0.571429	7	0.402857	0.87	0.405
PHAB	XPMGVEG	SB2	11	0.747273	19	0.210526	4.43	0
PHAB	XPMGVEG	HB	50	0.152	37	0.038108	2.32	0.024
PHAB	XPMID	NAT	106	0.984717	135	0.936222	3.11	0.002
PHAB	XPMID	SB0	11	0.983636	13	0.600769	3.08	0.009
PHAB	XPMID	SB1	7	0.96	7	0.752857	1.49	0.184
PHAB	XPMID	SB2	11	0.793636	19	0.579474	1.56	0.13
PHAB	XPMID	HB	50	0.3812	37	0.139189	3.62	0.001
PHAB	XSDGM	NAT	111	75.3036	143	56.2972	0.53	0.597
PHAB	XSDGM	SB0	11	5.1	14	3.857143	0.39	0.704
PHAB	XSDGM	SB1	7	48.51429	7	4.842857	3.18	0.018
PHAB	XSDGM	SB2	12	16.70833	19	19.98421	-0.23	0.822
PHAB	XSDGM	HB	50	3592.608	37	4178.819	-1.28	0.204
PHAB	XSLOPE	NAT	94	4.138298	129	1.802326	3.44	0.001
PHAB	XSLOPE	SB0	10	0.63	12	0.483333	0.67	0.511
PHAB	XSLOPE	SB1	5	2.84	4	0.775	NA	NA
PHAB	XSLOPE	SB2	10	1.49	19	0.257895	1.99	0.078
PHAB	XSLOPE	HB	47	0.993617	36	0.663889	1.59	0.115
PHAB	XSPGM	NAT	111	30.04134	143	14.60341	3.38	0.001
PHAB	XSPGM	SB0	11	3.262036	14	3.015033	0.11	0.913
PHAB	XSPGM	SB1	7	30.54679	7	3.580689	3.72	0.009
PHAB	XSPGM	SB2	12	9.802666	19	4.306569	1.04	0.317
PHAB	XSPGM	HB	34	4.032148	17	9.712121	-0.68	0.505
PHAB	XWAT	NAT	27	211.6296	84	289.4524	-4.5	0
PHAB	XWAT	SB0	5	244.2	12	255.875	-0.23	0.827
PHAB	XWAT	SB1	3	257	5	292.4	NA	NA
PHAB	XWAT	SB2	4	229	17	229.1765	NA	NA
PHAB	XWAT	HB	28	201.6964	17	174	1.05	0.3

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	XWDA	NAT	111	0.317161	143	0.343409	-1.12	0.262
PHAB	XWDA	SB0	11	0.332338	14	0.429906	-0.91	0.374
PHAB	XWDA	SB1	7	0.300036	7	0.362607	-0.56	0.593
PHAB	XWDA	SB2	12	0.298164	19	0.234497	0.66	0.523
PHAB	XWDA	HB	50	0.126861	37	0.076336	2.02	0.046
PHAB	XWDEPTH	NAT	111	9.225225	143	14.09441	-5.02	0
PHAB	XWDEPTH	SB0	11	10.24545	14	14.07857	-1.55	0.135
PHAB	XWDEPTH	SB1	7	16.57143	7	25.42857	-1.35	0.203
PHAB	XWDEPTH	SB2	12	15.40833	19	10.51053	1.37	0.191
PHAB	XWDEPTH	HB	50	5.12	37	3.427027	1.64	0.105
PHAB	XWDO	NAT	42	8.405238	102	14.30931	-0.84	0.401
PHAB	XWDO	SB0	6	8.255	12	9.329167	-0.7	0.497
PHAB	XWDO	SB1	4	8.7675	5	8.098	NA	NA
PHAB	XWDO	SB2	5	7.95	17	9.287059	-1.04	0.31
PHAB	XWDO	HB	44	10.2375	26	12.17269	-2.86	0.006
PHAB	XWDR	NAT	111	43.22627	143	66.13686	-2.18	0.031
PHAB	XWDR	SB0	11	61.21904	14	29.95031	1.2	0.256
PHAB	XWDR	SB1	7	36.83515	7	44.51383	-0.52	0.617
PHAB	XWDR	SB2	12	90.62877	19	80.30745	0.33	0.747
PHAB	XWDR	HB	50	229.3038	37	380.7061	-1.84	0.07
PHAB	XWIDTH	NAT	111	3.658559	143	5.686713	-3.57	0
PHAB	XWIDTH	SB0	11	5.4	14	3.735714	0.86	0.406
PHAB	XWIDTH	SB1	7	5.471429	7	8.842857	-1.4	0.195
PHAB	XWIDTH	SB2	12	10.25	19	5.831579	1.58	0.137
PHAB	XWIDTH	HB	50	8.066	37	9.835135	-0.45	0.652
PHAB	XWPH	NAT	42	7.895952	102	7.768039	1.66	0.101
PHAB	XWPH	SB0	6	7.981667	11	7.902727	0.44	0.67
PHAB	XWPH	SB1	4	7.7925	5	7.942	NA	NA
PHAB	XWPH	SB2	5	8.064	17	7.947647	0.66	0.519
PHAB	XWPH	HB	44	26.92341	26	8.901154	0.98	0.333
PHAB	XWSC	NAT	41	705.0561	102	2488.454	-9	0
PHAB	XWSC	SB0	6	1808	12	3295.667	-1.98	0.067
PHAB	XWSC	SB1	4	999.225	5	2198.8	NA	NA
PHAB	XWSC	SB2	5	1683.2	17	2012.059	-0.54	0.612
PHAB	XWSC	HB	44	1451.675	26	1452.05	0	0.999
PHAB	XWSL	NAT	40	0.3845	99	1.361212	-8.68	0
PHAB	XWSL	SB0	6	0.955	12	1.775833	-1.91	0.076
PHAB	XWSL	SB1	4	0.5525	5	1.14	NA	NA
PHAB	XWSL	SB2	5	0.876	17	1.062941	-0.57	0.591
PHAB	XWSL	HB	42	0.741429	25	0.7676	-0.17	0.865
PHAB	XWTB	NAT	19	3.833684	64	7.58875	-0.86	0.39
PHAB	XWTB	SB0	2	0.625	1	4.2	NA	NA

Type	Analyte	Class	n_top	mean_top	n_bot	mean_bot	t_stat	t_stat_p
PHAB	XWTB	SB1	0	NA	1	1.7	NA	NA
PHAB	XWTB	SB2	3	2.08	2	2.3	NA	NA
PHAB	XWTB	HB	10	2.72	3	12.19667	NA	NA
PHAB	XWTC	NAT	42	16.64524	102	20.01078	-4.47	0
PHAB	XWTC	SB0	6	21	12	21.10833	-0.09	0.93
PHAB	XWTC	SB1	4	17	5	21.68	NA	NA
PHAB	XWTC	SB2	5	18.26	17	20.97647	-2.29	0.05
PHAB	XWTC	HB	44	24.86591	26	24.87692	-0.01	0.995
PHAB	XWTF	NAT	42	61.95952	102	68.02255	-4.47	0
PHAB	XWTF	SB0	6	69.78333	12	69.98333	-0.09	0.928
PHAB	XWTF	SB1	4	62.575	5	71.02	NA	NA
PHAB	XWTF	SB2	5	64.84	17	69.76471	-2.31	0.048
PHAB	XWTF	HB	44	76.76591	26	76.78462	-0.01	0.995
PHAB	XWV_F	NAT	34	0.372059	80	0.417875	-0.55	0.581
PHAB	XWV_F	SB0	6	0.228333	8	0.08625	1.33	0.21
PHAB	XWV_F	SB1	3	0.356667	4	0.25	NA	NA
PHAB	XWV_F	SB2	5	1.182	12	0.238333	2.88	0.042
PHAB	XWV_F	HB	19	1.208421	4	1.33	NA	NA
PHAB	XWV_M	NAT	34	0.112647	80	0.12675	-0.56	0.577
PHAB	XWV_M	SB0	6	0.068333	8	0.0275	1.26	0.236
PHAB	XWV_M	SB1	3	0.11	4	0.0775	NA	NA
PHAB	XWV_M	SB2	5	0.36	12	0.071667	2.89	0.041
PHAB	XWV_M	HB	19	0.368947	4	0.4075	NA	NA