watershed and stormwater planning models, they may sit on the shelf between RAA milestones. On the other hand, if stormwater utilities coordinate with other municipal partners, aspects of the modeling tools developed for RAA, including calibrated hydrologic rainfall and runoff calculations or integrated land use data, can support other planning and research applications, helping justify investments in the modeling exercise.

Mapping potential RAA models to permit compliance requirements can provide guidance for understanding how to align appropriate models with analysis outcomes (LA-RWQCB 2013). Yet, like the classification of models themselves, there are not clearly delineated guidelines for linking types of models with planning needs. In available guidance to date, US EPA (2017) outlined detailed considerations for selecting models, including regulatory guidelines; practical considerations for data availability, cost, and expertise; and analytical capabilities for incorporating BMPs, identifying modeling resolutions, and other needs.

Some additional or corresponding critical factors that can help align analysis requirements with models include:

- Modeling cities or larger watersheds—Some models are tailored for simulating urban hydrology and hydraulics, but do not do well simulating larger watershed processes. Others are the opposite. Aligning the project region with models is important.
- Types of BMPs to incorporate—As noted in US EPA (2017), certain models do better at modeling LID and BMPs, including even having custom-developed modules for processes in various types of BMPs, such as swales or dry wells.
- Planning or verification—Most models, along with watershed classification methods, are useful for planning, helping to identify and prioritize contaminants of concern and estimate the scale of necessary new BMPs in a watershed. For verification, however, stochastic models that lump explanatory parameters often are not useful. Such models correlate existing conditions, which may not remain true after new infrastructure improvements or compliance actions.
- High-level targets or siting guidance—Models with greater geographic and temporal resolution that incorporate a variety of storm event magnitudes (modeled as either over a time record or as multiple storms) can best support siting and sizing guidelines for BMPs. For higher-level targets, models could identify a preferred mix of BMPs for watershed areas based on cost and performance metrics without identifying specific sites. For siting guidance, a high-detail model could help identify optimal BMP locations in a watershed towards meeting goals. Generally, lumped models with coarse spatial resolution have limited utility for siting BMPs in a watershed.
- Outcomes to measure—As noted in US EPA (2017), matching permit requirements and modeled outcomes are important considerations in selecting models. Reasonable assurance may apply to either RWLs, measured as concentrations of pollutants, or loads measured at discharge points. This varies by permit. TMDLs may apply in some areas that do not have specific requirements for MS4 permits, which can influence the geographic scale of modeling. Aligning a model with the desired model target requires expert judgement to understand capabilities.
- Stage of compliance plan—The details of aligning RAA results with measurable field parameters influences the compliance and monitoring process. Early in an RAA, watershed models can outline high-level planning targets and the types of BMPs that best address contaminants of concern. This is essentially the process of organizing information in support of analysis. Monitoring for improvements during subsequent stages of ACPs, after some number of BMPs are installed, requires comparisons to expectations. In early years, water quality improvements would most likely be measurable at the site scale, close to a discharge point of a BMP. Prudent monitoring

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would test that installed BMPs are operating as expected. Later in ACP stages, after perhaps a decade or more when municipalities have built out many more BMPs, field monitoring and subsequent modeling can look for expected improvements. Thus, early in ACP, site-specific models can be most helpful for verification and monitoring, while in later stages updated watershed models may provide insights.

- Model performance requirements—Some ACPs, such as in the Los Angeles region, outline specific model performance requirements, including periods for validation and calibration, tolerances for modeling specific contaminants, and statistical tests for flows. These requirements most closely align with distributed continuous simulation models. Thus, as regional water boards and permittees identify available data and assess necessary model outcomes that correspond with permit requirements, ensuring that model performance can be validated with reasonable assurance requires either knowing the type of model to be used or selecting a model that can meet given performance criteria.
- Available resources—As in all analysis, available resources, including data, expertise, and funds, must be considered in selecting a model. In the absence of data or funds, a robust continuous simulation model may not be feasible. In cases of developing more straightforward models, however, simplifications should be communicated transparently, including limitations of using computationally-intensive approaches.

Generally, models that use continuous simulation, are spatially-distributed at a high geographic resolution, and incorporate some capacity for understanding the certainty associated with the results are most robust and will likely meet the ACP requirements for reasonable assurance.

But, these models are also more expensive, time-consuming, and data-intensive. Requiring detailed models for a watershed with limited existing data would not provide near-term analytical solutions given the time required to gather field data and the limited number of storms that occur in most watersheds throughout California.

As an alternative, stochastic approaches may be less intensive to assemble. They can also be more flexible in dealing with mismatched temporal and spatial resolutions of underlying data. Smaller communities may look to these models to deal with limited data or lack of resources for large-scale modeling efforts.

This also has tradeoffs. Stochastic models that identify relationships between contributing factors and stormwater runoff are useful in planning, but typically not useful for later verification needs. For instance, the underlying statistical relationships in a regression model would not necessarily hold true after BMP implementations. Regression models derived from statistical relationships are only known to have good fit for the observed conditions. They may still perform well, but only after further evaluation.

Thus, a challenge for any municipality that uses a purely stochastic approach for RAA would be watershed-scale assessments for verification at later RAA milestones. These municipalities may need to undertake new modeling efforts capable of absorbing observed performance data to continue planning activities. Regional Water Boards should consider likely future regulatory actions when assessing and approving the use of models and tools for RAA. Regulators at the state level, similarly, should factor in the likely trajectory of regulatory mandates when providing guidance on model development, required outcomes, and assumptions for municipal expenditures on planning across the diverse municipalities of California.

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6. Conclusions

Effective RAA requires knowledge of the full regulatory process, facilitated by clear lines of communication among regulators, municipalities, and modelers. Alternative Compliance Plans must describe how quantitative analysis supports development of stormwater actions by a municipality over long time frames. The analysis should be devised to utilize the best available sources of data that respond to clear regulatory guidance with expectations for RAA results. Discussing and communicating the many types of uncertainty that exist throughout the process, not just in the development of models, is critical to assessing monitoring outcomes and opportunities for adaptive management. Model results must usefully support municipal plans for building new stormwater infrastructure, connecting ACPs to the many other local decision-making processes that ultimately influence how and where cities spend money.

The findings from the surveys, workshops, model reviews, and uncertainty analysis enables identification of important elements of RAA, which State and Regional Water Boards can use for guiding RAA processes. To assist in assembling statewide policy guidance, Appendix E presents the elements of RAA that can be considered as benchmarks in policy-setting actions.

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Appendix A: Survey Questionnaire

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STORMS PROJECT 3A: DEVELOP GUIDANCE FOR ALTERNATIVE COMPLIANCE APPROACHES FOR MUNICIPAL STORMWATER PERMIT RECEIVING WATER LIMITATIONS WORKSHOP #1

BACKGROUND

The Storm Water Planning Unit (through contract funding with Sacramento State Office of Water Programs and SCCWRP) is moving forward with implementation of Storm Water Strategy (STORMS) Project 3a: Develop Guidance for Alternative Compliance Approaches for Municipal Storm Water Permit Receiving Water Limitations. One of Project 3a's deliverables is a report describing alternative compliance pathways, and the conditions and supporting documentation (including quantitative analysis and minimum data requirements) under which the pathways are allowed and suggestions for improvement based on lessons learned.

To inform this report, two workshops have been identified:

Workshop #1 - One-day workshop with Water Board executive teams, managers, and attorneys to identify existing and potential future compliance pathways utilized in MS4 permits.

Workshop #2 - Follow-up to the first workshop with a broader combination of storm water program staff, regulated community, environmental organizations, and technical experts to share lessons learned in adopting compliance pathways and in implementing reasonable assurance analyses.

This request for information is being sent to all Regional Water Board Assistant Executive Officers and Program Managers overseeing the Storm Water Programs. The questionnaire responses will be used to develop materials for discussion during Workshop #1. **For regions that have a current and/or draft (pending approval) municipal permit, answer each question for both versions of the permit, as applicable. In addition, provide permit language and permit citations for each response.**

Please provide responses to the questions below, attach any relevant or supporting documentation (if needed), and email it to Beth Payne at Elizabeth.Payne@waterboards.ca.gov **by no later than May 15, 2017.**

PROJECT SCHEDULE

Project Milestone	Date
Workshop #1 Questionnaire due	**May 15, 2017**
3a Workshop #1 at SCCWRP	June 8, 2017
Notes sent out to participants	End of July
3a Workshop #2 at TBD	Fall 2017
Notes sent out to participants	Fall 2017
Final Summary Report due	December 2017

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REQUEST FOR PRELIMINARY INFORMATION

State Water Board Order No. 2015-0075 directed all Regional Water Boards to consider alternative compliance approaches to receiving water limitations compliance when issuing Phase I MS4 Permits going forward, as guided by seven principles (Section II.B.7, p. 52).

For the Regional Water Boards that have established or are currently considering alternative compliance pathways, please provide detailed responses to the following questions below, including applicable permit language and citations.

Principle 1: *The receiving water limitations provisions of Phase I MS4 permits should continue to require compliance with water quality standards in the receiving water and should not deem good faith engagement in the iterative process to constitute such compliance. The Phase I MS4 permits should therefore continue to use the receiving water limitations provisions as directed by State Water Board Order WQ 99-05.*

Question 1a. Does the municipal permit incorporate receiving water limitations?

Question 1b. If the receiving water limitations language varies the precedential language in State Water Board Order WQ 99-05, explain why.

Question 1c. Insert and cite applicable permit language for 1a here.

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Principle 2: *The Phase I MS4 permits should include a provision stating that, for water body-pollutant combinations with a TMDL, full compliance with the requirements of the TMDL constitutes compliance with the receiving water limitations for that water body-pollutant combination.*

Question 2a. Does the municipal permit include a provision stating that full compliance with TMDLs for water body–pollutant combinations constitutes compliance with the receiving water limitations for that water body-pollutant combination? (y/n)

Question 2b. If not, why?

Question 2c. Insert and cite applicable permit language for 2a/2b here.

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Principle 3: *The Phase I MS4 permits should incorporate an ambitious, rigorous, and transparent alternative compliance path that allows permittees appropriate time to come into compliance with receiving water limitations without being in violation of the receiving water limitations during full implementation of the compliance alternative.*

For the questions below, answer them relative to the alternative compliance pathway in the municipal permit, and cite the applicable permit section that addresses each question.

Question 3a. Does the current municipal permit allow an alternative compliance pathway to comply with receiving water limitations? (y/n)

Question 3b. Insert and cite applicable permit language for 3a here.

Question 3c. When does compliance with receiving water limitations through the alternative compliance pathway begin? What conditions must be satisfied to be deemed in compliance with receiving water limitations?

Question 3d. Does the alternative compliance pathway allow permittees time to come into compliance with receiving water limitations? (y/n)

Question 3e. What is the basis of the time permittees are given to come into compliance with receiving water limitations?

Question 3f. Is the time schedule proposed by the permittee, the regional board, or by some other means and who approves the time schedule? What is the public review process for proposed time schedules?

Question 3g. Can deadlines in permittees' time schedules be extended? If so, specify which deadlines may and may not be extended. If applicable what is the public review process for approving/disapproving the deadline extension?

Question 3h. What are the triggers for non-compliance with the alternative compliance pathway?

Question 3i. What are the consequences of non-compliance with the alternative compliance pathway?

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Principle 4: *The alternative compliance path should encourage watershed-based approaches, address multiple contaminants, and incorporate TMDL requirements.*

For the questions below, cite the applicable permit section that addresses each question.

Question 4a. How does the alternative compliance pathway in the municipal permit encourage watershed-based approaches?

Question 4b. How does the alternative compliance pathway in the municipal permit address multiple contaminants?

Question 4c. How does the alternative compliance pathway in the municipal permit incorporate TMDL requirements?

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Principle 5: *The alternative compliance path should encourage the use of green infrastructure and the adoption of low impact development principles.*

Question 5a. Does the alternative compliance pathway in the municipal permit encourage the use of green infrastructure and adoption of low impact development principles? If it does not, why?

Question 5b. Insert and/or cite applicable permit language for 5a here.

Question 5c. Does this principle create a conflict for capture and use projects that use and tie into grey infrastructure? And if so, which receives the higher priority?

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Principle 6: *The alternative compliance path should encourage multi-benefit regional projects that capture, infiltrate, and reuse storm water and support a local sustainable water supply.*

For the questions below, cite the applicable permit section that addresses each question.

Question 6a. Does the alternative compliance pathway in the municipal permit encourage multi-benefit regional projects? (y/n) If it does not, why?

Question 6b. Does the permit define "multi-benefit" projects? If so, provide the definition here. If it does not, why?

Question 6c. What types of benefits are considered in categorizing a project as multi-benefit?

(Examples of project benefits beyond water quality include, but are not limited to: water supply augmentation, flood management, greenhouse gas reduction, reduced energy use, water temperature improvements, heat island effect reduction, enhanced public use areas, urban blight mitigation, economic development, transportation rehabilitation and improvements, affordable housing, groundwater sustainability, habitat, conservation, and other public projects within the urban area that could increase the likelihood of implementation of storm water quality projects.)

Question 6d. How does the permit encourage projects that capture storm water?

Question 6e. How does the permit encourage projects that infiltrate storm water?

Question 6f. How does the permit encourage projects that use storm water?

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***Principle 7**: The alternative compliance path should have rigor and accountability. Permittees should be required, through a transparent process, to show that they have analyzed the water quality issues in the watershed, prioritized those issues, and proposed appropriate solutions. Permittees should be further required, again through a transparent process, to monitor the results and return to their analysis to verify assumptions and update the solutions. Permittees should be required to conduct this type of adaptive management on their own initiative without waiting for direction from the regional water board.*

For the questions below, answer them relative to the alternative compliance pathway in the municipal permit, and cite the applicable permit section that addresses each question.

Question 7a. Describe the analysis required to assure compliance with applicable receiving water limitations and TMDL WLAs.

Question 7b. Describe the basic principles and assumptions that guide the methods used in quantitative analysis, and/or selection of models or other software.

Question 7c. Are permittees required to show that they have analyzed the all existing and relevant water quality data and related water quality issues in the watershed?

Question 7d. If pollutant-specific analysis is not required, what are the guidelines for analyzing a surrogate pollutant for a class of pollutants or for all pollutants?

Question 7e. Are permittees required to describe the basis and analysis for prioritization of the water quality issues? If not, why?

Question 7f. Are permittees required to describe how the appropriate solutions were selected and how these solutions will resolve the water quality issues? If not, why?

Question 7g. Are permittees required to monitor the results and return to their analysis to verify the results or forecasts and update the analysis and solutions? If not, why?

Question 7h. Does the permit direct permittees to conduct this type of adaptive management on their own initiative? If not, why?

Question 7i. How does the quantitative analysis demonstrate that the alternative compliance pathway is rigorous and accountable?

Question 7j. How does the permit ensure transparency and public participation in relations to questions 7a-i?

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Appendix B: Sources of Uncertainty Workshop Charge

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Workshop for Enhancing Reasonable Assurance Analysis: Identifying and Minimizing Sources of Technical Uncertainty Associated with Alternative Compliance Pathways

Background

Alternative Compliance Pathways (ACP) represent an emerging approach to stormwater management that relies on adaptive management strategies and planning on timescales of 20 years or more. Unlike traditional approaches to stormwater management, which have shown limited progress towards achieving receiving water limitations, ACP takes a long-term view of watershed management, making the approach attractive to many stormwater managers. To increase confidence in the watershed management plans required by ACP, stormwater managers are required to perform Reasonable Assurance Analysis (RAA). In current practice, RAA focuses on computer watershed modeling to reduce uncertainty, enhancing the ability of ACP to achieve its stated regulatory goals.

On a statewide basis, there is an opportunity to provide clear, best-practices guidance for conducting RAA and for reporting and interpreting RAA model output. Statewide guidance can provide consistency in how RAA are designed and conducted, as well as in how regulated and regulatory agencies interpret and utilize RAA modeling output. Further, a consistent statewide approach can address some of the existing uncertainty in ACP decision-making that has resulted in potential inequities in follow-up monitoring toward regulatory compliance.

Workshop Overview

Given that planning decisions with significant financial implications are made based on RAA model outputs, it is imperative that stormwater managers receive adequate, consistent RAA guidance. The goal of this workshop is to enhance RAA and probability of ACP success by identifying sources of technical uncertainty. The outcome of the workshop will be a project (or series of projects) to quantify and minimize these areas of technical uncertainty.

It is important to note that other uncertainties will remain, including fiscal capability and administrative and policy implementation, which will need to be addressed separately to increase the potential for achieving success with ACP.

The Workshop for Enhancing Reasonable Assurance Analysis (Uncertainty Workshop) comes on the heels of a scoping session conducted in June 2017. The scoping session comprised regulatory staff from each of the nine California Regional Water Quality Control Boards. After spending an entire day itemizing and discussing their respective concerns about uncertainty in ACP and RAA, the largest technical uncertainties were distilled into two focus areas: (A) Accuracy and precision of modeling existing watershed conditions, and (B) Accuracy and precision of modeling management actions. These two focus areas will become the focal point of the Uncertainty Workshop.

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Focus Areas

A. *Accuracy and precision of modeling existing watershed conditions*

All RAA approaches currently utilize computer watershed modeling as the primary technical tool to limit uncertainty associated with ACP. The basic information that defines what an acceptable model is - and which performance characteristics these models should have - is already available. For example, the Los Angeles Regional Water Quality Control Board has stipulated model performance criteria in its RAA guidance, while the USEPA Region 9 has published its report on several modeling approaches to support RAA[1].

Even with this guidance, the quality and comparability of the model input data and how the model results are output can markedly contribute to technical uncertainty, ultimately undermining the confidence in making (or not making) watershed management decisions. For example, all watershed models generally rely on precipitation, land use definitions, and water quality event mean concentrations (EMCs) as model input parameters. There is variability, however, in each of these input parameters that can sometimes be significant: (1) Precipitation can vary substantially with elevation, temperature, timing, and duration; (2) National Land Cover Data defines dozens of land use categories, which are typically lumped into just a handful of land use categories for many watershed models and do not take into account watershed or social position; (3) EMCs at the same site can range an order of magnitude or more across storms throughout a season; and (4) EMC data used for many models are based on information that may be up to 15 years old, even though many stormwater managers believe these EMCs have changed over time as land use development and redevelopment practices have evolved.

In addition, RAA model output is not standardized among the various watershed models used for RAA. The USEPA Region 9 guidance for RAA attempts to address this issue by emphasizing development of a framework for model applications, but does not specifically address reporting uncertainty. As a result, regulatory and regulated agencies are left to interpret each model output from their individual perspectives on a case-by-case basis. Clearly some model output will always be watershed-specific, but there are several model results that are expected to be common to all modeling scenarios, including model calibration and model validation.

The Uncertainty Workshop will address both elements of uncertainty associated with modeling current conditions:

a) Model input parameterization
b) Model output and reporting

The workshop participants will help identify uncertainties associated with model input parameters and list standardized model output that can provide transparent evaluations of uncertainty for both regulated and regulatory agencies.

[1] https://www3.epa.gov/region9/water/npdes/pdf/stormwater/meeting-2016-09/dev-reasonable-assur-guide-model-base-analys-munic-stormw-prog-plan-2017-02.pdf

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B. *Accuracy and precision of modeling management actions*

Whereas the goal of the previous focus area is to increase accuracy and precision when modeling existing watershed conditions, the goal of this focus area is to increase accuracy and precision associated with predicting future management actions. Modeling future conditions is typically a function of selecting and optimizing structural and non-structural best management practices (BMPs). Ultimately, verification of model accuracy and precision relies on future monitoring as the optimized model scenario is implemented.

Most models use the state of the science for estimating median stormwater reductions (either volume, concentrations, and/or loads) – information that can be found in the International Stormwater BMP Database. The range of BMP effectiveness in the international BMP database is frequently quite large – up to an order of magnitude or more, creating a source of uncertainty that is exacerbated by the lack of data from California-specific BMP construction and monitoring. Yet, rarely is any of this uncertainty captured in modeling scenarios. Compiling the most current information on BMP effectiveness from within California will improve our confidence in watershed modeling of BMP performance. The number and range of BMPs continues to grow each year, especially given local and statewide funding initiatives. However, much of this data is not compiled and assessed, which limits modelers ability to use the information for sensitivity analysis. Complicating model uncertainty is BMP maintenance, where changes in BMP performance occur over time, and which is almost never considered in modeling future scenarios.

Adaptive management decision making is a hallmark of all current ACP approaches, and monitoring information will be foundational for making those decisions. However, guidance for how this monitoring is conducted and, more importantly, how this monitoring will be used for decision making is rarely explicit. Current ACP monitoring approaches and requirements are uneven, and much of the differences in monitoring efforts may result from unforeseen uncertainties in discharge or receiving monitoring data. That is, if model predictions overestimate reductions relative to future monitoring data, is this the actual outcome, and should adaptive management actions take place? Or, is the overestimation a function of uncertainties in the model? Alternatively, perhaps the uncertainty is in the monitoring? Providing guidance that accounts for monitoring uncertainties prior to implementing an expensive field program will greatly help in important (and costly) decision making at future milestone benchmarks.

The Uncertainty Workshop will look to address both elements of uncertainty associated with modeling future management actions:

a) BMP effectiveness
b) Monitoring to support ACP decision making

The workshop participants will help identify uncertainties associated with structural and non-structural BMP effectiveness and recommend projects to quantify this uncertainty for improving model sensitivity analysis. The workshop participants will also help identify and recommend project ideas for monitoring guidance to support ACP management decision making.

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Appendix C: Sources of Uncertainty Workshop Notes

The following notes are from the Uncertainty Workshop held on November 30, 2017.

Model sensitivity and critical data needs

- Critical data needs for each model type
- Develop standardized data layers to support data collection and aid in consistent analysis
- Minimum data needs and extrapolation opportunities
- Increasing reference and background data
- Develop a data inventory (a repository provided by state agencies to support planning would include land use, land cover, hydrology, EMC, and pollutographs by appropriate special scales)
- Data and analysis tools to optimize between structural and non-structural BMPs
- Sensitivity analysis on future predictions
- Sensitivity analysis, most important factors, and factors with greatest uncertainty
- Treatment needs relative to background variability in receiving water
- Source material analysis (e.g., bacteria, street dirt sediment pollutant/solids ratios, dissolved/total fractions)
- Guidance on selecting BMP effectiveness rates for modeling (selected for further scoping)
- BMP data needs
  - Structural efficiency
  - Non-structural efficiency
  - Efficiency relative to background variability and timing in RW (Do the loads that are removed affect the water that is monitored in the RW? Does RW type matter?)
  - Location of BMPs vs. pollutant generation areas; not all pollutants are ubiquitous
  - Are BMPs constructed as modeled?
  - Adaptability of BMP types to variability in climate, soils, available space, etc.
  - Should multi-benefit BMPs be incentivized? What are the incentives/tradeoff?
  - How well do different BMP types handle emerging pollutants? Which types have more robust performance across BMP types?
  - How are data generated for new technologies? Is there a need to track and verify new technology?
- Climate and climate change effects: Models and infrastructure must be designed for success given a future of more extreme climate scenarios

Uncertainty guidance, standards, and communicating model outputs

- How to make modeling tools more accessible beyond highly specialized modelers? How can understanding for clients and regulators be improved?
- Standardized reporting of uncertainty analysis
- Error acceptability standards
- Interpreting uncertainty relative to receiving water variability, lack of data, progress towards implementation of the ACP, scale of implementation, and resolution of the model
- Guidance on California outcome metrics (e.g., outfall loading, receiving water values, etc.)
- How does lag time between data collection and use affect uncertainty? How can uncertainty in recent changes in receiving waters be estimated?

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- Ability to incorporate variability and natural variation in monitoring: How is natural variation accounted for in model calibration? How is natural variation in background (target) conditions accounted for in monitoring results at compliance milestones?
- Predicting the ability to detect a change in receiving waters or outfall loads
- Level of modeling effort relative to affordability and rigor
  - Influence of uncertainty?
  - How much is enough?
  - Relative implementation activity to modeling
- Appropriate spatial scale to detecting responses
- Guidance on uncertainty relative to BMP size
- Uncertainty/confidence relative to compliance deadlines
- Uncertainty/confidence relative to readiness to implement
- Uncertainty/confidence relative to spatial scale of implementation

Optimizing evaluations/assessments for decision-making

- What to measure for program effectiveness
- What decisions to make with monitoring: for compliance and for adaptive management; Linking post-construction monitoring to adaptive management
- Optimizing when and where to monitor BMPs, subwatersheds, outfalls, and receiving waters; monitoring to verify load reductions; monitor to understand loss of effectiveness
- Predicting the ability to detect a change in receiving waters or outfall loads
- Appropriate implementation tracking: installation, maintenance, and load reductions; implementation tracking feedback for improving adaptive management and future model reruns

Alternative Compliance-Related Themes

A few big-picture project themes emerged that do not fit well within existing and pending projects, but they are captured here for further consideration by the State Water Board to add clarity to the overall approach to alternative compliance. Those projects were: 1) process mapping that laid out detailed steps in the development of ACP implementation plans, 2) increasing confidence in decision making, and 3) RAA tools outside the modeling process. The issues associated with each are described below.

Process Mapping

A process map is all the steps in developing watershed plans from TMDL participation to ultimate RWL compliance via the ACP. Themes that aligned with the identification and explanation of these steps include the following requests:

- Map the ACP and RAA process and identify potential improvements; apply to pilot watersheds; integrate feedback into existing guidance; outfall monitoring to improve model calibration; identify case studies where implementation led to receiving water improvements
- Define how confidence can be increased throughout the ACP process
- How to coordinate monitoring to enhance model development
- Describe how numeric targets are set and translated to desired model conditions; Describe how pre-RAA investments in those efforts can yield better data
- Consider how uncertainty in water quality targets should be incorporated into models supporting RAA
- Integrate sanitary sewer orders with ACP efforts for stormwater

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- Define critical conditions in terms of water quality statistics (average, max, percentiles); define critical conditions in terms of consistency over periods of time versus specificity at a particular point of comparison
- Implementation feedback and iteration; guidelines for frequency in revisiting models and for knowing when a better understanding of baseline conditions should prompt revisiting models
- Using models to address multiple goals (e.g., TMDLs, RWL)
- Potential disconnect between models and receiving waters; explore the need to link model outputs to receiving water outcomes and identify models that have this ability; ensure model outputs match targets
- Explore the need to link model output to instream biology and identify models that have this ability
- Describe models appropriate for desired resolution
- Connecting models to implementation activities (i.e., moving from valuation of the "market basket" of BMPs to those that are actually used)
- Linking watershed models with beneficial uses
- Level of modeling effort relative to affordability and rigor
  - Influence of uncertainty?
  - How much is enough?
  - Relative implementation activity to modeling
- Appropriate spatial scale to detecting responses
- Choosing appropriate temporal and spatial scales for modeling versus planning
- Appropriate implementation tracking: installation, maintenance, and load reductions; implementation tracking feedback for improving adaptive management and future model reruns
- Maximizing benefits of BMPs to other parameters/conditions
- Confidence in mulit-benefit quantification
- Uncertainty/confidence relative to compliance deadlines
- Uncertainty/confidence relative to readiness to implement
- Itemizing appropriate milestones to counter-balance uncertainty
- Conceptual development of a credit program

Increasing Confidence in Decision Making

Many decisions are required throughout the ACP process. The following themes aligned with increasing confidence in decision making:

- Adapting to increasing confidence with increasing information and data. Panelist often returned to discussing how confidence should increase over time for compliance plans that follow adaptive management principles (as may need to be specified in a solid ACP permit requirement). Several acknowledged that initial confidence need not be high when the ACP approach assures that confidence will increase. Adapting to increasing confidence could also affect initial RAA levels of confidence, future data requirements, modeling requirements, etc.
- Differentiating confidence (in model outcomes) versus decision making, which considers many other constraints outside of what a model might identify as optimal
- Guidance in decision making that reflects the effort for modeling relative to the effort in implementation
- Guidance on model complexity versus likely confidence (based on uncertainties)
- Dealing with changing baselines as more data changes the picture (e.g., unanticipated de-listings)

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- Choosing appropriate temporal and spatial scales for modeling versus planning
- Choosing the best model for each constituent (e.g., bacteria)

Addressing Planning Tools that are Outside the Modeling Process

- Understanding relative cost per unit action and developing viable finance plans
- Validating construction versus design
- Confidence in multi-benefit quantification for funding requests and public/political marketing
- Conceptual development of a credit program
- Improving capital and operational and management costs
- Training program to develop modeling expertise within municipalities, NGOs, and regulators
- Independent model review program where results are submitted to a team that can validate the modeling approach; confidence will be increased because of the review

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Appendix D. Potential Projects to Address Uncertainty

The following three projects were developed from the input from the Uncertainty Workshop.

Scope of Work: Reducing Uncertainty Through Updated Land Use Data

Currently, Reasonable Assurance Analyses (RAA) is built upon watershed models relying on land use data such as runoff coefficients, event mean concentrations (EMCs), or build-up/wash-off coefficients. Except in the Los Angeles Region, the use of land use data is not standardized. Outside of the Los Angeles Region, modelers can select their own land use terms potentially introducing uncertainty in modeling output – especially if model validation data is limited and uncertainty is unknown. In the Los Angeles Region, modelers are specified to use a relatively rigorous land use data set, but this data set is over 15 years old. Data end users are concerned that land use parameters (particularly water quality parameters) may have changed over the last decade and a half based on changes in building practices and source control.

The goal of this project is to update the land use data available for RAA, providing a common platform for modelers to access comparable high-quality data and reducing uncertainty from one watershed to another. The product from this project will be a publicly accessible data set with updated EMCs, including distributions of EMCs for calibration and uncertainty analysis. Land uses targeted will include those identified in the Los Angeles RAA guidance, and other land uses (or derivatives of existing land uses) as available. The EMCs will cover the entire State, with regionalized EMCs where applicable.

Tasks:

Task 1: Review existing land use data to identify priority knowledge gaps

Since several land use data sets already exist, this task will summarize the current state of information and identify the priority areas for additional data requirements. The prioritization will include criteria such as land uses, geography, timeliness, hydrologic or chemical parameters, and model applications.

Task 2: Compile and organize priority monitoring land use data

This task will focus on searching and retrieving the data necessary to fill priority data gaps. The data may arise from recent MS4 monitoring, NPDES special studies, academic research or other sources. All data will be evaluated for quality assurance and quality control, and validated before finalizing in the project data management system.

Task 3: Analyze data to assess differences among land uses and ranges of uncertainty

Based on the data compiled in tasks 1 and 2, conduct data analysis to determine if old land use data is different from newer data (and if subsequent model updates are necessary). Also, conduct analysis to estimate uncertainty due to land use data, and provide recommendations to how models should calculate and standardize land use uncertainty for decision makers.

Task 4: Create the public data platform for data users

This task will create the access point for data users to retrieve the land use data for modeling or other needs. Several options exist including SMARTS, CEDEN, or open data portal. The data set will be fully qualified and documented, with options to update the data set as new data becomes available.

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Scope of Work: Reducing Uncertainty Through Enhanced BMP Effectiveness Data

Stormwater best management practices (BMPs) are a critical element of reasonable assurance analyses (RAA). Currently, BMPs are utilized in the RAA process for planning what structural and non-structural activities will achieve water quality standards. Thus, predicting the future likelihood of achieving water quality standards is largely dependent on how well the RAA can represent BMP effectiveness at volume and/or pollutant reductions. Imprecision or inaccuracies in BMP performance can lead to uncertainty in RAAs.

Current RAA models often simulate BMPs based on existing effectiveness data from other studies such as the International BMP database (http://www.bmpdatabase.org/). However, existing data are rarely region specific where factors such as rainfall, geology, and/or design specifications are similar to the RAA application. To compound this uncertainty, median or average BMP effectiveness values are often utilized when effectiveness may range one or more orders of magnitude based on a large number of factors including BMP design, rainfall intensity or volume, influent concentrations, and/or maintenance operations.

The goal of this project is to update the information on BMP effectiveness for RAA applications specific to the various regions of California. The product from this project will be a compilation of region-specific BMP effectiveness data, and public access to the median and range of these BMP effectiveness data for inclusion in RAA modeling of future scenarios. Where data gaps exist, either new data will be collected, or a workplan for future data collection will be created.

Tasks:

Task 1: Review what structural and non-structural BMP data will be compiled

There are many types of BMPs and many ways to assess effectiveness. This task will prioritize what BMP effectiveness data will be compiled. For example, several BMP effectiveness endpoints exist in the literature including effluent concentrations, percent reductions, or efficiency curves. This task will evaluate which effectiveness approach(es) will be collated for the final product.

Task 2: Compile California-Specific BMP Effectiveness monitoring data

To compliment the International BMP Database, data on BMP effectiveness (and necessary metadata) will be compiled from throughout California including SWRCB Water Bond grantees (i.e., Props 13, 50, 84, 1), local bonds (i.e., Prop O), and local implementation (TMDL or NPDES requirements). This data set will require enhanced aspects for data management and validation to ensure accuracy. In addition, these data should interact with other SWRCB data systems such as SMARTS, CEDEN, or open data portal.

Task 3: Update effectiveness data for RAA utilization.

Empirical volume and water quality efficiency data will be analyzed by BMP type and regions of the state. Additional analysis will focus on intra-regional differences potentially confounding BMP effectiveness such as rainfall and geology. Output will include the median and distribution of BMP effectiveness data for maximum applicability at watershed-specific RAA models. Where, BMP effectiveness data are limited or missing, future data collection will be recommended.

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Scope of Work: Assessing Model Sensitivity to Address Uncertainty

Currently, Reasonable Assurance Analyses (RAA) is built upon watershed models calibrated and validated to existing conditions. Only when watershed models quantify existing conditions well can modeled predictions of future scenarios be conducted with certainty.

There are a number of different watershed models utilized around the state for RAA. Some models are simple with relatively larger assumptions, but less overall data requirements. Alternatively, some models are more complex requiring fewer assumptions, but also require greater data requirements. Simple models typically predict larger spatial and longer temporal scales (i.e., annual averages) while complex models can predict at smaller spatial and shorter time scales (i.e., hours). Each has their application, depending on the watershed implementation strategies being pursued, and the amount of uncertainty managers are willing to accept.

The goal of this project is to compare uncertainty among various watershed models by examining sensitivity to priority model parameters. Direct head-to-head comparisons of various models will be conducted relative to "truth" in a known watershed. Then, individual model input parameters will be varied to ascertain how sensitive each model is to that parameter. When evaluating RAA output, this type of analysis will empower managers (both regulated and regulatory) to focus on the variables most important to uncertainty, and also empower modelers to improve their modeling system. The product from this project will be a report documenting sensitivity analysis, and recommendations for how to conduct standardized sensitivity analysis for all RAAs statewide.

Tasks:

Task 1: Select candidate water quality models and recruit volunteer modelers

There are a wide range of watershed models being used throughout California. This task will define the most commonly used models for the sensitivity analysis in task 3. In addition, this task will select the modelers to conduct the analysis. Letting RAA practitioners conduct the modeling will remove any potential bias from a single entity conducting all modeling.

Task 2: Generate model set-up information

This task will create the "virtual" watershed to be used in the project. The same model set up parameter specifications will be given to all modelers identified in Task 1. Parameters will include watershed delineation, topography, climate and precipitation, geology, land use, routing, amongst others. In addition, sufficient information on hydrology and water quality will be provided to all modelers for calibration and validation.

Task 3: Evaluate model accuracy.

This task will provide standardized model input data for estimating watershed flows and volumes, plus concentrations and loads. Modelers will use their calibrated and validated models to generate standardized output and each model's results will be compared to field collected data.

Task 4: Evaluate relative model sensitivity

Based on the outcome from Task 3, a list of critical model parameters will be varied, and the magnitude of change in standardized model output will be compared. Parameters with the largest relative change in model output are the most sensitive. The change in model parameters will be based on the distribution of data observed in the field.

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Appendix E: Elements of Reasonable Assurance Analysis

Elements of RAA can build off of the seven ACP principles identified in Order 2015-0075. From those principles, the seventh ACP principle is particularly relevant for devising elements of RAA because it directly addresses the types of analysis that comprise RAA:

> "The alternative compliance path should have rigor and accountability. Permittees should be required, through a transparent process, to show that they have analyzed the water quality issues in the watershed, prioritized those issues, and proposed appropriate solutions. Permittees should be further required, again through a transparent process, to monitor the results and return to their analysis to verify assumptions and update the solutions. Permittees should be required to conduct this type of adaptive management on their own initiative without waiting for direction from the regional water board."

It is noteworthy that rigor and accountability were also addressed by the same order in Conclusion 9, which states,

> "In order to add greater rigor and accountability to the process of achieving receiving water limitations, we revise the WMP/EWMP provisions to add that the Permittees must comprehensively evaluate new data and information and revise the WMPs/EWMPs, including the supporting reasonable assurance analysis, by June 30, 2021, for approval by the Executive Officer."

The deadline of 2021, six years out from the date of the order, indicates the need for time to allow for data collection and analysis. It also indicates that addressing rigor and accountability can be accomplished over time and is not necessarily immediately achievable.

Incorporating the stated needs for rigor, accountability, and long-term planning into the findings above, the following elements of RAA are proposed to achieve increased assurance from the regulatory perspective that, when implemented, the watershed plan will result in compliance with RWL requirements in MS4 permits, including loading limits set by TMDLs. These limitations are met by demonstrating that either MS4 discharges comply with quality requirements (concentration or load) or receiving waters do not exceed water quality standards. It is recognized that most modeling approaches will choose the former, however, it may more valuable in some circumstances to demonstrate receiving water standards will be met (e.g., MS4 may contribute to non-point source pollutant abatement outside the urban area sufficient to meet receiving water standards in the receiving water). Consequently, the elements should not be construed as limiting the discretion exercised by the discharger in demonstrating how compliance is demonstrated or achieved.

Element 1: RAA Supports Planning

Planning and implementation activities that MS4 permittees plan for and undertake to attain permit compliance status shall be supported.

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Element 2: RAA Quantifies Links between Actions and Water Quality Targets

Detailed quantifications and modeling to assess relationships between water quality targets and planned implementation activities in the watershed shall be used.

Element 3: RAA Uses Peer-reviewed Methods and Best Available Data

Models and quantification methods shall use the best available data. Methods shall be peer-reviewed. RAA shall use modeling and quantification methods that best address permit compliance analysis requirements based on available data, expertise, and resources. Best available data may require merging region-specific data with state and national datasets to fill data gaps en route to addressing critical needs for permit compliance and reasonable assurance [1,2].

Element 4: RAA Communicates Uncertainty

Uncertainty will be characterized, minimized, and communicated, as well as reduced over time by specifying the needed data collection.

The ways uncertainty in models inputs (e.g., land use, water quality, hydrology, and soils) and outcomes (including future BMP behavior) affects the likelihood that the prescribed treatments (in size, type, and location) will be sufficient for MS4 discharges to comply with RWLs shall be communicated. Assessments or quantifications of uncertainty should be undertaken, which could include a sensitivity analysis of input values, Monte Carlo methods to develop distributions of modeled outcomes, or other methods (Zoppou 2001, Obropta and Kardos 2007). Reasonable estimates of ranges for input parameters should be used (RWQCB 2014).

Uncertainty shall be reduced over time by the collection of data that will verify or clarify assumptions of the model inputs and address the variables of greatest uncertainty. It is acknowledged that parameters with the most significant effect on modeled outcomes may not be the parameters that contribute most to analysis uncertainty. Data collection needs will likely evolve to address areas of greatest uncertainty as part of adaptive management

Element 5: RAA is Transparent

To ensure that RAA is an open and transparent process, RAA shall disclose the procedures used to identify modeling and quantification methods. Transparency is achieved by communicating data selection decisions and differentiating between data used for calibration and validation. Transparency is also achieved by communicating how TMDL requirements are translated into targets within models. For example, TMDL load allocations attributed to all MS4s may need to be allocated to more specific subwatersheds associated with stormwater management authorities.

Element 6: RAA Avoids Unsupported Simplifications

Methods to reduce the complexity of analysis and modeling used in RAA shall use the best available scientific information in making simplifications or streamlining procedures. For instance, representing fate and concentrations of multiple pollutants using a single indicator pollutant is only appropriate when pollutant behavior, source areas, and response to removal mechanisms are similar. Pollutant-specific analysis is appropriate when broader classes of pollutants have different fate and transport

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[1] The tradeoff between the uncertainty associated with small local datasets and the uncertainty associated with location factor of external datasets needs further exploration.

[2] The need and benefit of standardization of datasets for communities that lack data needs evaluation

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characteristics. Pollutant-specific analysis is also appropriate when source areas (e.g., dispersed and non-uniform distribution of legacy pollutants) or control strategies are unique (e.g., identification and repair of leaking septic). As another example, using hybrid mathematical models in support of RAA that combine statistical and numerical modeling shall be undertaken as appropriate for analysis goals and data availability, but simplifications should not preclude the reasonable pursuit of additional watershed data that enhances long-term analysis and modeling capacity among permittees.

Element 7: RAA Includes Validation Milestones at Appropriate Scale

Validation milestones should align appropriate goals and outcomes with achievable timelines. Initial compliance actions undertaken based on RAA likely will not provide specific BMP locations, assess optimal costs, or maximize multiple benefits. ACP compliance milestones requirements include data reporting to demonstrate compliance. These can also be appropriate milestones to validate model assumptions by revisiting RAA procedures.

Watershed-scale water quality improvements likely require converting or mitigating a significant area of hardscape or effective impervious area. Monitoring procedures to assess watershed quality outcomes early in ACP implementation would be most effective in verifying site-specific performance through targeted monitoring and evaluation procedures, as too few BMPs would be installed to decipher statistically-relevant watershed scale effects. Later in ACP implementation, continued monitoring and modeling can look to discern watershed-scale improvements, as municipalities have had more opportunities to build revenue sources and get projects built through inclusion in capital improvement pipelines.

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