Review of Seven Scientific Reports utilized in the Development of the Central Valley-wide Salt and Nitrate Management Plan's (SNMP's) Salinity Management Strategy and Nitrate Permitting Strategy

Pursuant to the letter dated March 5 of Gerald W. Bowes, PhD, Manager, Cal/EPA Scientific Peer Review Program; the letter dated March 7, 2018, of Glenn T. Meeks, PG, Senior Engineering Geologist, CV-SALTS Program; and the letter dated March 15, 2018, of Dr. Daniel T. McGrath, Ph.D., University Program Manager, Interagency Agreement for Scientific Peer Review, this review evaluated the seven scientific reports and the accompanying supplementary documents that were utilized in the development of salt management strategy and nitrate permitting strategy. As per discussions with Dr. McGrath, the focus of this review was on conclusions 1 and 2. Conclusion 1, containing three parts a, b, and c, is on the salt management strategy with an out-of-valley solution, while Conclusion 2 deals with nitrate implementation measures.

Context of the SNMP Studies:

Before commenting on parts a, b, and c of Conclusion 1, it is considered appropriate to briefly revisit the context for the Salt and Nutrient Management Plan (SNMP) that is being developed under the jurisdiction of the Central Valley Regional Water Quality Control Board (Central Valley RWQCB) as enumerated in Attachment 1. In order to achieve the goal of ensuring safe, reliable and affordable drinking water supply, preserving the global competitiveness, and sustaining the long-term viability of agriculture, a comprehensive salinity management program has been developed. The salt management strategy is three pronged. First, it develops a prioritization and optimization strategy for salinity study with the overall goal of defining the conceptual design of SSALTS for a feasibility study identifying appropriate regional and sub-regional projects. Second, it does environmental permitting, securing funding, and engineering and design of salt management projects. Third, it deals with the construction and operation of salt management projects.

The Central Valley Water Board needs strategies for addressing both short-term and long-term salt management needs and additional regulatory framework. Short-terms salt management may include identifying salt sources, evaluating emerging technologies for Total Dissolved Solids (TDS) for locally managing salt, and working with ILRP Coalition groups. Short-term projects must be in conformity with long-term salt management solutions. Long-term salt management may entail initial planning and development phase, construction of base regulated brine line, and phased expansion of the system as needed. The management strategy for implementation is aimed at controlling the rate of degradation, achieving long-term sustainability, and restoring groundwater basins.

It is considered appropriate to briefly revisit the basis of the Salt and Nutrient Management Plan (SNMP) that is being developed under the jurisdiction of the Central Valley Regional Water Quality Control Board (Central Valley RWQCB) for achieving three main objectives: (1) provide safe drinking water for impacted communities; (2) balance current salt and nitrate loading to groundwater; and restore impacted groundwater aquifers, where reasonable and feasible. The

SNMP comprises two main strategies: a salt management strategy, and a nitrate permitting strategy. Constituting the basis of the SNMP and these two strategies is four studies.

The first study was the Initial Conceptual Model (ICM) which provided a methodology for determining the spatial distribution of salt and nitrate within the Central Valley. The foundational data thus yielded by the ICM was employed for Strategic Salt Accumulation Land and Transportation Study (SSALTS) and Nitrate Implementation Measures Study (NIMS) which aimed at evaluating options for sustainable management of accumulating salt mass and nitrate mass. The fourth study was the Aggressive Restoration Study (ARS) which dealt with the feasibility and practicability of long-term restoration of nitrate-impacted groundwater aquifers.

Review of Initial Conceptual Model:

The ICM (Task #5) aims at a concept level analysis of surface and ground water balance as well as salt and nitrate load balances for the entire Central Valley. The methods employed for assessing salt and nitrate concentrations in groundwater and surface water are sound. Data and decision matrices have been developed in a satisfactory manner. Methods for calculating salt and nitrate balance are well founded. The report is concluded with recommendations of assessment criteria for identifying hotspots and high priority areas or sub-regions. The assumptions made in the ICM methodology have been clearly stated and do not pose a serious restriction to the use of ICM data.

The ICM Technical Services Tasks 7 and 8 deal with salt and nitrate analysis for the Central Valley and a focused analysis of two subregions: Modesto and Kings. This report describes the approach, milestones, and deliverables. It is a well-conceived, well-thought out, and well-organized workplan to achieve the stated objectives.

Using the data from the ICM study, the Strategic Salt Accumulation Land and Transportation Study (SSALTS) was conducted for the SNMP with the objective to identify a range of viable Central Valley alternatives for salt disposal. The findings of the SSALTS will serve as a guide for establishing regional salt management policies and amending the existing Central Valley RWQCB Water Quality Control Plans (Basin Plans) in order to facilitate salt disposal in a manner beneficial to the region and consistent with the State Water Resources Control Board (SWRCB) Recycled Water Policy. The SSALTS is comprised of three parts each constituting a phase: (1) selection of representative salt accumulation study areas, (2) development of potential salt management alternatives, and (3) selection of acceptable salt disposal alternatives.

Review of Phase 1 Report:

The Final Phase 1 Report is on the identification and characterization of existing salt accumulation areas. Using a set of four criteria 10 representative areas or sites were selected which included City of Dixon, City of Tracy, Hilmar Cheese, Industrial Food Processing Facilities, Red Rock Ranch, Grasslands Water District, Stevinson Water District, Tulare Lake Bed, Westside Regional Drainage Plan, and San Luis Unit Ocean Disposal. Each study area was characterized, based on physical, land cover, and institutional attributes; sources of water and of salt; salt accumulation capacity; cost/benefits of current salt management; and institutional barriers. The study areas were analyzed for their longevity and sustainability in the long term. Regulatory background, including federal and state laws and regulations, state water board policies, discharge permits, state and

regional programs, and Lower San Joaquin River Total Maximum Daily Load (TMDL), was then comprehensively reviewed. The sources of salt are not the same in all study areas. For example, in the city of Dixon, it is the use of water softening that introduces chloride and sodium to the sewer system and the wastewater treatment facility does not remove salt from influent wastewater. However, the city has implemented programs to reduce salinity, such as water softener incentive program. In a similar vein, other study areas are analyzed and the overall discussion of each study area is quite informative.

The report clearly establishes that salt emanates from a variety of sources and each study area has unique sources and potential sinks and therefore requires different management solutions to achieve long-term sustainability of salt disposal management. Salt mitigation entails (1) source control, (2) treatment of salt, and (3) disposal. Then, potential salt management strategies are analyzed for each study area. For long-term sustainability, disposal methods are analyzed keeping in view several aspects that include: implementability, salt disposal capacity, regulatory challenges, institutional requirements, capital and operation and maintenance costs, potential environmental issues, and public acceptance.

Also, the report deals with sustainability timeframes and planning horizons beyond typical 50-yeat engineering time horizons keeping in view the uncertainty associated with extrapolations beyond this period. The uncertainty will also occur due to a number of trends that we face today as enumerated by World Economic Forum in its 2011 report. The long-term sustainability of each study area is then analyzed. The report is concluded with a discussion potential alternative disposal options and next steps. On the whole, the report is well done.

Review of Phase 2 Report:

The Final Phase 2 Report on Development of Potential Salt Management Strategies deals with the development of long-term alternatives for salt disposal which include in-valley, out-of-valley, and hybrid strategies. As the name suggests, in-valley alternatives utilize study areas themselves or potential new areas in the Central Valley. Out-of-valley alternatives involve transporting salt out of the Central Valley. Hybrid alternatives combine in-valley and out-of-valley alternatives. This report provides planning-level information on salinity strategy alternatives considering various combinations of source control Best Management Practices (BMPs), treatment options, and storage/disposal/use options. It determines the magnitude of salt accumulation and strategies that could mitigate accumulation.

Any strategy for salt management will depend on the salt accumulation and potential regulatory target. Both these aspects are discussed in considerable detail. The report discusses the initial conceptual model for estimating salt and nitrate fluxes and loads to initial analysis zones. The USGS Central Valley Hydrologic Model was employed to establish the basis for water balance determinations.

Source control measures include source control BMPs, land management, and de-designation of management zones or Initial Analysis Zones (IAZs). These may encompass municipal, agriculture, food processing industry, other industries.

Desalination and brine minimization technologies are then elaborated. Desalination technologies include membrane based and thermal technologies. Membrane based technologies are reverse osmosis and electrodialysis reversal. Emerging treatment technologies that are said to be more efficient and cost effective are forward osmosis, membrane distillation, and other proprietary technologies. Concept level capital cost estimate for salinity treatment was developed, based on estimated flow requirements and a number of parameters related to initial analysis zones.

Any source that produces concentrated brine or salt residue must entail either reuse, storage, or reuse. Brine storage, disposal and use options are discussed, that include deep well injection; use for hydraulic fracturing; and San Joaquin River real-time management that includes stakeholder participation, real time monitoring, data management, predictive modeling of flow and salinity, and physical infrastructure; salt accumulation areas and landfilling; ocean disposal; and salt marketability.

Brine and salt transportation options include trucking and rail, regional pipeline, concept level cost estimate for regional brine line. Salt management includes four alternatives and costs of alternatives are summarized. Potential salt disposal alternatives are evaluated to determine acceptable alternatives for implementation.

Overall, this is a comprehensive report and is well done. It considers almost all essential aspects.

Review of Phase 3 Report:

The Phase 3 Report on Evaluation of Potential Salt Disposal Alternatives to Identify Acceptable Alternatives for Implementation discusses feasibility criteria as a basis for evaluating each alternative and does feasibility analysis. The result is the prioritization of acceptable salt disposal alternatives which can be implemented for salt management in the Central valley. This entails the development of planning level feasibility criteria for evaluating alternatives, screening level feasibility analysis of salt management alternatives, and preparation of the SSALTS report containing results of feasibility analysis, conclusions and recommendations, and recommendations of salt management alternatives for inclusion in SNMP.

Feasibility criteria included technical feasibility, salt capacity of disposal methods, regulatory challenges, institutional requirements, capital and operation and maintenance costs, potential environmental issues, public acceptance, funding, and compliance credits. Each criterion was assigned a weight ranging from one to five, with regulator, cost and compliance credits being assigned a weight of four and all other criteria assigned a weight of three.

Feasibility analysis of salt mitigation alternatives comprised summarizing results of analysis and scoring alternatives, and ranking of feasibility analysis of salt management and disposal options. It is quite a comprehensive report cover all essential elements pertaining to salt disposal alternatives.

Review of NIMS Final Report:

This study discusses nitrate contamination in groundwater basins in Central valley and develops appropriate implementation measures using a phased approach to mitigate nitrate concentration that will lead to safe drinking water, reducing or eliminating impacts on drinking water resources, and implementing managed restoration activities to restore beneficial uses of groundwater. These measures are to be incorporated into the SNMP. Defining the objectives of NIMS, the study provides a comprehensive discussion of hydrologic and geologic features of the Central Valley comprising the Sacramento River Hydrologic region, the San Joaquin Hydrologic Region, and the Tulare Hydrologic Region. It then discusses existing nitrate mitigation measures, including irrigated land regulatory program, dairy monitoring program, and waste discharge requirements. Building on these measures, it discusses complementary planned measures using a phased approach that includes a schedule for implementation, IAZ-level nitrate and TDS prioritization, estimation of loading and trends, and prioritization of groundwater basins. Then, nitrate implementation measures, including source control measures, groundwater remediation, and alternate water supplies, are presented in detail. Next, a comprehensive program of implementation for nitrate and TDS is presented. This is an excellent report covering in great detail all pertinent aspects related to nitrate implementation measures.

Alta Irrigation District (AID) Management Zone Archetype Analysis:

Alta Irrigation District (AID) Management Zone Archetype Analysis is one of the tasks to inform the larger Central Valley Salt and Nitrate Management Plan (SNMP) planning effort and future local /regional analyses. This analysis, as part of the SNMP, serves to validate, on a spatially refined basis, the application of selected policies, data analysis methods, and salt and nitrate management approaches being considered by CV-SALTS. The analysis included an analysis of several management scenarios using the AID management Zone (MZ) model to determine the effects of managing salt and nitrate on groundwater quality in the MZ area over both near-term and long-term time horizons. Five scenarios, including a baseline scenario and five management scenarios, were modeled. Also done was an aggressive restoration alternative modeling scenario regarded as critical for CV-SALTS. This is detailed in a Technical Memorandum which describes the rationale, methodology, and results of model validation, including sensitivity analyses, and implications and lessons learnt. The modeling effort is well conceived and well done. The report is highly informative and clearly shows how a targeted approach can help the CV-SALTS to achieve its objectives.

Comment on Conclusion 1:

With the above brief review of the documents provided, we can now comment on Conclusion 1 and its components. **Conclusion 1** states that annual salt accumulation must be addressed with an Out-of-Valley solution. Based on the documents provided, this conclusion seems reasonable. However, in-Valley solutions must not be discarded outright. The in-Valley solutions may include reducing the influx of chemicals in agriculture as well as reducing the sources of salts coming to the valley. Reducing the salt through wastewater and other sources is admirably discussed in the report. However, greater emphasis and effort must be put in to stem the flow of salt at the source itself. Likewise, greater use of organic manure, such as compost, can significantly reduce the use

of chemical fertilizers in agriculture. The use of organic manure is already on the rise. There can be other others to reduce the sources of salt. In other words, in the long run it will pay rich dividends to solve the problem at the source rather than creating it in the first place and then solving it.

Comment on Conclusion 1a:

Data generated by the WARMF watershed modeling tool used in conjunction with the USGS CVHM and SWAT model was appropriate to evaluate ambient groundwater quality and changes in groundwater quality within the Central Valley and resulted in assumptions regarding import and export of salt that were reasonable estimates for the Central Valley. First, it will be appropriate to revisit the WARMF model and the SWAT model that were employed to compute salt and nitrate loading to groundwater, and the CVHM that was used to model the fate and transport of salt and nitrate in groundwater within the Central Valley.

A watershed model and a decision support system, called Watershed Analysis Risk Management Framework (WARMF), developed by Herr and Chen (2012), was employed to develop a watershed management plan for controlling point and non-point source pollution and assessing hydrologic and water quality constituents which are fundamental to SSALTs. This model provided the data needed for the SNMP. The model has a built-in geographical information system (GIS) and has a graphical user interface (GUI). The model is arguably physically based and is mechanistic. It simulates 13 hydrologic parameters and 43 water quality constituents. WARMF simulates snowpack accumulation, snowmelt, canopy interception, throughfall, evaporation and transpiration (ET), infiltration, percolation, groundwater lateral flow, and surface runoff. The kinematic wave approximation is utilized to route river flow. Flow is routed downstream between river segments and reservoirs according to the drainage network. Radiative heat balance is used to calculate temperature and evaporation from river and lake surfaces. The model developers do not explicitly state the hypotheses and assumptions made in simulating these processes. Nor do they specify the limitations for its application. The model can be used to develop a watershed management plan for controlling point and non-point source pollution. Looking at model results, it is clear that the model gives at best a first approximation of hydrologic and water quality constituents. However, for practical purposes, the model may accepted as a reasonable approximation. It has an advantage in that it simulates real conditions. The data generated by the model can be regarded as reasonable for the Central Valley.

The SWAT (Soil and Water Assessment Tool), originally developed by Arnold from the U.S. Department of Agriculture (USDA) and expanded by Neitsch, Arnold, Kiniry and Williams from the USDA Agricultural Research Service (ARS) and Texas A&M AgriLife Research, is a watershed scale model for predicting the impact of land management practices on water, sediment, and agricultural chemical yields in watersheds with varying soils, land use, and management conditions over long periods of time. The model is physically based which is arguable and continuous time. It is a state-of-the art model and is widely used all over the world. The assumptions and the hypotheses employed in the model are reasonable and can be regarded as based on acceptable hydrologic scientific principles.

For estimating water budget, the Central Valley Hydrologic Model (CVHM) was employed. The CVHM comprises a comprehensive Geographic Information System (GIS), a texture model to characterize the aquifer system, a numerical hydrologic model with the Farm Process (FMP) for estimating water-budget components, and a simulator for assessing hydrologic conditions. Each of these components is based on sound science. It is a state-of-the art hydrologic model. The data generated by the CVHM can be considered to be of high quality.

Of course, other models than WARFM and SWAT can be used to generate data for the SNMP which may be equally good but it will be difficult to argue that those data will be of superior quality to those generated by these models. Likewise, other models can be employed to determine the fate and migration of salt and nitrate in groundwater but CVHM does just as good a job as other models would.

Comment on Conclusion 1b:

The management options identified to treat and dispose of the annual salt accumulation included a reasonable range of feasible treatment and disposal measures that can be implemented in the Central Valley.

The salt management disposal options includes agricultural reuse area and evaporation /long term storage under the in-valley category; hydraulic fracturing and deep well injection, salt storage/disposal under the in-valley category; and real-time management and ocean disposal under the out-of-Valley category of salt disposal.

The treatment options include both mature and emerging technologies. Mature desalination technologies include membrane t-based technologies and thermal technologies. Emerging technologies include forward osmosis, membrane distillation, zero discharge distillation, aqua4 system from water FX, sulfate-based electrolysis processing, elemental renewal system, brine treatment system, effluent free desalination technology, Calgon Carbon's catalytic treatment of brine, and graphene membrane technology.

Thus, the management options employed in the studies encompass a broad range and are quite comprehensive in that they cover a viable range of practical treatment and disposal measures. It is hard to think of other measures than what is already included in the plan.

Comment on Conclusion 1c:

This conclusion states that a brine line is the most reasonable alternative to remove excess salt accumulation in the Central Valley. This conclusion seems reasonable but there can be other alternatives that do not permit the accumulation of salt in the first place. Such alternatives should be explored. Until then, the conclusion is acceptable.

Comment on Conclusion 2:

This conclusion states that nitrate contamination in some locations may not be reasonably treated to achieve drinking water quality. Geology and nitrate concentrations in some locations are

conducive to restoration. Reduction of nitrate levels in groundwater is possible in certain geologic settings (sandy soil conditions and relatively shallow groundwater levels). However, even with significant restoration activities, it may take 40 to 70 years to achieve drinking water standards in groundwater, and in some cases, even longer. This conclusion is very reasonable and is based on sound geological considerations and can be accepted without dispute.

Overall Comment:

All things considered, the work reported in the seven scientific studies is quite comprehensive and is based on solid science. The models used are state-of-the art and the analyses, including cost estimates, reported are commendable. Conclusions reached are acceptable. However, alternatives for mitigation of salt and nitrate loading which do not permit salt accumulation and nitrate loading in the first place should be explored. Until such alternatives become feasible, the proposed measures seem viable. Overall, the work is well done.