STETSON ENGINEERS INC.

WATER RESOURCE PROFESSIONALS SERVING CLIENTS SINCE 1957

**DRAFT**

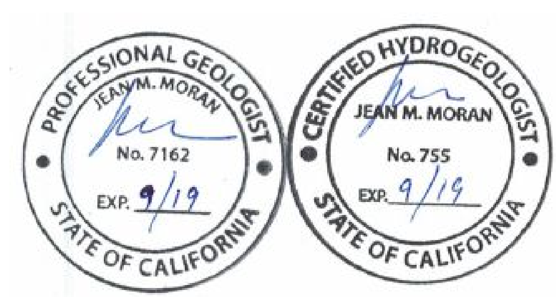
# Review of the Indian Wells Valley Groundwater Basin Model documented in *Groundwater Resource Sustainability: Modeling Evaluation for the Naval Air Weapons Station, China Lake, California*,

**by Desert Research Institute, September 2016**
**for Naval Air Warfare Center Weapons Division**

Prepared for:
**Indian Wells Valley Groundwater Authority (IWVGA)**

December 6, 2017

At the request of the Indian Wells Valley Groundwater Authority, Stetson Engineers Inc. reviewed the Naval Air Weapon Station's groundwater model developed by Desert Research Institute (DRI) to evaluate the model's suitability for supporting the development, implementation, and performance of the IWVGA Groundwater Sustainability Plan (GSP). This review included evaluating DRI's model documentation, meetings with DRI modelers and Navy personnel, a hydrogeologic site visit, and assessment of model output files. The guidelines used to evaluate the model included GSP Emergency Regulations, California Department of Water Resources (DWR) best management practices for modeling, and the U.S. Geological Survey's recommendations for evaluating groundwater models. The results from this review recommend that the model be updated, re-calibrated, and adapted to address the development, implementation and performance of the IWV GSP.




Jean M Moran, PG, CHG
Supervising Hydrogeologist

The Indian Wells Valley (IWV) groundwater basin was identified by the Department of Water Resources (DWR) as a 'critically overdrafted basin'[1], and is required to develop a plan to sustainably manage its groundwater resources by January 31, 2020. Plan implementation and management actions are required to have the basin under sustainable management within 20 years, by 2040, and a 50-year planning horizon through 2070.

The purpose of this review of the Naval Air Weapons Station (NAWS) numerical groundwater model (model) is to 1) evaluate its efficacy in describing the groundwater basin structure, hydrogeologic characteristics, and inflows/outflows, and 2) determine its suitability for supporting the implementation of the IWVGA Groundwater Sustainability Plan (GSP) through 2040. The intended GSP modeling effort is to provide tools necessary for estimating the groundwater aquifer's hydrologic water budget (GSP §354.14), identifying data gaps (GSP §354.12), assessing groundwater level and quality trends (GSP §354.16), determining sustainability criteria (GSP §354.22), and evaluating different strategies to provide long-term sustainable groundwater management for the Indian Wells Valley groundwater basin (GSP §354.44). The model would also provide ongoing analysis and support as needed for the annual reports and periodic evaluations that will be required for submittal to DWR (GSP §356.2).

This review included evaluating model documentation (DRI, 2016 and 2017), meetings with DRI modelers and Navy personnel, a hydrogeologic site visit, and assessment of model output files. The guidelines used to evaluate the model included GSP Emergency Regulations (GSP, 2016), DWR best management practices for modeling (DWR, 2016a), and U.S. Geological Survey's recommendations for evaluating groundwater models (Reilly and Harbaugh, 2004). The results from this review recommend that the model be updated, re-calibrated, and adapted to address the development, implementation and performance of the IWV GSP.

## 1 INTRODUCTION

NAWS has offered to provide the IWV Groundwater Authority (IWVGA) with in-kind services for model development and use for the GSP. NAWS retained Desert Research Institute (DRI) to develop a numerical groundwater model for the Indian Wells Valley groundwater basin. Model construction, calibration, and future scenarios were documented in *Groundwater Resource Sustainability: Modeling Evaluation for the Naval Air Weapon Station, China Lake, California* (DRI, 2016). NAWS continues to support ongoing model development as new data become available. The model was recently updated in 2017 to improve model calibration by incorporating two regional faults as groundwater barriers (DRI, 2017).

[1] SGMA (Sustainable Groundwater Management Act) definition: "A basin is subject to *critical overdraft* when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts." (http://www.water.ca.gov/groundwater/sgm/cod.cfm)

The existing model was developed to support NAWS's mission at China Lake. The purpose of developing the calibrated transient model was to predict groundwater level declines and the potential impact on the Navy's water supply wells. Its focus was to evaluate the long-term effects of overdraft within the basin on the Base's water resource supply. Given that purpose, the model was calibrated to rates of drawdown within the basin.

The GSP modeling effort will need to focus on groundwater levels and the changes of groundwater in storage over time, past and future. Model simulations will need to provide water budget analyses, including zone budgets for different potential management areas. The GSP model will need to be updated through current measured data, and projected through the 2070 planning period.

## 2 MODEL REVIEW CHECKLIST FOR GSP APPLICATION

Existing hydrogeologic reports (see reference list) and monitoring data were reviewed to understand the elements of the conceptual model that were being simulated by the numerical model. A groundwater model review checklist (Attachment A) was developed based on the U.S. Geological Survey's guidelines (Reilley and Harbaugh, 2004), GSP Emergency Regulations (GSP, 2016), and DWR modeling best management practices (DWR, 2016a).

The model review evaluated the hydrogeologic representation of the available historical data and conceptual model, model construction, boundary conditions, aquifer properties, and fluxes (recharge, pumping, evapotranspiration). The model output file was assessed for water budget consistency and numerical convergence criteria. Steady state and transient model calibration was evaluated based on the hydrogeologic conceptual basin model.

The attached review checklist provides specific comments and notes for adapting the existing model to the GSP requirements. Some of the comments provide recommendations or identify modeling elements to consider. Other comments state concerns, or requirements that need to be incorporated for the GSP. Some of the primary model updates that need to occur are:

- Develop stress periods for two planning horizons – 20 years for achieving the sustainability goal (operating the basin within the sustainable yield), and 50 years for maintaining sustainable aquifer conditions.
- Incorporate variable hydrologic conditions, and seasonal fluxes (seasonal or monthly stress periods).
- Calibrate the transient model to measured groundwater levels, stream gages, rate of drawdown, and sub-regional water budget elements.

Some of the recommendations for model improvements include:

- Consider using the unstructured grid (USG) package to incorporate smaller cell size along the southern and western boundaries with the Base. This will improve accuracy of the head near pumping wells, and allow the pumping stresses to be more defined in these sub-regions, while maintaining the larger grid spacing in areas with few stresses.

- Consider assigning the recharge at the tributary mouths to account for the coarser sediments and conveyance of stormflow runoff. Have the recharge zones correlate with precipitation to account for different hydrologic conditions.
- Evaluate groundwater levels for seasonal signatures, especially near the mountain blocks.
- Incorporate Brown and Caldwell (2009) lithologic discretization files into the GSP model to improve the hydrogeologic representation of aquifer sediments. (note: this study was completed for IWVWD).
- Have IWV-TAC provide seasonal pumping data/estimates for domestic, agricultural, mining, and municipal wells for model input.

# 3 MODEL ELEMENTS REQUIRED TO PROVIDE ANALYSIS FOR THE GROUNDWATER SUSTAINABILITY PLAN (GSP)

The existing model will need to be updated and re-calibrated to support GSP development. It will be used to assess historical groundwater conditions, establish a sustainable water budget, develop sustainable management criteria, and evaluate projects and management actions. Following are some of the key components that the model will need to address for the GSP.

## 3.1 MODEL CALIBRATION TO HISTORICAL GROUNDWATER CONDITIONS (GSP§ 354.16)

The GSP Model will be used to evaluate how groundwater responds to the changes in hydrologic conditions on seasonal, annual, and decadal timeframes. The GSP Model will be calibrated to groundwater levels, rates of drawdown, changes of groundwater in storage, and a balanced water budget. These components of the model will be the foundation for the IWV-TAC and IWVGA to develop the water resource management changes required to bring the basin into a sustainable balance.

## 3.2 WATER BUDGET (GSP§ 354.18)

A fundamental accounting of the volume of water within the basin (inflow, outflow, and change in storage) is required to manage the basin. Kern County Planning and Community Development Department retained Todd Engineers (2014) to summarize previous studies and estimate current supply and uses of water resources in the basin. Todd's study provides an initial estimate of the historical water budget. In addition, the United States Geological Survey (USGS) Recharge Study, anticipated to be completed by Spring 2018, will include an estimate of the water budget. Future pumping needs to be confirmed for the GSP baseline conditions (IWV Farmers Group, 2014). For the GSP, annual water budgets will be developed for historical, current and projected conditions, based on balanced hydrologic conditions. Inflow to the basin will include natural and anthropogenic recharge, and contributing springs and streams. Outflows will include evapotranspiration and groundwater production for domestic, municipal, mining, commercial, and agricultural uses. Changes to groundwater in storage will be correlated with groundwater levels within sub-regions of the basin. The water budget results will be presented in the GSP.

### 3.3 Determine Management Areas as Appropriate (GSP§ 354.20)

If warranted, management areas may be evaluated during development of the GSP to see if the occurrence and movement of groundwater vary substantially within the basin. This analysis will be based on groundwater level measurements and GSP Model results. Recommendations will be reviewed with the IWV-TAC and Board for adoption into the GSP. The GSP Model will need to develop zone budget files to accommodate sub-watershed water budgets.

### 3.4 Development of Sustainable Management Criteria (GSP§ 354.22 to 354.30)

The GSP Model will be used as a tool to establish the appropriate sustainable management criteria to monitor the basin's water supply. These criteria will provide necessary input for the GSP and future basin management. Transient modeling will provide triggers and thresholds for different areas of the valley. The Model will be used iteratively to work with the IWV-TAC in developing sustainable management criteria: measurable objectives, minimum thresholds, undesirable results, and interim milestones, for recommendation to the IWVGA.

### 3.5 Evaluate Monitoring Network (GSP§ 354.38) and Identify Data Gaps

Once the sustainable management criteria are developed, the GSP Model will be used to identify locations that require monitoring for groundwater management. This will include the identification of which wells are to be monitored by which triggers/thresholds, frequency of monitoring, and potential data gaps.

### 3.6 Evaluate Projects and Management Actions (GSP§ 354.44)

The IWVGA and IWV-TAC will identify future demand and management scenarios to be evaluated by the GSP Model. Projected changes in land use, population, and extended drought will need to be considered. Potential water sources, supply projects, and management alternatives will be evaluated. These future management scenarios will be compared to the baseline run to assess what effects the different basin management alternatives have on sustainable groundwater within the basin. Potential changes in climate will also be evaluated for the effects on sustainable water supply within the basin.

In addition to water supply, future management alternatives will be analyzed for impacts to water quality and land subsidence. Transport modeling will be calibrated to establish a salinity baseline model run. Future management scenarios will be evaluated for changes in salinity within the basin; and compared with the baseline. A recent InSAR Study[2] was conducted to analyze aquifer response to pumping in the Indian Wells Valley groundwater basin. The results were evaluated and documented by DRI (2016). If warranted, future management scenarios may be compared with the baseline to evaluate the potential for compaction and land subsidence.

## 4 CONCLUSIONS

The NAWS numerical groundwater model is robust and accounts for the major elements of the hydrogeologic conceptual model. The model was initially developed to study the rate of decline of groundwater levels under overdraft conditions, and potential future effects on well production, water quality degradation, and land subsidence at NAWS water supply wells. It is recommended that some model elements and stresses be modified based on the review outlined in Attachment A to address requirements of the GSP. It is also recommended that the transient model be calibrated based on groundwater levels under variable hydrologic conditions and water budget elements for Indian Wells Valley basin.

NAWS has invested in the model as a tool to evaluate the occurrence and movement of groundwater within the IWV Basin. NAWS Range Sustainment Office has identified it as a tool to enable informed decisions and mitigate potential mission encroachments (DRI, 2016). They have committed to having the model updated and incorporate new data as basin studies are completed (Boggs, 2017).

## 5 RECOMMENDATIONS

- Use the NAWS numerical groundwater model for development, implementation, and performance of the IWV GSP.
- Update and re-calibrate the existing model to include the comments addressed in this review and GSP Emergency Regulations.
- Review and incorporate findings from the U.S. Geological Survey Recharge Study, Salt and Nutrient Management Plan, and Brackish Water Study as these data become available.
- Request a logistical exception for DWR model review to fulfill CCR §352.4(g) requirements
- Collaboratively integrate NAWS/DRI model findings, recommendations, and analysis into IWVGA and IWV-TAC working groups/meetings to address the requirements for GSP development and implementation.

[2] South Dakota School of Mines and Technology, 2015. InSAR Analysis of Aquifer-System Response to Pumping in the Indian Wells Valley, CA.

## 6 REFERENCES


Berenbrock, Charles and Peter Martin, 1991. *The Ground-Water Flow System in Indian Wells Valley, Kern, Inyo, and San Bernardino Counties, California.* USGS Water-Resources Investigations Report 89-4191. Prepared in cooperation with Indian Wells Valley Water District and the U.S. Deportment of the Navy, China Lake Naval Weapons Center. 87pp.

Bloyd, R.M. and S.G. Robson, 1971. *Mathematical Ground-Water Model of Indian Wells Valley, California*. USGS Open-File *Report* 72-41. Prepared in cooperation with the Indian Wells Valley County Water District and the Department of the Navy. 39pp.

Boggs, Mathew 2017. Personal communication October 12, 2017.

Brown and Caldwell, 2009*. Indian Wells Valley Basin Groundwater Flow Model and Hydrogeologic Study*. Prepared for IWVWD. March 2009.

California Department of Water Resources (DWR), 1980. *Groundwater Basins in California*. Bulletin 118-80. Sacramento, CA.

____, 2016a. *Modeling Best Management Practice*. Sustainable Groundwater Management Program BMP, 42pp. December, 2016.

____, 2016b. *Water Budget Best Management Practice.* Sustainable Groundwater Management Program BMP, 53pp. December, 2016.

____, 2017a. *SGMP Technical Assistance - Climate Change Analysis*. Water Storage Investment Program (WSIP), 2pp. August, 2017.

____, 2017b. *Draft Sustainable Management Criteria Best Management Practice*. Sustainable Groundwater Management Program BMP, 38pp. November, 2017.

Dessert Research Institute (DRI), 2016. *Groundwater Resource Sustainability: Modeling Evaluation for the Naval Air Weapons Station, China Lake, California*. Prepared by DRI Nevada System of Higher Education, September 2016.

____, 2017. *Technical Memorandum re: Indian Wells Valley Groundwater Model Update*. November 17, 2017.

Dutcher L.C. and W.R. Moyle, 1973. *Geologic and Hydrologic Features of Indian Wells Valley, California*. USGS Water Supply Paper 2007. Prepared in cooperation with the California Department of Water Resources.

GSP §## from CCR, 2016. California Code of Regulations; Title 23. Waters; Division 2. Department of Water Resources; Chapter 1.5. Groundwater Management; Subchapter 2. Groundwater Sustainability Plans.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald, 2000. *MODFLOW-2000, The U.S. Geological Survey modular ground-water model - User guide to modularization concepts and the Ground-Water Flow Process*. U.S. Geological Survey Open-File Report 00-92, 121pp.

Harbaugh, A.W., 2005. MODFLOW-2005, the *U.S. Geological Survey modular ground-water model - the Ground-Water Flow Process*. U.S. Geological Survey Techniques and Methods 6-A16.

IWV Cooperative Groundwater Technical Advisory Committee (IWVCGW-TAC) and Geochemical Technologies Corporation (GTC), 2008. *AB 303 Phase II; Installation and Implementation of a*

*Comprehensive Groundwater Monitoring Program for the Indian Wells Valley, California*. Prepared for Local Ground Water Assistance Program AB303 State of California. March 2008.

IWV Farmers Group, 2014. Letter from Sierra Shadows Ranch, Art Hickle, Mojave Pistachios, Quist Farms, Amber Flow Ranch, Max Hovaten, and Simmons Alfalfa Ranch to Mick Gleason, County of Kern regarding comments to Todd 2014 report. March 4, 2014.

Kunkel, Fred and G.H. Chase, 1969. *Geology and Ground Water in Indian Wells Valley, California*. USGS Open-File Report 69-329. Prepared in cooperation with the Naval Weapons Center, China Lake, California. 89pp.

Lamb, Charles E. and D.J. Downing, 1978. *Ground-Water Data, 1974-76, Indian Wells Valley, Kern, Inyo, and San Bernardino Counties, California*. USGS Open-File Report 78-335. Prepared in cooperation with the Navy and Indian Wells Valley County Water District. 45pp.

Lee, C.H., 1912. *Ground-Water Resources of Indian Wells Valley, California*, California State Conservation Commission Report, p. 403-429.

Lipinski, Paul, 1980. *Map of Indian Wells Valley, California, Showing Change in Water Level, 1963-78, and Hydrographs of Selected Wells*. USGS Open-File Map 80-342

____ and Darwin D. Knochenmus, 1981. *A 10-Year Plan to Study the Aquifer System of Indian Wells Valley, California*. USGS Open-File Report 81-404. Prepared in cooperation with the U.S. Deportment of the Navy and Indian Wells Valley Water District. 19pp and 3 plates.

Moran, Tara, 2016. *Projecting Forward, A Framework for Groundwater Model Development Under the Sustainable Groundwater Management Act*. Stanford University, Water in the West Program, 56pp.

Rajtora, Stan, 2017. October 27, 2017 email to Steve Johnson regarding *DRI Report observations*.

Reilly, T.E. and A.W. Harbaugh, 2004. *Guidelines for Evaluating Ground-Water Flow Models*. U.S. Geological Survey Scientific Investigations Report 2004-5038, 30pp.

RMC, 2017. *DRAFT Indian Wells Valley Groundwater Basin Salt and Nutrient Management Plan*. November 2017

Tetra Tech EM, Inc. (TtEMI), 2003a. *Draft Basewide Hydrogeologic Characterization Summary Report. SAWS China Lake, California.* Prepared under CLEANII Contract for Department of the Navy. January 2003.

Tetra Tech EM, Inc. (TtEMI), 2003b. *AB 303 Grant; Groundwater Management in the Indian Wells Valley Basin, Ridgecrest, California.* Prepared for Eastern Kern County Resources Conservation District. June 2003.

Todd Engineers, 2014. *Indian Wells Valley Resource Opportunity Plan, Water Availability and Conservation Report*. Prepared for Kern County Planning and Community Development Department. January 2014.

U.S. Bureau of Reclamation (USBR), 1993. *Indian Wells Valley Groundwater Project: USBR Technical Report Volume II*. A cooperative effort among the BOR, IWVWD, North American Chemical Company, and NAWS. December 1993. Prepared by USBR Lower Colorado Region. 464pp.

## Attachment A   Groundwater Model Review for Application to Sustainability Plan

| | Review Element | Source | Comments and Notes |
|---|---|---|---|
| 1 | Provide a scientific basis and professional judgement to sustainably manage the basin | BMP | Coupling the high standards of DRI's academic research of water resources in the Southwest with peer review by IWVGA and IWV-TAC will provide a strong base from which to develop management strategies and adaptively bring the basin to a sustainable condition. |
| **Model's Purpose an Objectives** | | | |
| 2 | Establish the model's purpose and objectives | USGS BMP | - The existing model was developed to predict the decline in groundwater levels, water quality degradation, and land subsidence that could be expected if the current annual production continued through 10, 25, 50, and 100 years (2114).<br>- The GSP Model will need to provide the elements required to support the development of the IWV Groundwater Sustainability Plan (GSP) and adaptive management of the basin. (See individual items below) |
| **Incorporate Measured Hydrogeologic Data into the Model** | | | |
| 3 | The model shall be based on field or laboratory measurements, or equivalent methods that justify the selected values, and calibrated against site-specific field data. | BMP; CCR §352.4(f) | Multiple studies, monitoring wells, and aquifer testing have been completed in the IWV groundwater basin since 1912. A full review of the documents was completed by Todd Engineers (2014) and DRI (2016). The existing model is based on these historical data. |
| 4 | data availability | BMP | - An earlier model completed by Brown and Caldwell (2009) included a lithologic model. This was not available when DRI constructed their model using the same extents. It would improve the aquifer parameters and structure if this earlier work could be incorporated into the IWV model.<br>- DRI revised earlier studies and available data. DRI qa/qc's (cleaned up) groundwater level and pumping datasets - this work should be incorporated as appropriate into the database for the GSP.<br>- seasonal pumping data is limited. |
| **Hydrogeologic Conceptual Model** | | | |
| 5 | Develop a conceptual model of the basin | BMP | The existing model documentation includes a description of the conceptual model. The modeling team will need to interface with the IWVGA and TAC to be consistent with the conceptual model presented in the GSP. |
| **Numerical Model Code** | | | |
| 6 | Select the appropriate model code. Use public domain model code and documentation. | BMP; CCR §352.4(f) | The IWV Model is constructed using the open-source USGS MODFLOW 2000 model code, fulfilling DWR's requirements. Model code and algorithms are available through USGS modeling group (https://water.usgs.gov/ogw/modflow/). |
| 7 | Simulating unsaturated flow | USGS | The existing model uses the MODFLOW-Newton solution which includes unsaturated flow above the water table. This will support simulating artificial recharge manatment actions. |
| 8 | Convergence criteria met for numerical solution | USGS | output file showed convergence criteria were met under annual stress periods. |

| | Review Element | Source | Comments and Notes |
|---|---|---|---|
| **Model Structure and Design** | | | |
| 9 | Spatial extent of the model and model boundaries | BMP | The active model cells of the existing model include the full extents of the alluvial aquifer surrounded by a bedrock boundary (no flow).<br>- Recent (DRI, 2017) updates and improvements to the model include simulated faults that influence the movement of groundwater within the basin. |
| 10 | Discretization and representation of the hydrogeologic framework | USGS | Overall model structure and extents were originally developed by Brown and Caldwell (B&C, 2009) and refined by DRI (2016).<br>- Model has 231 rows and 207 columns with 820-foot spacing (each cell is ~15.4 acres, refined from 41-acres in B&C model).<br>- Model has 6 layers that are refined from the 4-layer geologic interpretation by B&C.<br>- Consider using the unstructured grid (USG) package to incorporate smaller cell size along the southern and western boundaries with the Base. This will improve accuracy of the head near the wells, and allow the pumping stresses to be more defined in these sub-regions, while maintaining the larger grid spacing in areas with few stresses. |
| 11 | Hydraulic Properties | USGS<br>BMP | Initial hydraulic properties were based on historical values developed by B&C Model, and adjusted during model calibration.<br>B&C (2009) lithologic model files were not available during DRI model construction. Refining the simulated lithology would improve the hydrogeologic representation of the model if these files could be made available.<br>- Consider geostatistical methods (using a multiplier for calibration) for interpolating K (fig 19) and S data for a smoother distribution (USGS, 2004 p14) |
| 11 | Simulation of inflows | USGS<br>BMP | The existing model simulates the major natural inflow to the basin - mountain front recharge and runoff off the surrounding mountains.<br>- Mountain front recharge was refined from previous models based on the BBRM approach to proportion the extent of recharge by precipitation isohyetal distribution. The recharge was distributed evenly at the base of each mountain block.<br>- Consider assigning the recharge at the tributary mouths to account for the coarser sediments and conveyance of stormflow runoff. Consider using the RCH package (instead of WEL package) to simulate tributary recharge zones correlated with precipitation.<br>- Refine the conceptual model for natural recharge following the USGS Recharge study results.<br>- For the GSP water budgets, other anthropogenic sources of water (i.e. wastewater and irrigation return flows) will need to be accounted for in the water budgets. |

| | Review Element | Source | Comments and Notes |
|---|---|---|---|
| 12 | Simulation of outflows | USGS<br>BMP | Basin outflow is predominantly through pumping and evapotranspiration.<br>- The historical annual pumping was simulated using the production volumes developed by Todd (2014). The groundwater production for domestic and agricultural wells may need to be refined to develop seasonal demands required for the GSP.<br>- the WEL package was used for simulating pumping. The MNW package may be more appropriate for the GSP in order to calculate pumping based on a groundwater level constraint.<br>- The existing model effort performed a detailed analysis of the evapotranspiration at the playa within the basin. |
| 13 | Stress periods and hydrologic conditions | USGS<br>BMP | The existing model has annual stress periods with a constant mountain front recharge of 7,645 acre-feet per year (AFY). The model for the GSP will require a 50-year future Baseline and project model runs. Model updates should include variable hydrologic conditions that match the long-term average balanced conditions for the basin. Stress periods should be seasonal to account for the wetter winter season, dry summer months, and monsoonal storms. The pumping demand will also show a seasonal imprint. |
| 14 | Depletion of interconnected surface water | BMP:<br>CCR<br>§354.28 | The current hydrogeologic conceptual model does not include surface water. The mountain front surrounding the basin have arroyos that convey water from higher elevations to the dry lake-bed playas on the valley floor during storm events . These intermittent flows do not provide an continuous interconnected system. The mountain storms and resulting mountain front recharge are and the primary source of water to the groundwater basin. |
| 15 | Assessing impacts on adjacent basins. | BMP | The existing model simulates subsurface outflow to the Salt Wells Valley. Future modeling for the GSP will continue to evaluate this connection. |
| 16 | Importance of land use practices in agricultural basins | BMP | The existing model has built upon the Todd Engineers' report (2014) with respect to agricultural pumping. Future GSP model runs will need to incorporate the current agricultural concerns and plans for sustainable water use. |
| **Model Calibration to Historical Data and Sensitivity Analysis** | | | |
| 17 | Steady State Calibration | USGS | Steady state calibration was performed to meet pre-development conditions of 1920 |
| 18 | Representation of initial conditions in transient calibration | USGS | The calibrated steady state groundwater levels were used as the initial conditions to the 1920-2010 (91-year) transient model calibration. |
| 19 | Calibration criteria | USGS<br>BMP | The primary calibration criteria for the existing model were rates of drawdown.<br>- for the GSP model, additional calibration criteria to include are basin wide groundwater levels and water budget parameters. |

| | Review Element | Source | Comments and Notes |
|---|---|---|---|
| 20 | Transient model runs | USGS | - Mountain front recharge is simulated at a constant average annual rate.<br>- Account for the range of recharge influenced by the tributary recharge from the mountain blocks during above average and wet hydrologic conditions. This will improve the annual sub-regional water budgets and seasonal model calibration required to be evaluated for the GSP.<br>- Recommend development of pumping demand curves to distribute pumping seasonally.<br>- Monthly ET demand was developed for the existing model. |
| 21 | Assessing how annual changes in historical inflows, outflows, and changes in basin storage vary by water year type (hydrology) and water supply reliability. | BMP | The GSP model will be used to develop annual water budgets by water year type. |
| 22 | Evaluating how the surface and groundwater systems respond to the annual changes in the water budget inflows and outflows. | BMP | The GSP model will be used to develop hydrographs that include water year type. |
| 23 | Identifying which management actions and water budget situations commonly result in overdraft conditions or undesirable results. | BMP | The existing model address the rate of drawdown, chronic lowering of groundwater levels, overdraft conditions, salinity impacts, and potential land subsidence.<br>- The GSP model will be used to support the IWV-TAC and IWVGA with management actions to address undesirable results. |
| 24 | Supporting the development of the water budget and estimating changes in groundwater storage volume. | BMP; CCR §354.18 | The existing model provides an quasi-average annual water budget.<br>- The GSP model will be used to refine the water budget under different hydrologic conditions; and provide future baseline and management predictions.<br>-Determine if management areas are appropriate (CCR §354..20), and if so, developing zone budgets for managing different regions of the basin |

| | Review Element | Source | Comments and Notes |
|---|---|---|---|
| **Baseline and Future Sustainable Management Scenarios** | | | |
| 25 | Facilitating the estimate of sustainable yield for the basin. | BMP | The existing model has estimated the average annual natural recharge to the IWV basin at 7,650 acre-feet per year (AFY). This value is within the range of historical estimates.<br>- The sustainable yield estimate may be refined following the U.S. Geological Survey's recharge study to be completed spring 2018.<br>- Future estimates for sustainable yield for the GSP will need to consider proposed recharge projects and potential anthropogenic sources. |
| 26 | Optimizing proposed projects and management actions and evaluating the potential effects those activities have on achieving the sustainability goal for the basin. | BMP | The GSP model would be used to develop and evaluate management actions to achieve a sustainable groundwater basin. |
| 27 | Forecasting future conditions and evaluating future scenarios of water demand uncertainty associated with projected changes in local land use planning, population growth, and climate. | BMP | The GSP model would be used to forecast future conditions, evaluate management scenarios, and calculate uncertainties. |
| 28 | Informing development and quantification of sustainable management criteria, such as the sustainability goal, undesirable results, minimum thresholds, and measurable objectives. | BMP | The GSP model would be used to develop sustainability indicators within the basin |
| 29 | Helping identify potential projects and management actions and optimizing their design to achieve the sustainability goal for the basin within 20 years of GSP implementation. | BMP | Future use of the model will include assessing the impacts of potential GSP projects and management actions within the next 20 and 50 years. |
| **Uncertainty Analysis of Sustainable Management Scenarios** | | | |
| 30 | Identifying data gaps and uncertainty associated with key water budget components and model forecasts, and developing an understanding of how these gaps and uncertainty may affect implementation of proposed projects and water management actions. | BMP | The future use of the GSP model's uncertainty analysis can help prioritize the data gaps and monitoring needs for the basin. |
| 31 | Simulating the changing climate conditions that may occur during the 50-year planning and implementation horizon required under SGMA | BMP | The existing model developed a climate change scenario. Further climate change analysis may be required in evaluating sequenced hydrologic conditions. |
| **Model Documentation and Review** | | | |
| 32 | Model documentation of assumptions, development of input parameters, calibration, sensitivity, and uncertainty | BMP; CCR §352.4(f) | DRI has provided detailed descriptions of their assumptions and development of input files for historical conditions. Model calibration was improved during the 2017 model update when subsurface faults were simulated by the HFB package. In addition ion to rate of drawdown, the transient GSP model will need to be calibrated to groundwater levels, water budget, and other elements focused on the GSP. |

| | Review Element | Source | Comments and Notes |
|---|---|---|---|
| 33 | If requested, provide the Department with a free working copy of the complete modeling platform (for example native MODFLOW and IWFM input files, output files, and executables) that allows the Department to run the model, create and verify results, view input and output files, or perform any other evaluation and verification. | BMP: CCR §352.4(g) | The Navy has provided a cooperative effort to supply the needed files and meetings for Stetson's model evaluation and review. Given the model is the property of the Navy, an exception may need to be requested for DWR's model file review protocols. A similar path of meetings and in-office file review should be discussed with DWR staff. |
| **Ongoing GSP Support** | | | |
| 34 | Supporting the refinement of the monitoring network in the basin over time | BMP | The Navy has made a commitment to having the IWV Model be a planning tool that gets updated as new data becomes available. |
| 35 | Simulating changes in groundwater quality | BMP | A transport model (MT3D) has been coupled with the existing flow model to predict the migration of TDS from saline groundwater in portions of IWV. If warranted, additional transport modeling may need to be completed for the GSP using the re-calibrated flow model. The SNMP is planned to be completed at the end of 2017. These findings may need to be incorporated into future Baseline/Project model runs. |
| 36 | Simulating land subsidence | BMP | The existing model was used to evaluate the potential for land subsidence due to dewatering of clay lenses. If warranted, additional modeling might be required for the GSP development. |
| 37 | Model Adaptability - modeling is an ongoing effort to support sustainable groundwater management | BMP | The Navy has made a commitment to having the IWV Model be a 'living' planning tool that gets updated as new data and information become available. This will assure that it can be integrated into, and support, the ongoing reporting and management of the basin. |
| 38 | Model results presentation | BMP | It is recommended that the modeling team be integrated with the IWVGA and TAC given the intensive timeline for the GSP development and the interconnectedness of the modeling with (a) data gap identification and prioritization, (b) hydrogeologic conceptual model development, (c) sustainable management criteria, (d) sustainable alternative development, and (e) monitoring plan development. |

CCR GSP Emergency Regulations
Title 23 of the California Code of Regulations (CCR), Division 2, Chapter 1.5, and Subchapter 2

BMP California Department of Water Resources (DWR), 2016.
*Modeling Best Management Practices for Sustainable Management of Groundwater*

USGS Reilly, T.E. and A.W. Harbaugh, 2004. *Guidelines for Evaluating Ground-Water Flow Models*
U.S. Geological Survey Scientific Investigations Report 2004-5038