EXPERT REBUTTAL REPORT | DECEMBER 2025

APPLICATION OF THE STORAGE-BASED SAFE YIELD METHOD FOR

INDIAN WELLS VALLEY GROUNDWATER BASIN

Assessment of the "change-in-storage" method as the most scientifically sound and reliable approach for determining safe yield in the Indian Wells Valley Groundwater Basin (IWVGB)

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
AEM	Airborne Electromagnetic
AF	Acre Feet
AFY	Acre Feet per Year
ET	Evapotranspiration
GSP	Groundwater Sustainability Plan
IWV	Indian Wells Valley
IWVB	Indian Wells Valley Groundwater Basin
IWVGA	Indian Wells Valley Groundwater Authority
IWVGSP	Indian Wells Valley Groundwater Sustainability Plan
IWVWD	Indian Wells Valley Water District
LSCE	Luhdorff & Scalmanini Consulting Engineers
R/P	Recharge to Precipitation
SGMA	Sustainable Groundwater Management Act
Ss	Specific Storage
Sy	Specific Yield
TWG	Technical Working Group
WY	Water Year

SECTION 1. INTRODUCTION

This rebuttal responds to recent assertions that the storage-based mass-balance method, long recognized as a foundational and widely applied approach in basin-scale groundwater evaluations, is unreliable for determining safe yield in the Indian Wells Valley Groundwater Basin (IWVB). These assertions were presented in two expert reports submitted on August 15, 2025:

- Expert Report of Sean A. McKenna, PhD (McKenna, 2025), prepared on behalf of the U.S. Department of Justice.
- Expert Opinion of Dr. Todd Kincaid, P.G. (Kincaid, 2025), prepared for Richards Watson Gershon on behalf of the Indian Wells Valley Groundwater Authority (IWVGA).

In their 2025 expert reports, both Kincaid and McKenna argue that safe yield should be derived exclusively from a "recharge/ET budget" or "recharge-based mass balance," an approach that they contend produces a natural recharge estimate of only 7,650 acre-feet per year (AFY). Their critique relies heavily on the premise that basin sustainability can be accurately inferred from reconstructed pre-development conditions, even though such estimates depend on indirect hydrologic indicators, uncertain historical climate assumptions, limited early observational data, and conceptualizations of natural recharge processes dating back more than a century. In contrast, the storage-based approach presented by Luhdorff & Scalmanini, Consulting Engineers (LSCE), evaluates the IWVB's actual measured response to long-term pumping, integrating observed groundwater-level trends, modern aquifer test data, and updated hydrogeologic interpretations. This distinction is central to this rebuttal report: while recharge/ET reconstructions presented by Kincaid and McKenna rely on inferences and assumptions, the storage-change method presented by LSCE relies on empirical evidence and directly observed IWVB performance.

This rebuttal addresses the specific technical issues, analytical inconsistencies, and methodological flaws contained in the expert reports submitted by Kincaid (2025) and McKenna (2025). In doing so, it also presents additional, independently derived lines of evidence demonstrating why the LSCE change-in-storage method provides a more accurate, reliable, and scientifically grounded basis for estimating safe yield in the IWVB. As new information becomes available, whether through supplemental data, model refinements, expert testimony, or discovery, LSCE reserves the right to update, expand, or amend the opinions and analyses provided herein.

SECTION 2. PURPOSE

The purpose of this report is to demonstrate with clarity, technical rigor, and multiple independent lines of evidence that the criticisms of Kincaid and McKenna mischaracterize both the scientific basis and the analytical strength of the LSCE storage-change method. The LSCE storage-change approach directly evaluates the basin's actual performance over time by quantifying long-term pumping, measured groundwater-level responses, and aquifer storage properties. This LSCE method is firmly grounded in observable data rather than inferred or assumption-driven hydrologic components. As such, it represents the most empirically anchored and reproducible means of determining safe yield.

In LSCE's August 2025 expert report, LSCE determined that the long-term safe yield of the IWVB is 15,400 AFY. Multiple independent evaluations produce results that closely align with this estimate. Collectively, these analyses demonstrate that the true safe yield of the IWVB is substantially higher than the 7,650 AFY figure advanced by Kincaid and McKenna. These independent lines of evidence include:

1. Change in Storage Analysis - IWVB wide storage change analyses consistently demonstrate a long-term safe-yield range of approximately 14,300 to 17,000 AFY, based on observed groundwater-level trends across the monitoring network and aquifer storage properties representative of the IWVB.

2. IWVWD Numerical Model - The updated 2025 IWV Ramboll transient numerical model, which incorporates refined basin geometry, detailed fault mapping, AEM data, modern pumping records, and site-specific hydraulic parameters, reproduces observed groundwater behavior and produces a safe-yield estimate of 14,735 AFY.

3. Owens Valley recharge-to-precipitation (R/P) ratio method - Recharge estimates derived from McKenna's precipitation volumes combined with Danskin's corrected Owens Valley recharge ratio result in a recharge to precipitation ratio of 7% which is then applied to the IWVB, resulting in a recharge range of 12,797 to 27,601 AFY, with an average of 21,380 AFY.

4. Antelope Valley R/P ratio method - Recharge estimates derived from the adjudicated Antelope Valley results in a recharge to precipitation ratio (Beeby et al., 2010) or 8% which was then applied to the IWVB, resulting in a recharge rate of 25,431 AFY.

5. GSP Subbasin R/P ratio method was evaluated across multiple comparable groundwater subbasins and shows a consistent range of recharge to precipitation ratios of approximately 5% to 10%, reinforcing that the IWVB recharge estimates derived from analogous basins are reasonable and aligned with statewide observations for similar hydrogeologic settings. Applying this R/P ratio of 5% to 10% to IWVB yields an estimated recharge rate of 15,250 to 30,490 AFY.

6. Numerical modeling conducted by Ramboll simulates native recharge between 13,000 and 15,100 AFY over both long-term (1980–2023) and representative (2014–2023) base periods. These values fall clearly within the ranges produced by several R/P analyses and the LSCE storage-change method, providing further cross-validation among independent lines of evidence.

Although these methods differ in analytical framework, data inputs, and underlying assumptions, they point to the same conclusion: the IWVB's safe yield is approximately 15,400 AFY, consistent with LSCE's calculation and markedly higher than the 7,650 AFY estimate advanced by Kincaid and McKenna. This alignment across empirical, numerical, and hydrologic approaches provides a strong interdisciplinary basis that reinforces the reliability and scientific credibility of LSCE's storage-change method and its 15,400 AFY safe yield determination.

SECTION 3. ISSUES WITH NATURAL RECHARGE AND EVAPOTRANSPIRATION (ET) ESTIMATES

Kincaid and McKenna rely on "natural recharge" and ET estimates derived from certain historical studies. Those estimates are internally inconsistent and based on highly generalized assumptions:

1. Studies cited by Kincaid and McKenna include IWVGB inflow estimates that vary widely, spanning almost a two-fold range, from roughly 6,000 AFY to more than 11,000 AFY. This variation is driven primarily by differences in the elevation-precipitation regressions and evapotranspiration (ET) coefficients selected by different investigators, highlighting the sensitivity of inflow estimates to methodological assumptions rather than to measurable hydrologic differences.
2. Pre-development ET as used by Kincaid and McKenna cannot be directly measured, and historical estimates necessarily rely on indirect or sparse datasets such as limited vegetation surveys, coarse climate records, and simplified water-balance assumptions. As a result, the uncertainty in pre-development ET is inherently high, and any value derived from these early datasets must be interpreted with caution.
3. ET rates have changed measurably over time, as documented by McGraw et al. (2016) and others. Groundwater pumping and the resulting declines in groundwater elevations have reduced phreatophytic ET in many areas of the basin. Consequently, ET estimates calculated after significant groundwater development are not representative of pre-development conditions and therefore cannot be used as reliable proxies for natural recharge.
4. Mountain-front recharge estimates depend heavily on empirical relationships, including infiltration coefficients, runoff ratios, and soil/bedrock adjustment factors developed in other basins and misapplied to IWVB. These approaches often require subjective correction factors to account for local geology and climate, introducing substantial uncertainty and limiting their reliability as standalone estimates of basin inflow.

Kincaid and McKenna rely heavily on McGraw et al. (2016) in reaching their safe yield opinions. The recharge estimate from McGraw et al., however, is limited because it only accounts for mountain-front recharge and underflow from Rose Valley. As a result, it does not represent the full recharge budget for the IWVB. For a meaningful comparison between methods, both analyses must be evaluated over a consistent and representative base period.

In addition, relying on annual precipitation totals or annual averages commonly used in empirical recharge relationships does not provide sufficient accuracy. High-intensity storm events can generate substantial recharge that is not captured in an annual snapshot, particularly when recharge is constrained by a fixed precipitation threshold (e.g., areas receiving more than eight inches per year). As demonstrated in the TWG Safe Yield Paper (2024), areas receiving less than eight inches of precipitation annually can still contribute meaningful recharge during wetter years. Therefore, using average annual precipitation values and applying threshold-based area restrictions overlooks recharge contributions from infrequent, high-magnitude storms that can materially influence the IWVB water budget.

Kincaid and McKenna offer a chain of untestable assumptions; it is neither a reproducible nor a technically reliable foundation for assessing safe yield. Relying solely on natural recharge and ET estimates, whether

from climate datasets or hydrologic models, can bias the water budget because these methods primarily characterize root-zone fluxes and may not translate to percolation through a deep vadose (unsaturated) zone to the water table. A more reliable method is the groundwater-storage change analysis (ΔS) method, which is derived from direct measurements at groundwater monitoring locations (paired with appropriate storage parameters), and reflects the integrated response of the aquifer system and better captures the realities of percolation and basin-scale dynamics.

SECTION 4. CHANGE IN STORAGE METHOD IS THE MOST DIRECT, DATA-DRIVEN METHOD TO CALCULATE SAFE YIELD

Safe yield represents the volume of groundwater pumping that results in no net change in groundwater storage. It can be expressed as:

Safe Yield = Pumping +/- Change in Storage..... (Equation 1)

The method applies to the fundamental hydrologic mass balance by quantifying each component with observed, basin-specific data. Reliable and long-term pumping records provide a direct measure of outflows, while multi-decade groundwater-level trends document how the aquifer has responded over time, thereby defining the change in groundwater storage. Together, these measured datasets allow the mass-balance relationship to be evaluated empirically rather than inferred from historical assumptions:

Inflow = Outflow +/- Change in Groundwater Storage..... (Equation 2)

This formulation ensures that inflow is not assumed or reconstructed from uncertain recharge estimates but instead is derived from the aquifer's observed behavior under real pumping conditions.

Because it relies on observed water-level change rather than reconstructed pre-development conditions, it reflects the basin's true integrated hydrologic performance. This stands in contrast to recharge/ET-based safe-yield estimates of Kincaid and McKenna, which are derived from uncertain mountain-front recharge assumptions and simulations of conditions more than a century in the past.

The LSCE storage-change approach also incorporates current hydrologic and climatic conditions, which have been altered substantially by long-term pumping, land-use change, vegetation shifts, and climate variability. Evaluating how the aquifer behaves under recent conditions, not how it may have behaved pre-1920, provides a more accurate basis for determining safe yield.

In addition, the LSCE method used decades of monitoring data from hundreds of wells, translating basin-wide drawdown and recovery patterns into a direct empirical test of safe yield. This allows for a clear determination of whether the basin is stabilizing or continuing to lose storage under representative pumping, making the approach transparent, reproducible, and rooted in measurable basin behavior.

A key advantage of the LSCE storage-change method is its reliance on dynamic (drainable) storage, which is tied to observed groundwater-level changes and reflects the portion of groundwater that responds to pumping and climate. Static storage estimates, often produced by numerical models, represent total pore-space water and carry significant uncertainty because they depend on poorly constrained basin depths

and saturated thickness. Dynamic storage offers a more practical and reliable measure of the aquifer's usable water.

Finally, although portions of the IWVB display semi-confined behavior, the basin functions primarily as an unconfined system, where long-term groundwater-level changes are governed by specific yield (Sy), the volume of water that drains from pore spaces under gravity per unit volume of aquifer material for each unit decline in groundwater level. Because many wells intersect multiple hydrostratigraphic layers, both Sy and specific storage (Ss) influence water-level behavior. Ss represents the amount of water released from storage due to the elastic response of the aquifer and aquitard materials—meaning the slight, reversible compression of the soil or rock matrix and the expansion of the water itself when hydraulic head declines. This elastic response occurs rapidly and produces short-term, small-magnitude water-level changes, but it does not meaningfully affect long-term IWVB storage conditions.

In contrast, Sy controls the long-term release or uptake of groundwater because it reflects drainage from interconnected pore spaces during sustained declines or rises in groundwater levels. Given that long-term storage change in the IWVB is governed overwhelmingly by Sy, the storage-change method remains the most appropriate, scientifically reliable approach for estimating the basin's safe yield.

SECTION 5. CHANGE IN STORAGE ANALYSIS

Another concern raised by Kincaid (page 15 of 42 of his expert report) regarding the storage-change method is the claim that it will "over-estimate safe yield because the uncertainties associated with the estimation of S [storativity] (Sy in unconfined conditions and Ss in confined conditions) tend to favor higher values." However, the argument that storage-based analyses inherently "overestimate" simply because Sy or storativity carries uncertainty overlooks the rigor, constraints, and multiple safeguards built into modern groundwater-storage evaluation practices. Specifically:

- Sy and storativity values are not arbitrarily chosen. They are derived from multiple, independent sources of information, long-term aquifer tests, lithologic and depositional interpretations, historic drilling and well-construction records, and calibration against decades of observed groundwater-level responses. These data collectively constrain plausible ranges and reduce uncertainty.
- If Sy or storativity were systematically too high, the results would be inconsistent with the IWVB documented drawdown history. Overestimating Sy would cause both the storage-change estimates (LSCE method) and simulated groundwater-level responses (Ramboll model) to deviate noticeably from the extensive long-term water-level record. This divergence is not observed. Instead, the storage-change results closely match the groundwater-level trends reproduced by the calibrated Ramboll model, indicating that the Sy and storativity values used are appropriate and consistent with actual basin behavior.

The following subsections present additional technical explanation and multiple lines of supporting evidence demonstrating why the change-in-storage method represents the most appropriate and scientifically reliable approach for estimating safe yield in the IWV Basin. These sections also provide a detailed justification for the storativity and Sy values applied in the analysis—showing that these parameters are consistent with modern hydrogeologic data, supported by basin-specific well and aquifer

characteristics, and aligned with the long-term groundwater-level behavior observed throughout the basin. Together, this evidence confirms that the storage-change framework accurately captures the dominant hydrologic processes governing groundwater availability in IWV.

Section 5.1. Relationship Between Storage Change and Safe Yield

Safe yield is calculated as follows:

Safe Yield = Pumping +/- Change in Groundwater Storage ..... (Equation 3)

The ± term reflects whether groundwater storage increased or decreased during the base period:

- If storage increased, the positive change is *added* to pumping, indicating that the basin could have supported more extraction without causing depletion.
- If storage decreased, the negative change is *subtracted* from pumping, resulting in a lower safe yield estimate.

Change in groundwater storage is calculated as:

Change in Groundwater Storage = Change in Water Level x Basin Area x Specific Yield(Equation 4)

Because Sy directly scales the magnitude of storage change, higher Sy values increase the absolute magnitude of calculated storage gain or loss.

Section 5.2. Why the "High Sy Overestimates Safe Yield" Argument Does Not Apply to IWV Basin

Kincaid's concern would only be valid in basins experiencing a net increase in groundwater levels or storage, where an inflated Sy could artificially increase the calculated storage gain and thus inflate safe yield.

However, the IWVB has shown an overall decline in groundwater levels:

- When groundwater levels and storage change are negative, a higher Sy value increases the magnitude of the calculated decline, which in turn lowers the calculated safe yield.
- In other words, even if Sy were (hypothetically) overestimated, the result would be a more conservative (lower) estimate of safe yield, not an inflated estimate.

Additionally, in areas where parts of the basin may exhibit confined behavior, applying Sy (which is much larger than Ss) instead of Ss likewise increases the magnitude of calculated storage decline, again pushing the safe yield estimate downward and making it more conservative.

To better illustrate the implications of using different aquifer storage parameters, **Table 1** presents a simplified, hypothetical example in which changes in storage and safe yield are calculated for the same basin under two different assumptions: (1) the aquifer is unconfined and governed by Sy, and (2) the aquifer is confined and governed by Ss.

The example assumes a 210,000-acre basin with a confined aquifer thickness of 100 feet and identical annual pumping (24,000 AFY); however, for a one-foot decrease in groundwater level, the calculated change in storage, and therefore the resulting safe yield, differs substantially depending on whether Sy or Ss is applied.

Table 1. Hypothetical Comparison of Safe Yield Using Sy and Ss

Aquifer Type	Average Pumping (AFY)	Storativity (S)[1]	Annual Change in Storage (AFY)[2]	Calculated Safe Yield (AFY)
Unconfined	24,000	0.05	-10,500	13,500
Confined	24,000	0.005	-1,050	22,950

[1] = Sy (Unconfined) and Ss x Aquifer thickness (Confined)
[2] = Basin Area × Storativity × Groundwater Level Changes

In general, applying Sy to estimate change in storage results in a far more conservative assessment of basin conditions compared to using Ss. Because Sy represents the volume of water released or taken up through drainage of pore spaces in an unconfined aquifer, it is typically one to two orders of magnitude larger than Ss. As a result, any given water-level decline when multiplied by Sy translates into a substantially larger calculated loss in groundwater storage. This produces a more restrictive, lower estimate of safe yield and a greater apparent depletion of the aquifer system. In contrast, Ss reflects the elastic response of a confined system and therefore yields much smaller changes in calculated storage for the same measured decline. Consequently, Sy-based calculations provide a more conservative evaluation of basin safe-yield determination.

Therefore, even if Sy values used in the change in storage method were overestimated, their use in a basin with declining groundwater levels would result in a more conservative (lower) estimate of safe yield. Furthermore, since specific yield is much greater than specific storage, the use of specific yield values in potentially confined areas would also cause safe yield to be underestimated if the change in groundwater storage is negative.

Concerns about Sy "overestimating" safe yield fundamentally misinterpret how the change in storage method behaves in a basin with declining groundwater levels. For the IWV Basin:

- Higher Sy values do not inflate safe yield; they depress it.
- Any potential overestimation of Sy would make the safe-yield calculation more conservative, not less.
- The storage-change method, when applying Sy to a basin with declining storage, naturally produces a lower-bound estimate of safe yield.

This demonstrates that the storage method is far from overstating safe yield and provides a technically reliable and conservative evaluation for the IWV Basin.

SECTION 6. NUMERICAL MODEL CORROBORATION STRENGTHENS CHANGE IN STORAGE RESULTS

LSCE's change in storage-derived safe-yield estimate was independently benchmarked against the Ramboll transient numerical model (Ramboll 2025). The Ramboll model incorporates the basin's full hydrologic history-decades of pumping records, detailed aquifer geometry, lithologic variability, boundary conditions, and observed groundwater-level responses. When evaluated over the same base period (WY 2014–WY 2023), both the storage-change method and the calibrated numerical model produce safe-yield estimates within a similar range, providing a strong cross-validation between fundamentally different analytical approaches.

- LSCE change in storage-derived safe yield: 15,400 AFY
- Ramboll calibrated numerical model: 14,800 to 16,600 AFY

By contrast, the Kincaid and McKenna recharge-only methods continue to generate a broad and shifting inflow range because they rely heavily on uncertain precipitation–elevation correlations, poorly constrained ET estimates, and empirical mountain-front recharge relationships that are not directly tied to observed groundwater-level trends or basin performance. As a result, recharge-only estimates remain highly variable and lack the empirical anchoring that both the LSCE storage-change method and the calibrated model provide.

The Ramboll calibrated numerical model's safe-yield estimate closely aligns with the LSCE change-in-storage method, providing a strong and independent benchmark that validates the relationship between observed groundwater-level trends, calculated storage changes, and the basin's safe yield. Numerical groundwater models are among the most robust tools available for representing the full aquifer system, and a well-constructed transient model integrates hydrologic and climate datasets (precipitation, ET, streamflow, and inflows/outflows), represents aquifer geometry, layering, hydraulic properties, and boundary conditions, simulates groundwater-level responses and storage changes under historical stresses, and produces hydraulic property estimates (K, S, and T) that reflect basin-scale conditions rather than localized field measurements. Hydraulic parameter estimation, especially for storage parameters (Sy, Ss), is one of the most challenging aspects of groundwater science. Individual pumping tests or lithologic logs provide valuable point-scale data, but they cannot by themselves define basin-scale parameter values. Only after a thorough calibration process, where model parameters are adjusted until the simulated water-level trends match decades of observed measurements, do aquifer properties reflect the true integrated behavior of the groundwater system.

Section 6.1. Why Calibrated Model Parameters Strengthen the Change in Storage Analysis

Although all groundwater models carry inherent uncertainties, the Ramboll calibrated numerical model is the most reliable groundwater model currently available for evaluating groundwater conditions in the IWVB. This model was developed using an extensive and diverse dataset, allowing it to closely replicate observed basin behavior and provide reliable estimates of storage change and system response. Key components of the model include:

- Multi-decade groundwater-level datasets, capturing long-term trends, drought and recovery cycles, and spatial differences in aquifer response.
- Verified pumping records, incorporating municipal, domestic, industrial, and agricultural extractions to accurately represent historical stresses on the system.
- Detailed lithologic and geophysical inputs, including airborne electromagnetic (AEM) data, significantly improve characterization of subsurface stratigraphy and aquifer properties.
- Representation of vertical and lateral hydraulic connectivity, ensuring realistic movement of water between hydrostratigraphic units and across the basin.
- Comprehensive basin-wide water-balance constraints align model results with known recharge, discharge, and storage dynamics.

Pumping tests and other field measurements serve as initial inputs, but after calibration, the Ramboll model-derived aquifer parameters are more reliable than the DRI model and other models because the Ramboll model honors both the physics of the system and its observed behavior.

Accordingly, for the LSCE storage-change analysis:

- Storativity values (S) were taken directly from the calibrated Ramboll numerical model, ensuring consistency with basin-wide aquifer behavior.
- These model-derived values are anchored by multiple independent datasets, including groundwater levels, streamflow interactions, subsurface geology, aquifer tests, and historical pumping patterns, which collectively constrain and validate the modeled storage response.
- As a result, the analysis does not depend solely on localized or limited field-test data, but instead incorporates storage parameters that reflect the integrated, system-wide properties of the aquifer.

The LSCE change in storage approach ensures that the storage-change calculation reflects basin-scale aquifer behavior, not isolated test conditions. In summary, the close agreement between the LSCE storage-derived safe yield (15,400 AFY) and the Ramboll calibrated numerical-model estimate (14,800 - 16,600 AFY) provides strong technical validation of both methods.

SECTION 7. RECHARGE TO PRECIPITATION RATIO ANALYSES IN OTHER SUBBASINS SUPPORT THE LSCE CHANGE IN STORAGE METHODOLOGY

An R/P ratio approach, when applied carefully, can produce safe-yield estimates that are consistent with both the change-in-storage method and the Ramboll numerical-model results for safe yield.

The McKenna analysis estimated an R/P ratio for the Owens Valley Basin by dividing the total ‘mountain-front recharge’ reported in Danskin (1998) by the volume of precipitation for watershed areas receiving more than eight inches of annual precipitation. McKenna then applied these ratios to IWVB precipitation volumes to estimate expected mountain-front recharge for the IWV Basin. Although such basin-to-basin comparisons can be useful as a general check on recharge estimates, a significant methodological flaw exists in McKenna’s approach.

Specifically, McKenna relied on the Danskin (1998) water-budget term described as "mountain-front recharge between tributary streams" to represent the total mountain-front recharge for Owens Valley. However, Danskin (1998) explicitly defines this term as "hidden recharge", precipitation occurring on ungauged drainage areas located between the major gaged tributary streams. This term does not include recharge from the gaged tributary drainages themselves, which are widely recognized as the primary sources of mountain-front recharge in Owens Valley. In short, by treating a minor, interdrainage component as the full recharge contribution, McKenna substantially underestimates the true magnitude of mountain-front recharge entering the basin.

Further, the precipitation area McKenna used encompasses the entire watershed contributing runoff to Owens Valley, not just the ungauged areas to which Danskin's 'between-tributary' recharge term applies. Treating this minor component as the totality of mountain-front recharge, therefore, disregards the substantial inflows from major tributaries into the Owens Valley basin.

Danskin's (1998) hydrologic evaluation also incorporates irrigation return flow as a recharge source, despite water-table depths of 'many hundreds of feet' in portions of the basin, including alluvial-fan areas with irrigated acreage. Flow, and thus recharge, from Owens Valley's main tributaries is well documented and supported by more than 600 continuous gaging stations operated by the Los Angeles Department of Water and Power. This gaged tributary recharge, which represents the dominant component of Owens Valley recharge, was omitted entirely from McKenna's analysis omits this primary recharge component entirely, resulting in a severe underestimation of total recharge, which in turn leads to an artificially low assessment of available water supply and basin safe yield.

Section 7.1. Owens Valley and Corrected Recharge-to-Precipitation Ratios for the IWV Basin

When applied correctly, the R/P ratio approach can be considered a complementary method for strengthening safe-yield estimates. This approach has been quantitatively recognized and incorporated into groundwater budgets in numerous arid and semi-arid basins with climatic and geologic conditions comparable to those of the IWV Basin. The closest approximation of total natural recharge in the Owens Valley Basin, representing all recharge directly attributable to precipitation falling on the adjacent mountains and the valley floor, would include the following components from the water budget presented in Table 10 of Danskin (1998): precipitation, tributary stream inflow, mountain-front recharge between tributary streams, and runoff from bedrock outcrops within the valley fill.

Using McKenna's calculated precipitation values together with this corrected estimate of combined natural recharge from Danskin (1998) yields R/P ratios of approximately 7% (**Table 2**). By comparison, the R/P ratios presented in McKenna's expert report based on an incomplete accounting of mountain-front recharge were substantially lower, ranging from 0.9% to 1.6%, and therefore do not reflect the full magnitude of recharge entering the basin.

Table 2. Corrected Calculation of Recharge/Precipitation Ratios for the Period 1970-1984						
	Precipitation Volume 1 (AFY)	Natural Recharge from Precipitation in Watershed Area Tributary to Owens Valley[2] (AFY)				Percent and Recharge/Precipitation Ratio[3]
		Recharge From Gaged Tributaries	Recharge From Ungauged Tributaries	Runoff From Bedrock Outcrops	Total	
Minimum	1,590,260	90,000	15,000	0	105,000	6.6% (0.0660)
Maximum	2,219,228	115,000	35,000	2,000	152,000	6.9% (0.0685)
Average	1,854,124	103,000	26,000	1,000	130,000	7% (0.070)

[1] McKenna (2025), Table 3
[2] Danskin (1998), Table 10
[3] = Total Recharge [2] / Precipitation [1]

Applying the corrected Owens Valley Basin R/P ratios to McKenna's estimated precipitation for the IWV Basin yields the following recharge estimates (**Table 3**).

Table 3. Annual Recharge Volumes for the IWV Basin Using Corrected Recharge-to-Precipitation Ratios Derived from Owens Valley.			
	Precipitation Volume[1] (AFY)	Percent and Recharge/Precipitation Ratio[2]	Estimated Recharge[3] (AFY)
Minimum	193,820	6.6% (0.0660)	12,797
Maximum	402,975	6.9% (0.0685)	27,601
Average	304,932	7% (0.070)	21,380

[1] McKenna (2025), Table 4
[2] As calculated in Table 2 above
[3] = Precipitation [1] x Recharge/Precipitation Ratio [2]

Applying McKenna's analysis with corrected R/P relationship results in a recharge range for the IWV Basin of 12,797 to 27,601 AFY, with an average estimate of about 21,380 AFY, which is nearly three times greater than the 7,650 AFY referenced in the McKenna report.

For comparison, the Ramboll groundwater-flow model simulates an average of approximately 13,000 AFY of native recharge over the calibration period from 1980 through 2023 (Tonkin, 2025). For the representative base period from 2014 through 2023, as presented in the TWG's safe-yield paper (2024), the model simulates approximately 15,100 AFY of native recharge. These model-derived values fall within and are consistent with the range of recharge estimated using the corrected Owens Valley Basin R/P ratios (12,800 to 27,600 AFY).

Section 7.2. Antelope Valley Recharge-to-Precipitation Ratios Applied to IWV Basin

LSCE considered additional basins using the recharge to precipitation approach in evaluating the estimate of recharge for the IWVB. The Antelope Valley Groundwater Basin (Basin No. 6-044), an adjudicated basin

located in the western Mojave Desert, south of the IWV Basin, was selected because it exhibits a similar climate, has an arid/high-desert setting, and comparable average annual precipitation.

During the Antelope Valley adjudication, a team of technical experts determined the basin yield, which incorporated septic return flows, irrigation return flows, and percolation of treated wastewater as recharge components in the basin water budget (Beeby et al., 2010). The adjudication report also notes that a large part of the overall aquifer system, to a depth of about 300 feet, is unsaturated, similar to IWV Basin characteristics. In conducting the R/P ratio analysis for Antelope Valley, the following input values were used by their technical experts:

- Average annual precipitation: 676,000 AFY
- Average annual recharge: 56,400 AFY
- Calculated recharge-to-precipitation ratio: 0.0834 (8%)

Applying the same R/P ratio approach to the IWV:

- Average annual precipitation based on McKenna (2025), the average annual precipitation volume (AFY) estimate is 304,932 AFY.
- Recharge/Precipitation ratio: 0.0834 (8%)
- Estimated safe yield: 25,431 AFY

Section 7.3. Multiple GSP Basins and Recharge-to-Precipitation Ratios

LSCE conducted a recharge to precipitation analysis for other basin R/P ratios. LSCE identified basins with hydrogeologic and climatic characteristics that are broadly similar to those of the IWVB.

Considerations were given for a variety of factors in identifying comparable basins. Deep percolation is the primary driver of groundwater inflow in arid and semi-arid basins, occurring from precipitation, applied irrigation water, and outdoor municipal water use. When precipitation or irrigation saturates the soil to field capacity, excess water begins to migrate downward under gravity. Once this water moves below the root zone, it becomes part of the groundwater system. Deep percolation of irrigation water is commonly estimated by assuming that the portion of applied water exceeding crop ET, due to irrigation inefficiency, percolates below the root zone and reenters the groundwater system.

Other groundwater inflow components include, but are not limited to, stream leakage, lateral subsurface inflow, and mountain-front recharge. These components may be considered part of ‘recharge’ when applying an R/P ratio approach.

To develop a representative R/P ratio, LSCE identified and evaluated five additional basins. These basins share similar hydrogeologic characteristics with the IWVB, particularly those where deep percolation from precipitation constitutes the principal recharge component (see **Table 4**).

Table 4. Average Annual Precipitation and Deep Percolation from Precipitation for Selected Basins/Subbasins.				
Basin/Subbasin Name (Number)	**Period of Calculation**	**Average Annual Precipitation (AFY)**	**Deep Percolation from Precipitation (AFY)**	**Percent and Recharge/Precipitation Ratio**
Santa Cruz Mid-County (3-001)	2010 – 2015	82,000	4,000	4.9% (0.049)
Cuyama Valley (3-013)	1998 - 2023	224,000	19,000	8.5% (0.085)
San Joaquin Valley - Eastern San Joaquin (5-022.01)	1996-2023	988,000	60,000	6.1% (0.061)
San Joaquin Valley - Merced (5-022.04)	2006 - 2022	437,000	87,000	19.9% (0.199)
San Joaquin Valley - Madera (5-022.06)	1989-2014	329,000	32,000	9.7% (0.097)
Average		412,000	40,400	9.8% (0.098)

Table 4 presents the period of calculation, average annual precipitation, deep percolation from precipitation, and the resulting R/P ratio for the selected basins. The calculation periods vary because each GSP selected a different base period depending on data availability and the hydrologic and hydrogeologic characteristics of the respective study area. In several basins, average annual precipitation was estimated directly from basin-wide precipitation data.

Across the selected basins, the minimum R/P ratio was 4.9% (Santa Cruz Mid-County Basin), and the maximum value was 19.9% (San Joaquin Valley, Merced). The average ratio across all basins is 9.8%, which is substantially higher than the average value of 1.4% advocated by McKenna (2025).

McKenna (2025) applied an R/P of only 0.9 to 1.6 percent. In our opinion, this ratio is unrealistically low for the hydrologic and hydrogeologic conditions of the IWVB and does not reflect the IWVB's historical groundwater behavior. McKenna's proposed long-term safe yield of 7,650 AFY corresponds to an implied R/P ratio of approximately 2%. In contrast, the safe-yield range of 14,200 to 15,700 AFY estimated using the LSCE change-in-storage method yields an approximate ratio of 4%, which is substantially more consistent with R/P ratios observed in comparable California basins, typically 7 to 9.8% on average, and is, if anything, maybe slightly conservative relative to regional analogs.

Although the R/P ratio approach is a simplified method, it provides a reasonable approximation of basin safe yield and serves as a valuable cross-check on more detailed analyses. The R/P ratios and resulting safe-yield estimate for IWV derived from this method align closely with the results from both the storage-change evaluation and the calibrated numerical groundwater-flow model, reinforcing the reliability of the higher safe-yield estimates.

SECTION 8. SUMMARY AND CONCLUSION

The comprehensive technical evidence presented in this report demonstrates that the LSCE change in storage-based safe-yield method is the most scientifically rigorous, empirically grounded, and reliable approach for determining the safe yield of the IWVB. Unlike recharge-only approaches, which rely on uncertain historical reconstructions, indirect empirical relationships, and assumptions about pre-development conditions, the storage-change method directly evaluates the basin's actual response to decades of pumping. This distinction is fundamental: the LSCE method measures what the basin has done, not what it is assumed to have done.

Key findings supporting this conclusion include:

- Direct empirical evidence supports a safe yield of approximately 14,200–15,700 AFY. Decades of groundwater-level data, modern aquifer tests, and updated hydrogeologic interpretations consistently indicate that long-term changes in groundwater storage correspond to a long-term safe-yield pumping rate of nearly twice the value calculated by Kincaid and McKenna. This empirical signal is clear and robust.
- Aquifer storage parameters used in the LSCE analysis are scientifically reliable and IWVB-specific. The specific-yield and storativity values applied in the LSCE evaluation are derived from multiple independent datasets and validated through calibration of the Ramboll transient model. These values reflect integrated basin-scale behavior, not speculative or outdated estimates, and they produce results consistent with IWVB's documented groundwater-level trends.
- Independent numerical modeling corroborates the LSCE safe-yield calculation. The Ramboll 2025 calibrated groundwater-flow model simulates long-term basin behavior and produces a safe-yield range of 14,800–16,600 AFY, nearly identical to the LSCE storage-change result of 15,400 AFY. This agreement between a process-based numerical model and an observational mass-balance analysis provides powerful cross-validation, indicating that the safe yield is the range calculated by LSCE and far above the 7,650 AFY assumed by the Kincaid and McKenna analyses.
- R/P ratio analyses independently support the LSCE safe-yield analysis. Corrected Owens Valley R/P ratios (7%), Antelope Valley adjudicated R/P ratios (8%), and R/P ratios from comparable GSP subbasins (5–10%) all converge on a recharge and safe-yield range that aligns with the LSCE and Ramboll findings. When applied to IWVB conditions, these analyses yield recharge estimates between roughly 12,800 and 27,600 AFY, with central values in the range calculated by LSCE and Ramboll and far above the analysis of Kincaid and McKenna.
- The 7,650 AFY safe-yield value presented by Kincaid and McKenna is inconsistent with observed basin behavior. The recharge/ET-based methods used by McKenna and Kincaid systematically undercount recharge because they rely on incomplete tributary inflow components, restrictive precipitation thresholds, uncertain historical ET estimates, and long-abandoned pre-development conceptualizations. Their resulting inflow estimates do not match the basin's actual measured response to pumping and therefore cannot form a reliable basis for determining safe yield.

Taken together, the multiple, independent lines of evidence, empirical storage-change analysis, calibrated numerical modeling, and correctly applied R/P ratios all point to the same conclusion: the long-term safe

yield of the IWV Basin is 15,400 AFY, and not the 7,650 AFY value presented by Kincaid and McKenna. This convergence across fundamentally different analytical frameworks underscores the scientific robustness of the LSCE change in storage method. It also highlights the necessity of updating hydrogeologic assumptions to reflect the basin's actual hydrologic behavior. Ultimately, the LSCE method provides the most accurate, transparent, and reliable basis for establishing the IWVB safe-yield.

SECTION 9. REFERENCES

Beeby, R., T. Durbin, W. Leever, P. Leffler, J.C. Scalmanini, and M. Wildermuth, 2010. Summary Expert Report Phase 3 – Basin Yield and Overdraft, Antelope Valley Area of Adjudication. Dated July.

Danskin, W.R., 1998. Evaluation of the Hydrologic System and Selected Water-Management Alternatives in the Owens Valley, California. United States Geological Survey Water-Supply Paper 2370-H. Prepared in cooperation with Inyo County and the Los Angeles Department of Water and Power.

Kincaid, T., 2025. Expert Opinion of Dr. Todd Kincaid, P.G., Regarding the Safe Yield of the Principal Aquifer in the Indian Wells Valley Groundwater Basin, Mojave Pistachios, LLC; et. al. v. Indian Wells Valley Water District; et. al. Case No. 30-2021-01187275. Prepared for Richards Watson Gersho, dated August 8.

McGraw, D., R. Carroll, G. Pohll, J. Chapman, S. Bacon, and R. Jasoni, 2016. Groundwater Resource Sustainability: Modeling Evaluation for the Naval Air Weapons Station, China Lake, California. Prepared for the Naval Air Warfare Center Weapons Division, China Lake, CA 93555-6100, dated September.

McKenna, S.A., 2025. Expert Report of Sean A. McKenna, PhD, in the matter of Mojave Pistachios, LLC, et al. vs. Indian Wells Valley Water District, et al. Case Number: 30-2021-01187275-CU-OR-CJC. Dated August.

Ramboll, 2025. Indian Wells Valley Groundwater Flow Model, Indian Wells Valley Basin, California. Received April 29.

Tonkin, M., 2025. Phase II Report of Matthew J. Tonkin, PhD: Evaluation of the Safe Yield and Storage Properties of the Indian Wells Valley (IWV) Basin, California. Dated August 15.

TWG (Technical Working Group), 2024. Assessment of Safe Yield for the Indian Wells Valley Groundwater Basin, dated September 4.