



CALIFORNIA DEPARTMENT OF WATER RESOURCES
SUSTAINABLE GROUNDWATER
MANAGEMENT OFFICE

Sustainable Groundwater Management Act Water Year Type Dataset Development Report

January 2021

1. Purpose

In response to the Sustainable Groundwater Management Act (SGMA), the Groundwater Sustainability Plan (GSP) Regulations require the California Department of Water Resources (Department) to provide a water year type (WYT) classification to assess the amount of annual precipitation in a basin (23 CCR Section 351(an)). The GSP Regulations, 23 CCR Section 354.18, requires the use of WYT for the development of the water budget. Therefore, the Department has developed the SGMA WYT Dataset which covers all groundwater basins in California, except for the groundwater basins underlying the Sacramento River and San Joaquin River Hydrologic Regions (see Figure 1). This document describes the process used to develop the SGMA WYT Dataset.



Figure 1. Statewide Map of Water Year Type Dataset

GSAs may choose to use the SGMA WYT dataset as a resource in the development of their water budget but are not required to. GSAs have the option to develop their own water year types based on best available information (23 CCR Section 354.18d).

2. Background

In 1978, the State Water Resources Control Board (SWRCB) adopted the Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun Marsh (1978 Delta Plan) through SWRCB Resolution 78-43 in accordance with Section 13170 of the California Water Code and the Water Right Decision 1485¹. The 1978 Delta Plan was developed to address the water quality conditions in the Sacramento-San Joaquin Delta (Delta) and Suisun Marsh. Salinity was identified in the 1978 Delta Plan as a major water quality factor which was affecting the beneficial uses of the Delta and Suisun Marsh water supplies. The major factors affecting Delta outflow included natural runoff, the regulatory effects of upstream developments, and operations from the Central Valley Project (CVP) and State Water Project (SWP). A need to adjust measured flows to reflect man-induced alterations to natural hydrology was identified since riparian water rights within the Delta and Suisun Marsh were only extended to natural flows and flows within the Delta and Suisun Marsh were known to be artificially altered on a seasonal basis from nearby storage operations. To that end, a hydrologic classification of year types had been developed for the 1978 Delta Plan².

The hydrologic year type classifications presented within the 1978 Delta Plan was composed of five stationary thresholds in million acre-feet:

- Wet – Equal to or greater than 19.6 (except to or greater than 22.5 in a year following a critical year)
- Above Normal – greater 15.7 and less than 19.6 (except greater than 15.7 and less than 22.5 in a year following a critical year)
- Below Normal – Equal to or less than 15.7 and greater than 12.5 (except in a year following a critical year)
- Dry – Equal to or less than 12.5 and greater than 10.2 (except equal to or less than 15.7 and greater than 12.5 in a year following a critical year)
- Critical – Equal to or less than 10.2 (except equal to or less than 12.5 in a year following a critical year)

It was noted that this system was similar to the year type classification system which had been proposed by the Department during the hearing process leading up to the development of this plan except that the “Year Following Critical Year” designation does not apply to agricultural, municipal, and industrial standards. The plan reasoned that the modification was necessary to “provide those uses the full protection to which they are entitled under their vested water rights”. Under this system, year classifications were determined from the forecast of unimpaired flow to the Sacramento Valley from its four principal tributaries as published in the California Department of Water Resources Bulletin 120 (Bulletin 120):

- American River (total inflow into the Folsom Reservoir)

¹ Water Right Decision 1485, page 10

² Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun Marsh (1978), pages 29-30

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- Feather River (total inflow into the Oroville Reservoir)
- Sacramento River (above Bend Bridge, near Red Bluff)
- Yuba River (at Smartville)

The plan stated that the preliminary determination of year classifications would be made in February, March, and April and that a final determination would be made in May. Preliminary determinations would be based on hydrologic conditions to date with the addition of forecasts of future runoff (assuming normal precipitation for the remainder of the water year (WY)).

By 1991, the SWRCB renamed the Delta Plan to the Water Quality Control Plan for Salinity – San Francisco Bay/ Sacramento-San Joaquin Delta Estuary (1991 Bay Delta Plan) and updated its content for its 10-year update. Additionally, the Water Right Decision 1485 was amended for changes to their monitoring stations and schedule. Within the 1991 Bay Delta Plan, the SWRCB renamed the hydrologic year type classification to “water year type” and adopted the “40-30-30 Water Year Index” to replace the “year following critical year” as proposed by the Operation Studies Workgroup. The 40-30-30 Index classifies the unimpaired runoff from two separate periods from the current water year (i.e. April through July and October through March) and a third parameter from the previous water year’s index for the effects of reservoir storage. In addition, the SWRCB requested that the workgroup develop a San Joaquin River Basin classification with a similar methodology as used for the Sacramento River Basin. The San Joaquin River Basin water year type was developed using a “60-20-20 Water Year Index” to better represent the hydrology and was presented in the following Bay Delta Plan update in 1995. The water year types were also determined from the forecast of unimpaired flow to the San Joaquin Valley from its four principal tributaries as published in Bulletin 120:

- Stanislaus River (total flow to New Melones Reservoir)
- Tuolumne River (total inflow to Don Pedro Reservoir)
- Merced River (total flow to Exchequer Reservoir)
- San Joaquin River (total inflow to Millerton Lake)

Table 1 shows the final water year type classifications and threshold values presented within the Bay Delta Plan for the Sacramento Valley and San Joaquin Valley.

Table 1. Water Year Type Thresholds for Sacramento Valley and San Joaquin Valley from 1995 Bay Delta Plan

Classification	Sacramento Valley Index (MAF)	San Joaquin Valley Index (MAF)
Wet	≥ 9.2	≥ 3.8
Above Normal	$7.8 < i \leq 9.2$	$3.1 < i \leq 3.8$
Below Normal	$6.5 < i \leq 7.8$	$2.5 < i \leq 3.1$
Dry	$5.4 < i \leq 6.5$	$2.1 < i \leq 2.5$
Critical	≤ 5.4	≤ 2.1

In 1999, Decision 1641 was adopted as part of the SWRCB’s implementation of the 1995 Bay Delta Plan (SWRCB 1999). The Bay Delta Plan has been updated twice since the adoption of the 1995 Bay Delta Plan (2006 and 2018), but no changes to the SWRCB water year indices have been made. The SWRCB’s

dataset for the Sacramento Valley Index (SVI) and San Joaquin Valley Index (SJI) is available in the Department's California Data Exchange Center³.

In 2014, the Sustainable Groundwater Management Act (SGMA) was signed into law in California to provide for the sustainable management of the state's groundwater basins, including establishing minimum standards for sustainable groundwater management, avoiding or minimizing subsidence and improving data collection and understanding about groundwater. SGMA requires local governments and water agencies in the designated high and medium priority basins to prepare a GSP or an alternate plan to a GSP⁴. Each GSP or alternate plan to a GSP must include a historical, current, and projected water budget to quantify a basin's inflows and outflows⁵. GSAs are directed to utilize water year types for the development of historical and current water budgets as available by the Department or other data of comparable quality. This initiated the Department's investigation of a SGMA WYT Dataset for the entire State.

3. Process for Developing the SGMA Water Year Type Dataset

Under SGMA, GSAs in the medium and high priority basins have been required to develop a water budget utilizing historical and current water year types as part of their GSPs. While the SWRCB has developed water year type process for specific areas within the state (e.g., Sacramento Valley and San Joaquin Valley), a consistent statewide process for the development of water year types has not been developed. As a result, the Department has developed a dataset of WYTs for the remaining area of the state not addressed by the SWRCB Bay Delta Plan efforts (SGMA WYT Dataset).

The Department chose to base its process on the process utilized by the SWRCB Bay Delta Plan because the SVI and SJI have already been approved by the state and are already in use. The SVI and SJI process determines the "classifications" or WYTs by calculating an index value for each WY and then comparing each index against a series of stationary thresholds to determine the corresponding WYT (e.g. Wet, Above Normal, Below Normal, Dry, Critical). When developing the SGMA WYT, three major modifications were made to the SVI and SJI process:

1. Precipitation data was utilized rather than unimpaired flow data. This change was made to maintain consistency with the Department's Water Budget Best Management Practice (BMP) and because the Department desired for the approach to be consistent throughout all parts of the state, which would be otherwise difficult to accomplish when utilizing unimpaired flow data since it is not readily available throughout the entire state.
2. Indices would be calculated by an equation using the current and previous annual precipitation data. The SVI and SJI are calculated by two equations using the current year's runoff data and the previous year's index. This approach is not consistent with the Department's Water Budget BMP. The Department's Water Budget BMP states that WYTs will be developed based on annual precipitation as a percentage of the previous 30-year average precipitation. During the development of the SGMA WYT Dataset, it was determined that comparing against a 30-year

³ <https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST>

⁴ <https://water.ca.gov/Programs/Groundwater-Management/Basin-Prioritization>

⁵ 23 CCR § 354.18(d)

average precipitation could skew the data and relating the percentage to the WYT thresholds may be a challenge.

3. WYTs were determined by nonstationary thresholds. Null and Viers (2013) states that the SVI and SJI were intended to divide runoff into wet, above normal, below normal, dry and critical classifications and were based on weighting the historic record as 30%, 20%, 20%, 15% and 15%, respectively. The Department utilized the weighting percentages to determine the thresholds for every 30-year ranking window (i.e. nonstationary threshold). This nonstationary threshold captures the current hydrologic effects.

In accordance with the Department's Water Budget BMP, WYTs were not prepared for the Sacramento Valley nor the San Jan Joaquin Valley since these regions already have WYTs prepared within the SWRCB Bay Delta Plan.

The steps below summarize the workflow taken to develop the WYT dataset:

- 1. Discretize the state into watersheds**

The Department determined that the USGS's Hydrologic Unit Code 8 (HUC8) watersheds are the most appropriate method of discretization for this dataset. HUC8 watersheds were selected because they provide statewide coverage and lend themselves well to the resolution of statewide precipitation data.

As mentioned previously, WYTs were not developed for the Sacramento Valley and San Joaquin Valley within this effort because SWRCB had already developed WYT datasets for these regions through the SWRCB Bay Delta Plan. At the time of this study, information detailing the Sacramento Valley and San Joaquin Valley boundaries considered within the SWRCB Bay Delta Plan was not discovered. As a result, the boundaries for the Sacramento River HR and the San Joaquin River HR were assumed to cover the areas considered within the SWRCB Bay Delta Plan. Thus, the HUC8 watersheds within these two HRs were excluded from this process.

- 2. Determine the WYT index for each watershed**

The WYT index was calculated using an index equation modified from the SVI equation and the SJI equation as presented in SWRCB Bay Delta Plan:

$$Index = (i * \text{Current WY's Precipitation}) + (j * \text{Previous WY's Precipitation})$$

Where:

- "i" represents the weight allocated for the current WY's precipitation
- "j" represents the weight allocated for the previous WY's precipitation
- "Current WY's Precipitation" is the total annual precipitation for the current WY
- "Previous WY's Precipitation" is the total annual precipitation for the previous WY

The weights "i" and "j" were prepared for each HR (excluding the Sacramento River HR and San Joaquin HR) and were modified from the weights used within the SVI equation and the SJI

equation (see Appendix A). Below, in Table 2, are the final weights used to develop the SGMA WYT Dataset:

Table 2. Water Year Type Index Equation Weights by Hydrologic Region

Hydrologic Region	Weight Allocated for the Current WY's Precipitation	Weight Allocated for the Previous WY's Precipitation
North Coast	0.70	0.30
San Francisco	0.80	0.20
Central Coast	0.60	0.40
South Coast	0.60	0.40
Sacramento River ¹	0.70	0.30
San Joaquin River ¹	0.80	0.20
Tulare Lake	0.70	0.30
North Lahontan	0.70	0.30
South Lahontan	0.60	0.40
Colorado River	0.55	0.45

¹The percentages for Sacramento River HR and San Joaquin River HR were taken from the SWRCB Delta Plan.

The “Current WY's Precipitation” and “Previous WY's Precipitation” was estimated for each HUC8 watershed using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group data for WY 1900 through WY 2018.

3. For each WY of each watershed, determine the WYT by comparing the rank against the nonstationary thresholds

Beginning with WY 1930, each WYT index was ranked against the preceding 29-years of WYT indices. The WYT was then determined for each WY by comparing its rank against the nonstationary thresholds, see below in Table 3:

Table 3. Water Year Type Thresholds by Rank

Classification	Weighted Percentage	Percentile	Nonstationary Thresholds
Wet	30%	$70^{\text{th}} < x \leq 100^{\text{th}}$	$21 < \text{rank} \leq 30$
Above Normal	20%	$50^{\text{th}} < x \leq 70^{\text{th}}$	$15 < \text{rank} \leq 21$
Below Normal	20%	$30^{\text{th}} < x \leq 50^{\text{th}}$	$9 < \text{rank} \leq 15$
Dry	15%	$15^{\text{th}} < x \leq 30^{\text{th}}$	$4 < \text{rank} \leq 9$
Critical	15%	$x \leq 15^{\text{th}}$	$\text{rank} \leq 4$

4. Analysis

The goal of this effort was to develop a WYT dataset for each HUC8 watershed in the state of California that are outside of the Sacramento River HR and the San Joaquin River HR with a consistent process. Additionally, it was desired that if this process were applied to the Sacramento River HR and the San

Joaquin River HR, it would produce results similar to those produced by the SWRCB for the Sacramento Valley and San Joaquin Valley. Of these constraints, the process was the only limitation, which was accepted to be flexible, or rather the components of the process, so long as it remained consistent when applied to each HUC8 watershed. With that in mind, the 30-year ranking window of preceding water years used to rank the current water year was examined: how would a different ranking window size affect the results of the Department's process for the Sacramento River HR and the San Joaquin River HR?

Since the Department's Water Budget BMP suggests using a 30-year ranking window size, it was determined that the use of a smaller ranking window size would not be ideal as it potentially minimizes the effectiveness of ranking in attempting to compare a WY's precipitation against its watershed's long-term precipitation. Additionally, it was determined that using a larger window size could also be potentially problematic when attempting to assess the performance of the Department's process against that of the SWRCB's. For example, using a 30-year ranking window precludes the Department from determining water year types for the first 29-years of available precipitation. Therefore, enlarging the ranking window would further reduce the number of possible water years developed through this process. This would limit the temporal coverage of the Department's process and limit its evaluation when comparing against the SVI and SJI (i.e., less Department results to compare against SVI and SJI results could skew the performance assessment). However, increasing the ranking window size has the potential to improve the effectiveness of ranking within the process as it captures a larger period of precipitation (e.g. long-term precipitation) against which it can compare. As a result, a water year type dataset was developed with the Department's method using a 50-year ranking window for the Sacramento River HR and San Joaquin River HR.

The WYTs for the Sacramento River HR and the San Joaquin River HR developed with a 50-year ranking window were compared against the WYTs developed by the SWRCB for the Sacramento Valley and the San Joaquin Valley. The comparison was done by WYT and by category, where the WYT would verify if the WYT matched for a given WY and where the category would categorize the WYTs into Category 1 (lower 50th percentile, e.g. below normal, dry, critical) or Category 2 (upper 50th percentile, e.g. above normal, wet) and verify if the category matched for a given WY. Since the HRs did not exactly match the valley boundaries, the Department's modified process was applied at various levels for this comparison (see Appendix B and C):

- (a) Hydrologic Region
- (b) HUC8 watersheds within the Hydrologic Region
- (c) HUC8 watersheds that represents the four principal tributaries

The results for the comparison using a 50-year ranking window are presented in Tables 4 and 5.

Table 4. Comparison Results using a 50-Year Ranking Window for the Sacramento River Hydrologic Region/Sacramento Valley

Comparison	Water Year Type	Category
(a) Hydrologic Region	55%	97%
(b) HUC8 watersheds within the Hydrologic Region	55%	95%
(c) HUC8 watersheds that represent the four principal tributaries	59%	94%

Table 5. Comparison Results using a 50-Year Ranking Window for the San Joaquin River Hydrologic Region/San Joaquin Valley

Comparison	Water Year Type	Category
(a) Hydrologic Region	70%	94%
(b) HUC8 watersheds within Hydrologic Region	65%	94%
(c) HUC8 watersheds that represent the four principal tributaries	73%	94%

The comparison results for a 50-year ranking window were compared against those of the original 30-year ranking window (see Tables 6 and 7). It was observed that the results for the 50-year ranking window provided better matching for the Sacramento Valley using the category comparison and the San Joaquin Valley using the individual WYT comparison. However, the results for the 30-year ranking window provided better matching for the Sacramento Valley using the individual water year type comparison and the San Joaquin Valley using the category comparison. As a result, the impact of increasing the ranking window size to 50-years yielded mixed results in performance. When this finding was considered alongside the realization that increasing the ranking window would reduce the temporal range for the Department's process, it was determined that 30-year ranking window is preferable to a 50-year ranking window.

Table 6. Comparison Results using a 30-Year Ranking Window for the Sacramento River Hydrologic Region/Sacramento Valley

Comparison	Water Year Type	Category
(a) Hydrologic Region	68%	92%
(b) HUC8 watersheds within the Hydrologic Region	65%	91%
(c) HUC8 watersheds that represent the four principal tributaries	72%	93%

Table 7. Comparison Results using a 30-Year Ranking Window for the San Joaquin River Hydrologic Region/San Joaquin Valley

Comparison	Water Year Type	Category
(a) Hydrologic Region	67%	94%
(b) HUC8 watersheds within Hydrologic Region	62%	95%
(c) HUC8 watersheds that represent the four principal tributaries	72%	96%

5. Conclusion

The Department developed the SGMA WYT Dataset for all HUC8 watersheds outside of the Sacramento River HR and San Joaquin River HR using a consistent statewide process. The Department's process was modified from the process used in the SWRCB Bay Delta Plan. There were three modifications based on the Department's Water Budget BMP: (1) using precipitation data rather than unimpaired flow, (2) modifying the SWRCB's index equation for each HR and (3) determining WYTs using nonstationary thresholds. The dataset covers 98 HUC8 watersheds from WY 1931 through WY 2018.

The impact of modifying the ranking window size from 30-years to 50-years within the Department's process was investigated. WYTs were developed for the Sacramento River HR and San Joaquin River HR

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using a 30-year ranking window and a 50-year ranking window. Both WYT datasets were compared against the WYTs presented in the SWRCB's Delta Plan. It was determined that a 50-year ranking window produced a dataset with similar accuracy (relative to the Bay Delta Plan water year types) but with a smaller temporal coverage to that of the dataset developed with 30-year ranking window. As a result, the 30-year ranking window produced a more optimal dataset. It is important to add that this investigation does not conclusively prove that increasing the ranking window does not have the potential to improve the quality (relative to matching the Bay Delta Plan water year type results for Sacramento Valley and San Joaquin Valley) of the Department's process. However, there are potential limits to how large the ranking window size could be increased to. For example, the Department examined the possibility of using a ranking window size of 117-years (e.g., the entire dataset size) but quickly discovered that utilizing such a large ranking window could heavily alter the Department's process and potentially deviate from the practices suggested in the Department's Water Budget BMP.

It is recommended that this dataset undergo additional refinement as needed. Below includes a list of recommendations which may further refine the SGMA Water Year Type Dataset:

- Water Year Type Index Equation Weights by HR – Adjust the weights for the current WY's precipitation ("*i*") and the previous WY's precipitation ("*j*") for each HUC8 watershed
- Nonstationary Threshold – Adjust the thresholds or weighted percentage for each HUC8 watershed
- Ranking window – Investigate other ranking window sizes

6. References

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7. Appendix

Appendix A. Current and Preceding Year Weighted Percentages

The WYT index was calculated using an index equation modified from the SWRCB Sacramento Valley Index equation and the San Joaquin Valley Index equation as presented in SWRCB Delta Plan. The Department's Water Year Type Index Equation includes two variables that represent the weight allocated to the current WY's precipitation ("i") and the previous WY's precipitation ("j").

The SWRCB Sacramento Valley Index equation follows the 40-30-30 rule, where the current year's runoff ("i") is 0.70 and the previous year's index ("j") is 0.30 and the SWRCB San Joaquin Valley Index equation follows the 60-20-20 rule, where the current year's runoff ("i") is 0.80 and the previous year's index ("j") is 0.20.

The Department had to determine the weighted percentages for the Hydrologic Regions that were not addressed by the SWRCB Bay Delta Plan. The Department tested various combinations of weighted percentages for the current and preceding years for each HR by applying the D'Agostino⁶ Goodness-of-Fit (GoF) Test ($\alpha=0.05$). The D'Agostino GoF Test helped verify that the tested weighted percentages for "i" and "j" for each HR would yield to a dataset that would follow a normal distribution.

The following are the various combinations of weighted percentages that were tested:

Process 1: Applies the SWRCB Bay Delta Plan percentages (current year-to-previous year ratio of 0.70-to-0.30 and 0.80-to-0.20) for the remaining hydrologic regions using the National Atlas California Average Annual Precipitation map (1961-1990)⁷, where a similar precipitation pattern to the Sacramento Valley (i.e. wetter) would be assigned with a 0.70-to-0.30 ratio and similar precipitation pattern to the San Joaquin Valley (i.e. drier) would be assigned with a 0.80-to-0.20 ratio.

Hydrologic Region	Current	Preceding	D'Agostino GoF Test	Pass/Fail
1 North Coast	0.70	0.30	100%	Pass
2 San Francisco	0.80	0.20	100%	Pass
3 Central Coast	0.80	0.20	45%	Fail
4 South Coast	0.80	0.20	33%	Fail
5 Sacramento River	0.70	0.30	100%	-
6 San Joaquin River	0.80	0.20	100%	-
7 Tulare Lake	0.80	0.20	90%	Pass
8 North Lahontan	0.70	0.30	100%	Pass
9 South Lahontan	0.80	0.20	61%	Fail
10 Colorado River	0.80	0.20	33%	Fail

Omitting the HR 5 and HR 6 results, three HRs (1, 2, and 8) had HUC8 datasets with a 100% pass, meaning that all HUC8s within those HRs followed a normal distribution.

⁶ D'Agostino, R. B., 1971. An Omnibus Test of Normality for Moderate and Large Size Samples. *Biometrika*, Vol. 58, No. 2, pp. 341-348. <https://pdfs.semanticscholar.org/1493/2aec5e2128d2373d57f6dede6c3c7ed71f07.pdf>

⁷ Viewed at: https://nationalmap.gov/small_scale/printable/images/pdf/precip/pageprecip_ca3.pdf

Process 2: Adjust the ratio from Process 1 by 0-0.10 for all HRs (except for HR 5 and HR 6)

Hydrologic Region	Current	Preceding	D'Agostino GoF Test	Pass/Fail
1 North Coast	0.60	0.40	100%	Pass
2 San Francisco	0.75	0.25	100%	Pass
3 Central Coast	0.85	0.15	36%	Fail
4 South Coast	0.85	0.15	13%	Fail
5 Sacramento River	0.70	0.30	100%	-
6 San Joaquin River	0.80	0.20	100%	-
7 Tulare Lake	0.85	0.15	80%	Pass
8 North Lahontan	0.80	0.20	100%	Pass
9 South Lahontan	0.85	0.15	54%	Fail
10 Colorado River	0.90	0.10	22%	Fail

Omitting the HR 5 and HR 6 results, three HRs (1, 2, and 8) had HUC8 datasets with a 100% pass (same HRs as in Process 1). The other HRs had a worst performance than in Process 1. This is an indication that the increase of current year weighted percentage for those HRs was incorrect.

Process 3: Adjust ratio from Process 2 by 0-0.10 for all HRs (except for HR 5 and HR 6)

Hydrologic Region	Current	Preceding	D'Agostino GoF Test	Pass/Fail
1 North Coast	0.65	0.35	100%	Pass
2 San Francisco	0.70	0.30	100%	Pass
3 Central Coast	0.75	0.25	64%	Fail
4 South Coast	0.75	0.25	53%	Fail
5 Sacramento River	0.70	0.30	100%	-
6 San Joaquin River	0.80	0.20	100%	-
7 Tulare Lake	0.75	0.25	100%	Pass
8 North Lahontan	0.75	0.25	100%	Pass
9 South Lahontan	0.75	0.25	69%	Fail
10 Colorado River	0.75	0.25	44%	Fail

Omitting the HR 5 and HR 6 results, four HRs (1, 2, 7, and 8) had HUC8 datasets with a 100% pass. The previous failed tests in Processes 1-3 are continued to show a fail test but have improved on the passing rate.

Process 4: Adjust ratio from Process 3 by 0-0.15 for all HRs (except for HR 5 and HR 6)

Hydrologic Region	Current	Preceding	D'Agostino GoF Test	Pass/Fail
1 North Coast	0.70	0.30	100%	Pass
2 San Francisco	0.80	0.20	100%	Pass
3 Central Coast	0.60	0.40	100%	Pass
4 South Coast	0.60	0.40	100%	Pass
5 Sacramento River	0.70	0.30	100%	-
6 San Joaquin River	0.80	0.20	100%	-
7 Tulare Lake	0.70	0.30	100%	Pass

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8 North Lahontan	0.70	0.30	100%	Pass
9 South Lahontan	0.60	0.40	92%	Pass
10 Colorado River	0.60	0.40	77%	Fail

Omitting the HR 5 and HR 6 results, six HRs (1-4 and 7-8) had HUC8 datasets with a 100% pass. HR 9 had a 92% pass which was deemed acceptable.

Process 5: Adjust ratio from Process 4 by 0.05 for HR 10

Hydrologic Region	Current	Preceding	D'Agostino GoF Test	Pass/Fail
1 North Coast	0.70	0.30	100%	Pass
2 San Francisco	0.80	0.20	100%	Pass
3 Central Coast	0.60	0.40	100%	Pass
4 South Coast	0.60	0.40	100%	Pass
5 Sacramento River	0.70	0.30	100%	-
6 San Joaquin River	0.80	0.20	100%	-
7 Tulare Lake	0.70	0.30	100%	Pass
8 North Lahontan	0.70	0.30	100%	Pass
9 South Lahontan	0.60	0.40	92%	Pass
10 Colorado River	0.55	0.45	89%	Pass

The HR 10 HUC8 datasets had an 89% pass which was deemed acceptable.

Process 6: Adjust ratio from Process 5 by 0.05-0.10 for HR 9 and HR 10

Hydrologic Region	Current	Preceding	D'Agostino GoF Test	Pass/Fail
1 North Coast	0.70	0.30	100%	Pass
2 San Francisco	0.80	0.20	100%	Pass
3 Central Coast	0.60	0.40	100%	Pass
4 South Coast	0.60	0.40	100%	Pass
5 Sacramento River	0.70	0.30	100%	-
6 San Joaquin River	0.80	0.20	100%	-
7 Tulare Lake	0.70	0.30	100%	Pass
8 North Lahontan	0.70	0.30	100%	Pass
9 South Lahontan	0.50	0.50	92%	Pass
10 Colorado River	0.50	0.50	89%	Pass

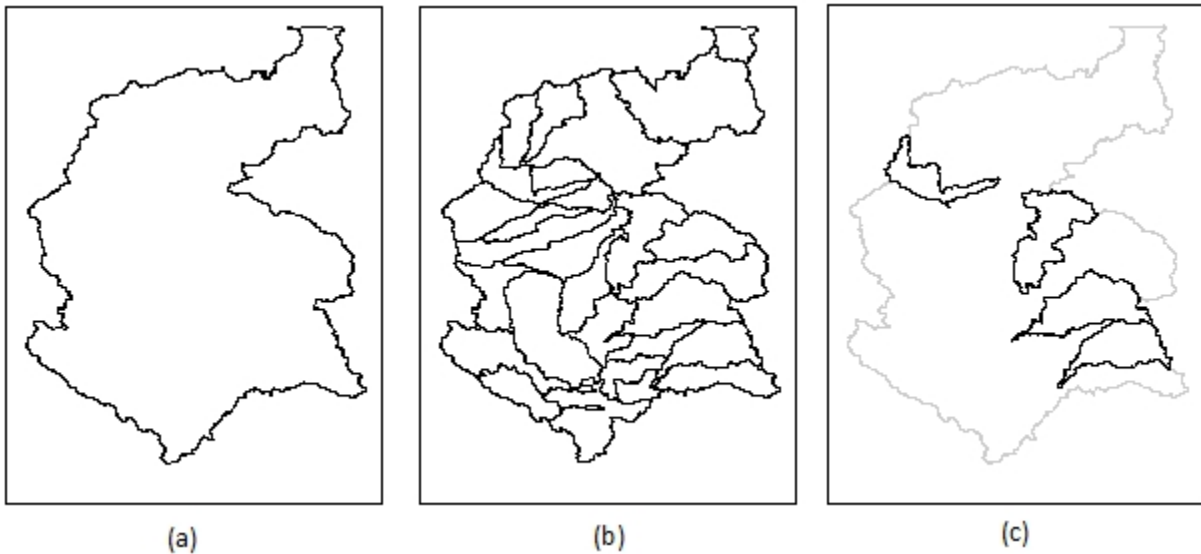
Process 6 was the last process that was tested. The process assigned an equal weighted percentage for the current and preceding years (0.50-to-0.50). Since the D'Agostino results were the same as in Process 5, the Department decided to make the Current-to-Preceding Ratio Process 5 as final.

Appendix B. Map Comparison

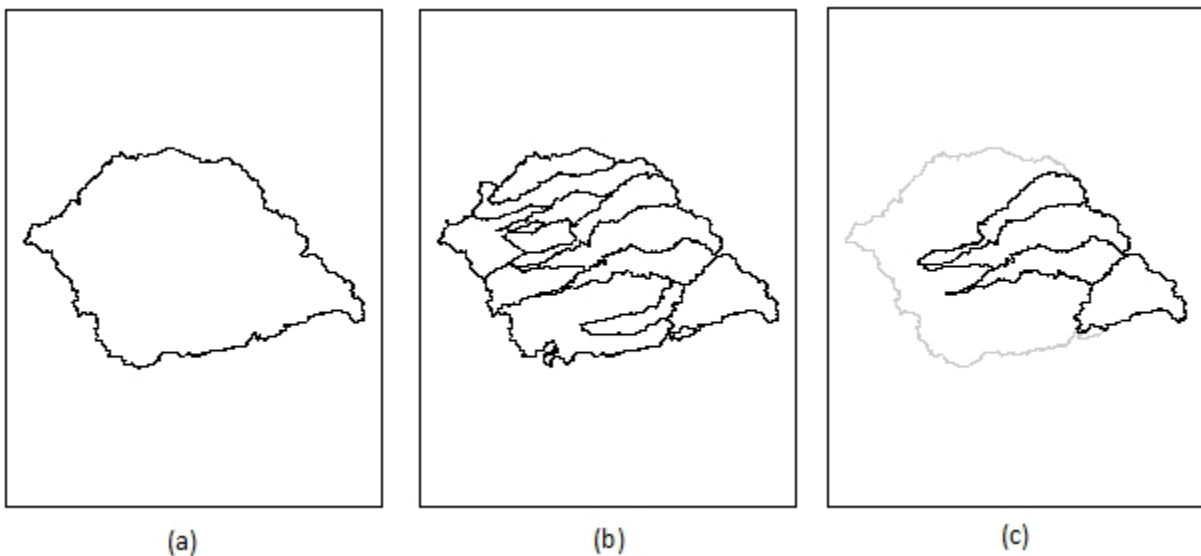
The Sacramento River Hydrologic Region and the San Joaquin River Hydrologic Region did not exactly match the Sacramento Valley and San Joaquin Valley boundaries, the Department's modified process was applied at various levels for this comparison:

- (a) Hydrologic Region
- (b) HUC8 watersheds within the Hydrologic Region
- (c) HUC8 watersheds that represents the four principal tributaries

Sacramento River Hydrologic Region:



San Joaquin River Hydrologic Region:



Appendix C. List of Boundaries used for Comparisons

Comparison (a):

Hydrologic Region ID	Name
5	Sacramento River Hydrologic Region
6	San Joaquin River Hydrologic Region

Comparison (b):

Sacramento River Hydrologic Region

HUC8 ID	Name
18020004	McCloud
18020154	Clear Creek-Sacramento River
18020158	Butte Creek
18020116	Upper Cache
18020122	East Branch North Fork Feather
18020111	Lower American
18020152	Cottonwood Creek
18020002	Upper Pit
18020155	Paynes Creek-Sacramento River
18020123	Middle Fork Feather
18020001	Goose Lake
18020129	South Fork American
18020151	Cow Creek
18020104	Sacramento-Stone Corral
18020121	North Fork Feather
18020003	Lower Pit
18020162	Upper Putah
18020115	Upper Stony
18020156	Thomes Creek-Sacramento River
18020157	Big Chico Creek-Sacramento River
18020125	Upper Yuba
18020128	North Fork American
18020163	Lower Sacramento
18020161	Upper Coon-Upper Auburn
18020005	Sacramento Headwaters
18020153	Battle Creek
18020159	Honcut Headwaters-Lower Feather
18020126	Upper Bear

San Joaquin River Hydrologic Region

HUC8 ID	Name
18040002	Lower San Joaquin River
18040003	San Joaquin Delta

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18040009	Upper Tuolumne
18040011	Upper Calaveras California
18040012	Upper Mokelumne
18040010	Upper Stanislaus
18040007	Fresno River
18040051	Rock Creek-French Camp Slough
18040008	Upper Merced
18040001	Middle San Joaquin-Lower Chowchilla
18040013	Upper Cosumnes
18040006	Upper San Joaquin

Comparison (c):

Sacramento River Hydrologic Region

HUC8 ID	Name
18020154	Clear Creek-Sacramento River
18020121	North Fork Feather
18020125	Upper Yuba
18020128	North Fork American

San Joaquin River Hydrologic Region

HUC8 ID	Name
18040010	Upper Stanislaus
18040009	Upper Tuolumne
18040008	Upper Merced
18040006	Upper San Joaquin