

Technical Memorandum 2

Specific Yield Values

The six Groundwater Sustainability Agencies (GSAs) in the Kings Groundwater Sub-basin (Kings Basin) are in the process of developing data and analyses to evaluate historical changes in groundwater storage. This memorandum provides a recommendation of the specific yield values to be used for each portion of the Kings basin for the groundwater storage calculation, and documents the research and reasoning for the recommendation. The recommendations are based on published sources and additional analysis by Kenneth D. Schmidt and Associates (KDSA).

Background

Specific yield is defined as the ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of rock or soil (Meinzer, 1932). Specific yield data derived from subsurface material textures are generally considered to be the most accurate values that can be obtained. To calculate storage change, specific yield for unconfined groundwater is multiplied by the change in groundwater level for an area. For instance, if over a 1,000 acre area there is a 10-foot per year decline in the groundwater level, and an estimated specific yield of 8%, then the volume of overdraft would be equivalent to 1,000 acres x 10 feet x 8% = 800 acre-feet per year. The Sustainable Groundwater Management Act (SGMA) requires, among other things, annual reporting of change in storage per GSA.

Historically, the Fresno Irrigation District (FID) has used specific yield values from U.S. Geological Survey Water Supply Paper 1469 (Davis et al., 1959), referred to herein as USGS 1469 to calculate changes in groundwater storage. The main emphasis of this evaluation focused on comparing specific yields from other published sources to USGS 1469 specific yields and to research additional sources of data in areas not covered by USGS 1469.

The six GSAs desire to use specific yield information from published sources where possible.

Storage change estimations will be limited to the unconfined aquifer which is described in Technical Memorandum 1 (TM 1).

Survey of Published Sources of Specific Yield

Table 1, below, is a list of published sources of specific yield information used in this evaluation, and a general description of what areas and depths these sources cover in the Kings Basin. **Attachment 1** is a Specific Yield Data Sources Coverage map showing the area covered by each source in **Table 1**.

Table 1 - Summary of Specific Yield Data Sources and General Coverage

Publication Information	Title	Data Coverage*	Depth of Coverage
USGS WSP 1469, (Davis and others, 1959)	Ground-Water Conditions and Storage Capacity in	San Joaquin Valley, except Fresno Slough Area and locations against the foothills	10-50 feet 50-100 feet 100-200 feet

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	the San Joaquin Valley, California		
Page and Leblanc, 1969	Geology, Hydrology, and Water Quality in the Fresno Area, California	San Joaquin Valley, except portions of Fresno Slough Area and locations against the foothills	0 - 300 feet
USGS PP 1401-D, (Williamson, Prudic and Swain, 1989)	Ground-Water Flow in the Central Valley, California	San Joaquin Valley, except locations against the foothills	Variable from 150 feet near the foothills to greater than 600 feet to the west
Kings River Conservation District, 1992	Alta Irrigation District, Groundwater Study	Alta Irrigation District and portions of Orange Cove Irrigation District	Unknown
USBR, 1947	Geologic Study of the Orange Cove Irrigation District	Orange Cove Irrigation District	20 to 234 feet
* See Attachment 1			

USGS WSP 1469

In USGS Water-Supply Paper (WSP) 1469 specific yield was estimated down to depths of 200 feet for most of the valley floor. The general method employed by USGS 1469 was to group the 300 drillers' terms commonly used to describe alluvial subsurface materials into five principal classes. These groupings were then assigned specific yield values that ranged from 25 percent for Group G – gravels, sand and gravel and similar materials down to a low of 3 percent for Group C materials - clay and related material. The data for the total footage for each Group of material were summarized for a given well and an average specific yield calculated for the depth intervals of 10 to 50 feet, 50 to 100 feet, and 100 to 200 feet by Township and Range. The Township and Range grid was modified by groundwater storage units so that the data more accurately represented the varying geologic conditions in the valley. Therefore, a given Township and Range may have two or more specific yield values, depending on how many different geologic units (which in USGS 1469 are referred to as storage units) are intersected by the overlying Township and Range. The authors recognized that in 1959 water levels in certain parts of the valley already exceeded depths of 200 feet, but the methodology they used could readily be made to determine specific yield in strata deeper than 200 feet. USGS 1469 data covers most of the Kings Basin, except in some areas near the foothills, and areas of lake beds deposits and overflows lands (the area termed the Fresno Slough Area in the Kings Basin). The extent of the Kings Basin covered by USGS 1469 is shown in **Attachment 1**.

Page and Leblanc (1969)

Page and Leblanc (1969) working for the USGS derived specific yield estimates based on geologic facies. Facies is a geologic term that means the appearance and characteristics of a sedimentary deposit that is used to distinguish a subsurface material from contiguous subsurface materials. The facies data are based on descriptions of alluvial texture. Six facies categories were defined from Facies A with an estimated specific yield of 5.3 percent to Facies F with an estimated specific yield of 18.7 percent. These data were plotted on a map and an average specific yield was generated by Township and Range based on the relative percentage of each facies. The data were compared to USGS 1469, and in general are within 2 to 3 percent, which is considered good agreement. There is a general trend between the two data

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sets where in the northeast portion of the basin, the Page and Leblanc (1969) estimated specific yields tend to be slightly higher than those in USGS 1469, and in the western portion of the basin the Page and Leblanc (1969) estimated specific yields tend to be slightly lower.

USGS PP 1401-D

USGS Professional Paper (PP)1401-D, was one of the original groundwater modeling efforts by the USGS in the Central Valley. Specific yield was estimated using methods and groupings of deposits by descriptions into five categories with similar properties as described in USGS 1469. The authors indicated that more than 7,400 driller's logs in the San Joaquin Valley were coded for analysis. Specific yield was assigned to subsurface materials according to a model grid oriented northwest along the axis of the valley. This report did not report specific yield by depth range but rather for the entire saturated thickness of the aquifer. Specific yield data from this report appears to be reasonable along the east side of the Kings Basin near the foothills where bedrock is shallow, and in most of North Fork GSA area. These data are not reasonable in areas where wells are much deeper than the upper confined groundwater.

KRCD 1992

The Kings River Conservation District (KRCD) prepared a groundwater study for the Alta Irrigation District (KRCD 1992). This study addressed a list of objectives through a District-wide water balance and groundwater/surface water model. As part of model development, KRCD used unpublished data from the California Department of Water Resources (DWR) that we could not verify. The KRCD report indicates that the DWR data was developed for each quarter-Township and Range from well drillers logs. This data was mapped as specific yield contours, and, to compare these data to USGS 1469, the average specific yield was used between two specific yield contours. For example, the area between the 11 percent and 12 percent specific yield contours would be 11.5 percent. The KRCD specific yields were averaged by Township and Range and compared to USGS 1469 specific yield data. The two sets of data matched within 2 or 3 percent where they overlap except for two small areas on the north part of the KRCD study area where the differences were 4.3 and 3.5 percent. A limitation of this information is that the depths of deposits corresponding to specific yield was not provided.

USBR 1947

The U.S. Bureau Reclamation prepared a Geologic Study and a Water Supply Study both for the Orange Cove Irrigation District (OCID) in 1947 (USBR 1947a & USBR 1947b). They divided the OCID into seven investigational subareas and estimated specific yield for each sub area. Specific yield values for standard textural descriptions were based on previous work done in the Mokelumne area (115 miles northwest of OCID) and from twenty percolation tests in OCID. These values were used along with the stratigraphy in 52 local well logs, and 115 large diameter auger holes drilled along the Friant Kern Canal, to estimate local specific yield. Specific yields ranged from a low of 6.5 percent to 8.3 percent. In most areas where USBR 1947 and USGS 1469 overlap, specific yields from both sources are within less than one percent. The maximum difference in specific yields between the studies is 2.1 percent in the south part of the investigational area. For those areas outside of USGS 1469 coverage, mainly near the foothills, the specific yields from USBR 1947 was used.

USDA Technical Bulletin 1604

USDA Technical Bulletin 1604 provides estimates of specific yield in the Fresno-Clovis northeast area at depths from 0 to 20 feet, 0 to 50 feet, 50 to 100 and 100 to 150 feet. This

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report develops estimated specific yield from soil texture as described on well drillers logs and in similar groupings as USGS 1469. However, for this study the descriptive terms were regrouped into four categories that reflected the reduced number of descriptive terms on the area's well logs. This report and analysis was done to aid in recharge investigations and is a resource for that purpose, but does not provide detailed specific yield coverage in some areas, and to the depths desired. The intent of this publication was to help focus future recharge studies, so areas where specific yield is higher are clearly delineated. However, there are significant portions of the USDA study area where specific yield data is sporadic or not estimated, and thus is not readily comparable to the more extensive data from the other sources.

McMullin Area Evaluation

KDSA prepared a memorandum documenting their estimates of specific yield in the McMullin Area GSA, James ID GSA and the northwestern most portion of North Fork Kings GSA area (**Attachment 3**). Additional evaluation was needed in this area where USGS PP 1401-D specific yields were estimated over the entire saturated thickness of the aquifer, i.e., down to depths of several thousand feet or more. As noted by Page and Leblanc (1969) the deeper Continental Deposits of Tertiary and Quaternary are finer grained than the overlying deposits of Quaternary age. These deep, finer deposits have lower specific yield and therefore the overall specific yield based on the entire saturated thickness of the aquifer are lower than specific yields in the unconfined aquifer above the Corcoran Clay. As previously noted the change in groundwater storage is based on water level changes in the unconfined aquifer, and in this area the base of the unconfined aquifer is the top of the Corcoran Clay. The KDSA analysis was based on electric logs, geologic logs and DWR Well Completion Reports with good descriptions of texture. The data were used to develop several subsurface geologic cross sections in the area. On the subsurface cross sections, three types of deposits; sand or coarser materials, clay or silt, and intermediate type materials such as sandy clay were shown. These deposit types were assigned specific yield values of 20 percent, 3 percent, and 8 percent, respectively. Specific yield was estimated from the Spring 2005 water table to the top of the Corcoran Clay. Based on this evaluation, average specific yields in the area above the Corcoran Clay range from 10 percent southwest of the City of San Joaquin to 15 percent south of the City of San Joaquin near McMullin Grade and the Fresno Slough (**Attachment 2**). Proposed specific yields for deposits above the Corcoran Clay in this area based on the KDSA evaluation are shown on **Attachment 2**.

Friant Area Evaluation

The northernmost portion of the North Kings GSA is not covered by any of the referenced specific yield data sources. Previous work by KDSA in 2012 (described in **Attachment 11**) included development of a subsurface geologic which extends from near Friant to south of Little Dry Creek. Specific yield was estimated for three segments along the subsurface cross section as follows; from near Friant to the southern part of Beck Ranch, south end of Beck Ranch to north end of Ball Ranch, and from Ball Ranch to near Little Dry Creek. Specific yield was estimated to be 25 percent, 20 percent and 14 percent, respectively, for a proposed average of 20 percent for this portion of the North Kings GSA (**Attachment 10**).

Depth to Water and Specific Yield

For the overall Kings Basin, USGS 1469 appears to have the best data for the area covered in the publication. As mentioned above, USGS 1469 provides specific yield estimates in the depth range from 10-50 feet, 50 to 100 feet and 100-200 feet, and therefore does not apply in areas

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where depth to water is greater than 200 feet. In the areas covered by USGS 1469 and water levels shallower than 200 feet, the depth to water will be used to determine which depth interval specific yield is appropriate to use for calculating storage change, if the water levels are shallower than the base of the unconfined aquifer. For example, if an average depth to water of 185 feet is obtained for a Township and Range, then the depth interval specific yield used would be 100 to 200 feet from USGS 1469. However, recent depth to water maps indicate that in some areas, the depth to water has already exceeded 200 feet. In those areas, providing there is coverage by USGS 1969, the average specific yield from that study would be used for depths to water between 200 and 300 feet. The subsurface geologic cross section derived specific yield is proposed to be used in the west part of the Kings Basin where the base of the unconfined groundwater is deeper.

Kings Basin – Eastside Specific Yield Coverage

The three main sources consulted for this study, USGS 1469, USGS 1969, and USGS 1401-D all have gaps in coverage on the valley floor near the foothills on the east side of the Kings Basin. A few gaps are covered by the USGS PP 1401-D model grid which indicate that specific yield in those areas is about 6 to 7 percent for most of the area, which is in the interfan area, and is likely about 20 percent along the San Joaquin River below Friant, based on subsurface geologic cross sections available in this area. Because of the shallow depth to bedrock, USGS PP 1401-D can be used along the east edge of the area. In those areas not covered by one of the USGS studies, use of KRCD 1992 or USBR 1947 is appropriate where information from these reports is available. However, this still leaves gaps in coverage against the foothills, and, as the sources indicate that specific yield is lower in these areas, it is proposed that a specific yield of 6 percent is used along the foothills in interfan areas lacking data coverage. A specific yield of 6 percent, except near Friant, appears reasonable and agrees well with adjacent USGS 1401-D model grid cells, USGS 1969 and USGS 1469 estimates of specific yield. In addition, these areas are relatively small and probably have few wells, so the impact to storage change estimates will likely be minimal.

Conclusions

The following is a list of specific yield data prioritized by publication source:

1. USGS 1469 – use in areas covered by that study
2. Page and Leblanc (1969) – use in areas lacking USGS 1469 coverage and for areas where base of unconfined water is between 200 and 300 feet where covered by this study.
3. Use subsurface geologic cross sections evaluation in west part of area, near Friant, and in parts Fresno urban area.
4. USGS 1401-D – use in North Fork Kings GSA Area where base of unconfined aquifer is greater than 300 feet, and along foothills in areas not covered by other studies or additional evaluation.
5. In areas along the foothills in interfan areas lacking specific yield coverage, use a specific yield of 6 percent.
6. Use only values below the water level, i.e., only for saturated strata.

Attachment 4 shows the recommended sources of specific yield data for all areas in the Kings Basin. **Attachment 5 to 10** are maps of each GSA showing the recommended specific yields for use in calculating storage change.

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Attachments

- 1 – Kings Basin, Specific Yield Data Sources Coverage
- 2 – McMullin GSA Area of Evaluation, Location of Subsurface Geologic Cross Sections and Specific Yield Values
- 3 – KDSA, Memorandum on Specific Yield Estimates from Subsurface Geologic Cross Sections, June 19, 2017
- 4 – Kings Basin, Recommended Sources of Specific Yield
- 5 – Central Kings GSA, Data Sources and Recommended Specific Yield
- 6 – James ID GSA, Data Sources and Recommended Specific Yield
- 7 – Kings River east GSA, Data Sources and Recommended Specific Yield
- 8 – McMullin Area GSA, Data Sources and Recommended Specific Yield
- 9 – North Fork Kings GSA, Data Sources and Recommended Specific Yield
- 10 – North Kings GSA, Data Sources and Recommended Specific Yield
- 11 – KDSA, Memorandum on Friant area Specific Yield Estimates

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Cehrs, D., Soenke, S., and Bianchi, W.C., (1980), *A Geologic Approach to Artificial Recharge Site Selection in the Fresno-Clovis Area, California*, U.S. Department of Agriculture, Technical Bulletin 1604

Davis, G.H., Green, J.H., Olmstead, F.H., and Brown, D.W., (1959), *Ground-Water Conditions and Storage Capacity in the San Joaquin Valley, California*, U.S. Geological Survey Water-Supply Paper 1469. Prepared in cooperation with the California Department of Water Resources.

Meinzer, O.E., (1932), *Outline of Methods for Estimating Ground-water Supplies*, U.S. Geological Survey Water Supply Paper 638-C

Page, R.W., and Leblanc, R.A., (1969). *Geology, Hydrology and Water Quality in the Fresno Area, California*, U.S. Geological Survey, Water Resources Division, Open File Report. Prepared in cooperation with the California Department of Water Resources

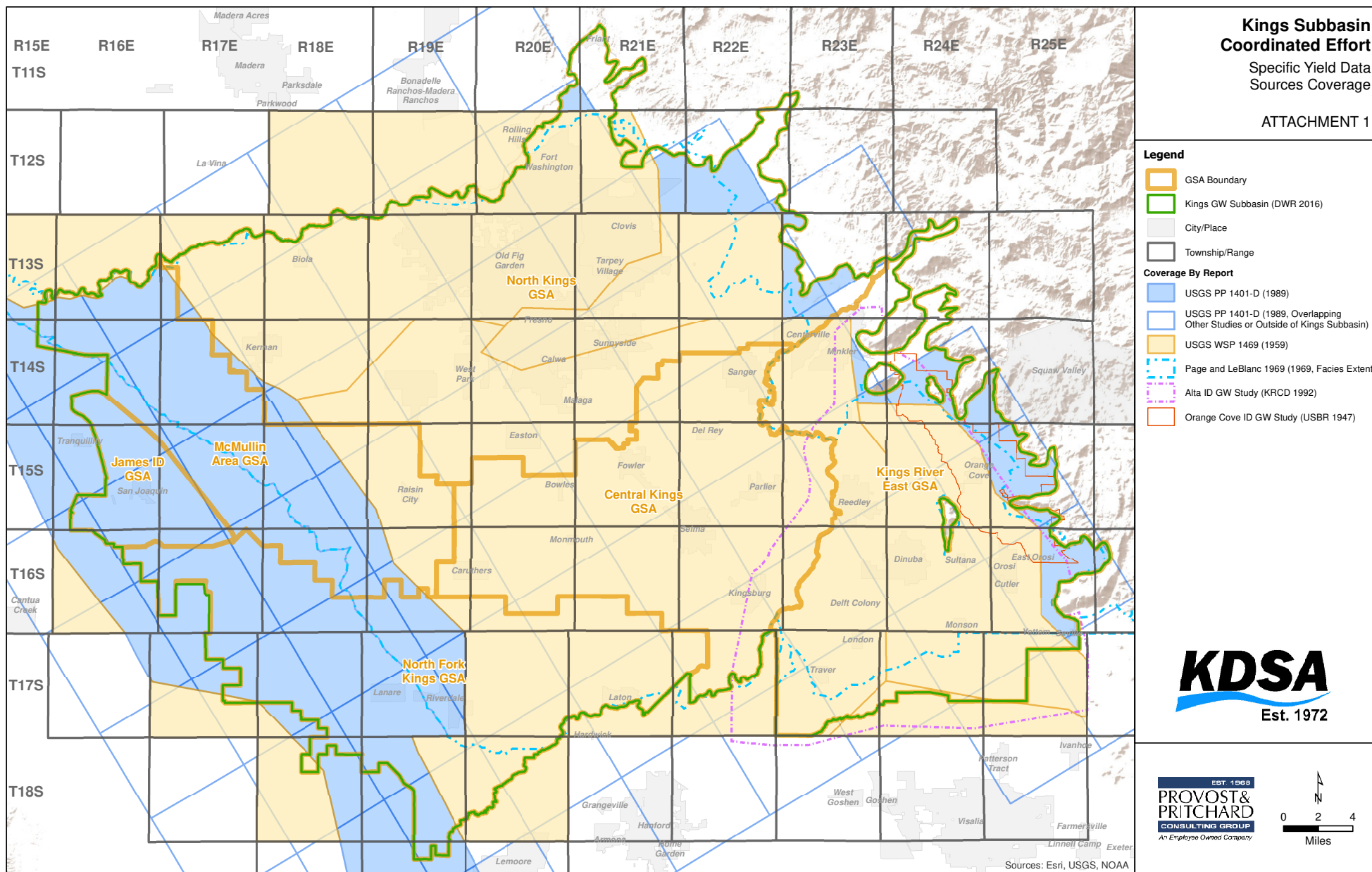
U.S. Bureau of Reclamation, Tulare Basin District (1947a), *Geologic Study of the Orange Cove Irrigation District*.

U.S. Bureau of Reclamation, Tulare Basin District (1947b), *Water Supply Study, Orange Cove Irrigation District*.

Williamson, A.K., Prudic, D.E., and Swain, L.A., (1989). *Ground-Water Flow in the Central Valley, California, Regional Aquifer System Analysis-Central Valley, California*, U.S. Geological Survey Professional Paper 1401-D.

Attachments 1

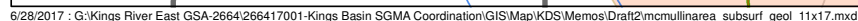
Kings Basin, Specific Yield Data Sources Coverage



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Attachments 2

McMullin GSA Area of Evaluation,
Location of Subsurface Geologic Cross Sections and Specific Yield Values



Attachments 3

KDSA, Memorandum on Specific Yield Estimates from Subsurface Geologic Cross Sections,
June 19, 2017

MEMO

To: Ron Samuelian, Provost & Pritchard
From: Ken Schmidt
Topic: Specific Yield Estimates from
Subsurface Geologic Cross Sections
Date: June 19, 2017

As part of an evaluation for the James Irrigation District (JID), KDSA developed four subsurface geologic cross sections that extend through the District and its associated well fields (Figure 1). The westerly parts of these cross sections are located where the base of the unconfined aquifer is relatively deep, beyond the depths of where specific yields have been estimated in U.S. Geological Survey reports. These cross sections show three types of deposits: 1) sand or coarser material, 2) clay or silt, and 3) intermediate type materials, such as sandy clay. Specific yield values were assigned to these three types as follows: 20 percent, 3 percent, and 8 percent, respectively. The cross sections also show static water levels for the upper aquifer as of Spring 2005. The specific yield estimates were made to cover deposits between the water level and the top of the Corcoran Clay

Cross Section A-A' extends along McMullin Grade to the southwest, to the west edge of the Kings Sub-Basin. The part of this section that was evaluated extended from the southwest edge of the section (Well T16S/R16E-18N) to the northeast to James I.D. Well D-34, located near McMullin Grade and Huntsman Avenue. Eleven wells with the best logs were evaluated. For the westernmost segment, the calculated specific yields for five wells ranged from 7 to 11 percent and averaged 10 percent. The 1401-D specific yield values in the nearest T&R were 8 and 15 percent, or an average of 11.5 percent. For the next segment to the northeast, extending from C-76 at the Fresno Slough to D-32 (three wells), the specific yields ranged from 13 to 17 percent and averaged 15 percent. The closest 1401-D T&R values were 15 percent and 16 percent. For the northeasternmost segment, extending from Well D-35 to D-34, the specific yields ranged from 12 to 13 percent and averaged 13 percent. The closest 1401-D T&R value was 13 percent. Overall, specific yields derived from Cross Section A-A' are in good agreement with the 1401-D estimates.

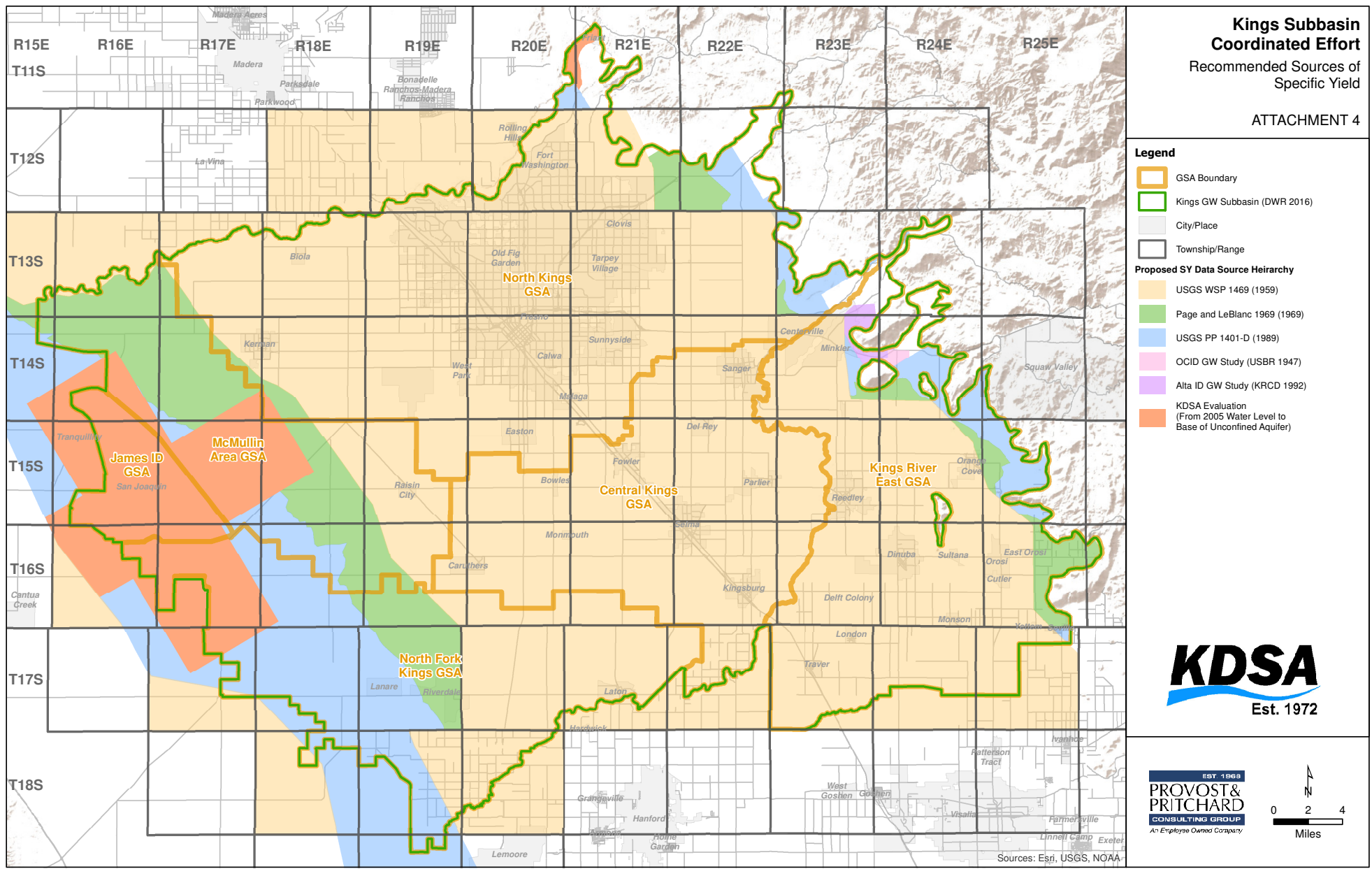
Cross Section B-B' extends along the Fresno Slough. Fifteen wells with good logs were selected for evaluation. The northwestmost segment evaluated comprised five wells (28B to C-65). Specific yields ranged from 9 to 15 percent and averaged 11 percent. The closest 1401-D T&R values ranged from 10 to 11 percent. The next segment evaluated along the cross section extended from D-59 to D-30 (seven wells). Specific yields ranged from 12 to 17 percent and averaged 14 percent. The closest 1401-D T&R values ranged from 9 to 10 percent, and are considered too low for the area. The last part of the segment included three wells (11B to 18M). Specific yields ranged from 12 to 20 percent and averaged 15 percent. The closest 1401-D T&R values were 13 and 15 percent, in good agreement. Overall, specific yields along Cross Section B-B' were in good agreement with the 1401-D values, except in T15S/R17E, where the 1401-D value appears to be too low.

Cross Section C-C' extends from the west edge of the Kings Sub-Basin (7P) to the northeast to well 8C. This section passes through San Joaquin, and nine wells with good logs were selected for evaluation. For the segment southwest of San Joaquin (4 wells), specific yields ranged from 5 to 14 percent and averaged 10 percent. The nearest 1401-D T&R values were 9 and 10 percent. For the other five wells (24M to 8C) along the section, specific yields ranged from 6 to 20 percent and averaged 14 percent. The nearest 1401-D T&R values were 9 to 10 percent, and are indicated to be too low. Again, the 1401-D value for T15S/R17E appears to be too low.

Please call me if you have any questions

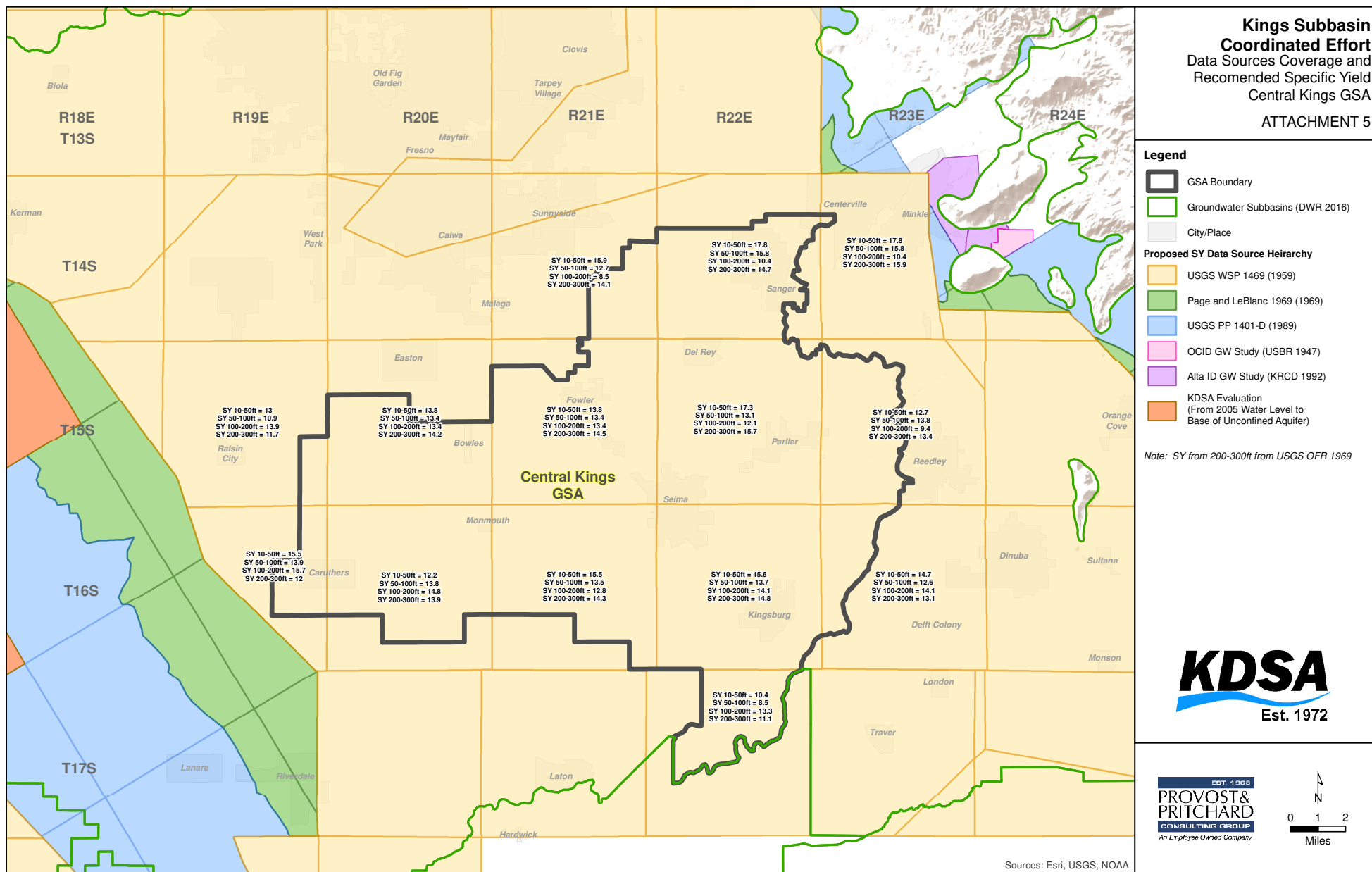
Attachments 4

Kings Basin, Recommended Sources of Specific Yield



Attachments 5

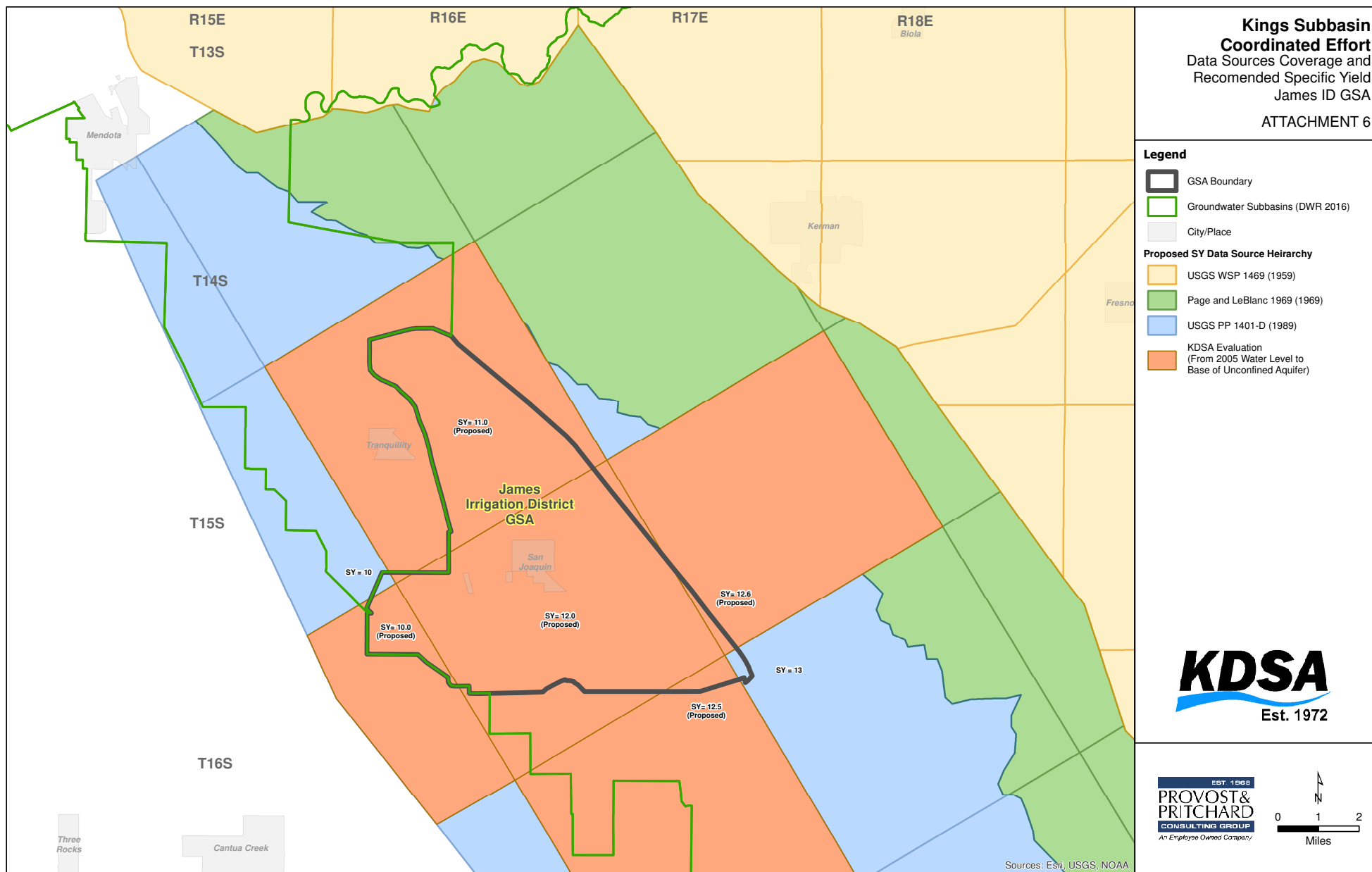
Central Kings GSA, Data Sources and Recommended Specific Yield



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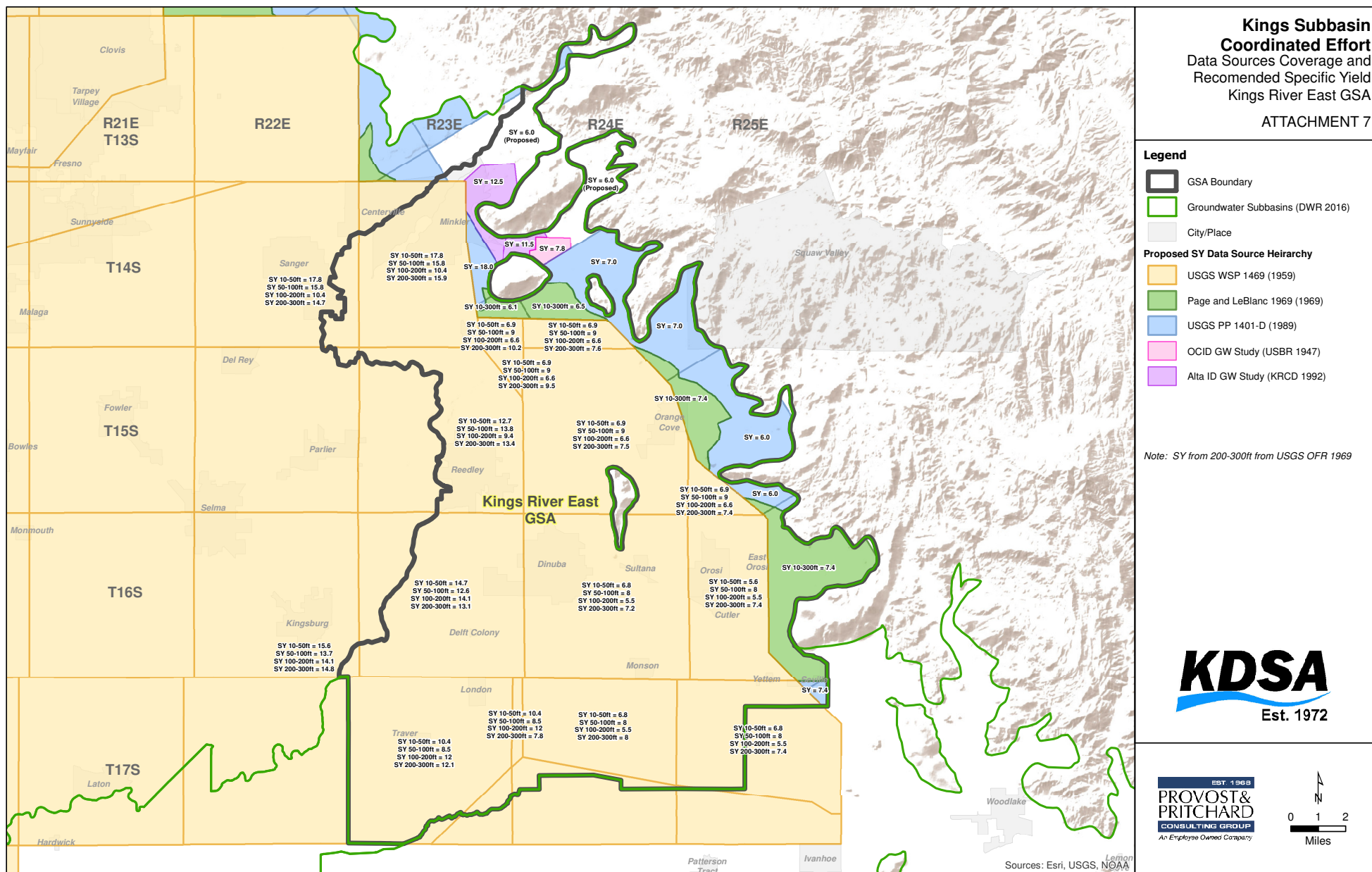
Attachments 6

James ID GSA, Data Sources and Recommended Specific Yield



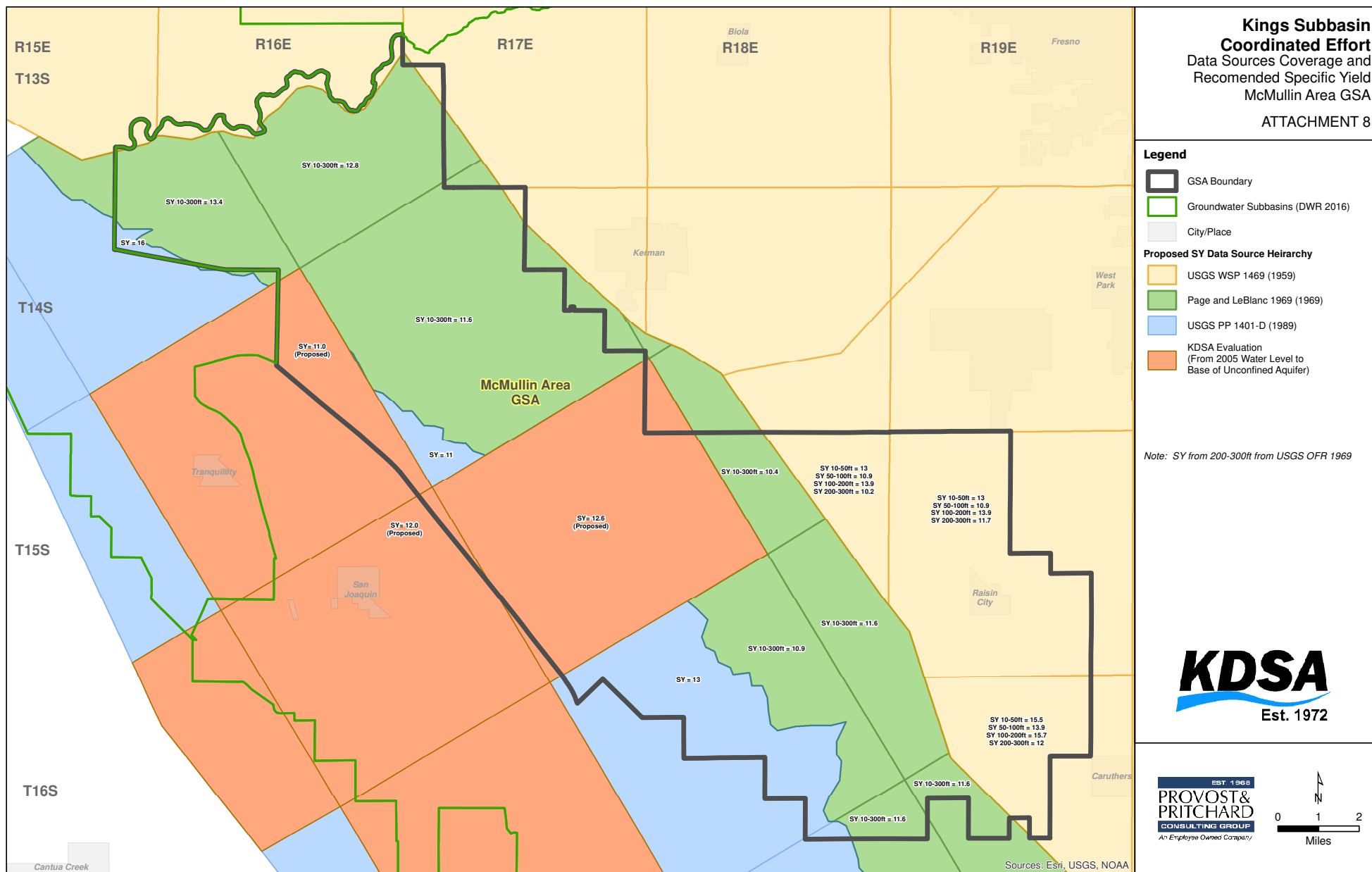
Attachments 7

Kings River east GSA, Data Sources and Recommended Specific Yield



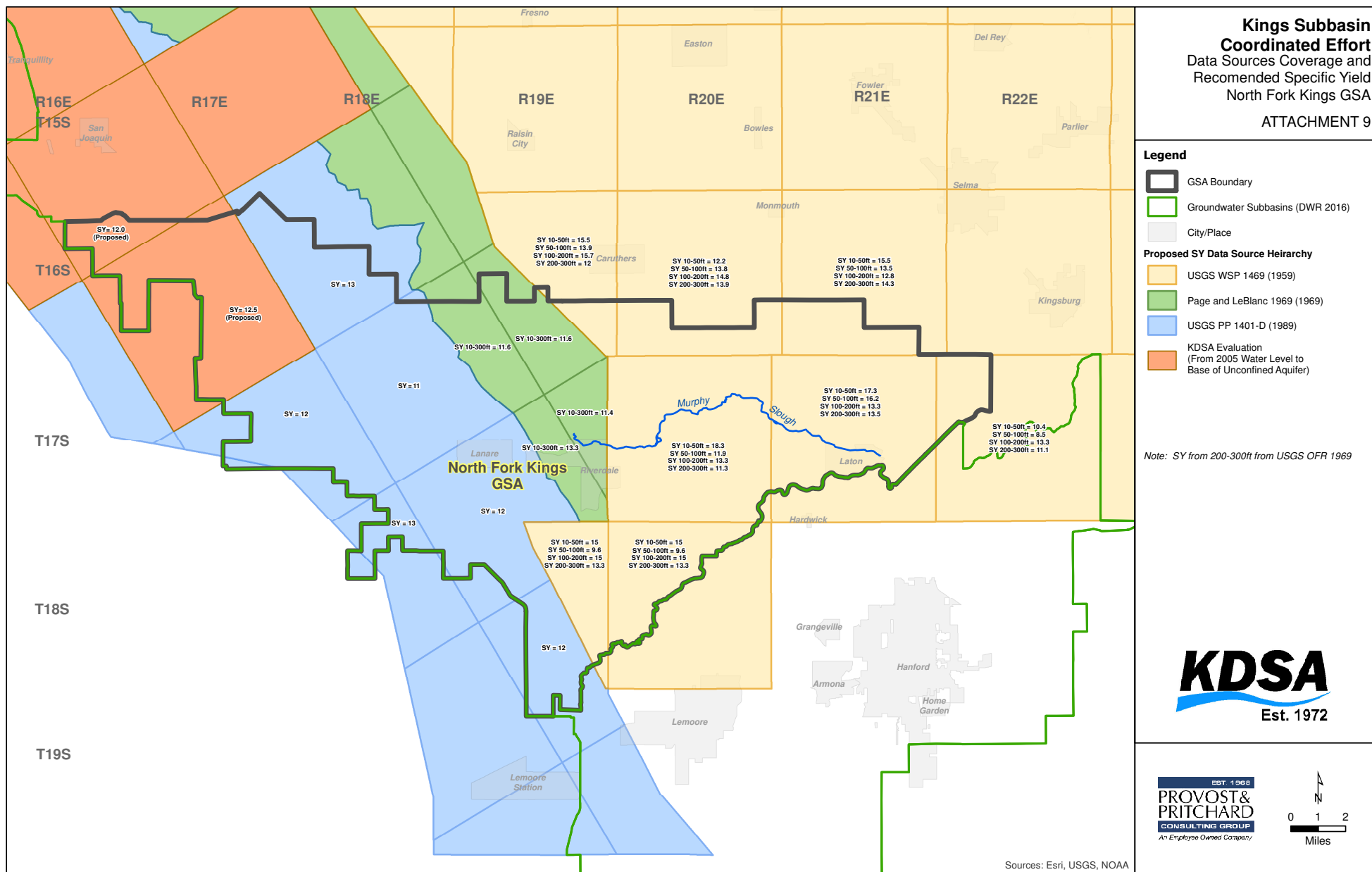
Attachments 8

McMullin Group GSA, Data Sources and Recommended Specific Yield



Attachments 9

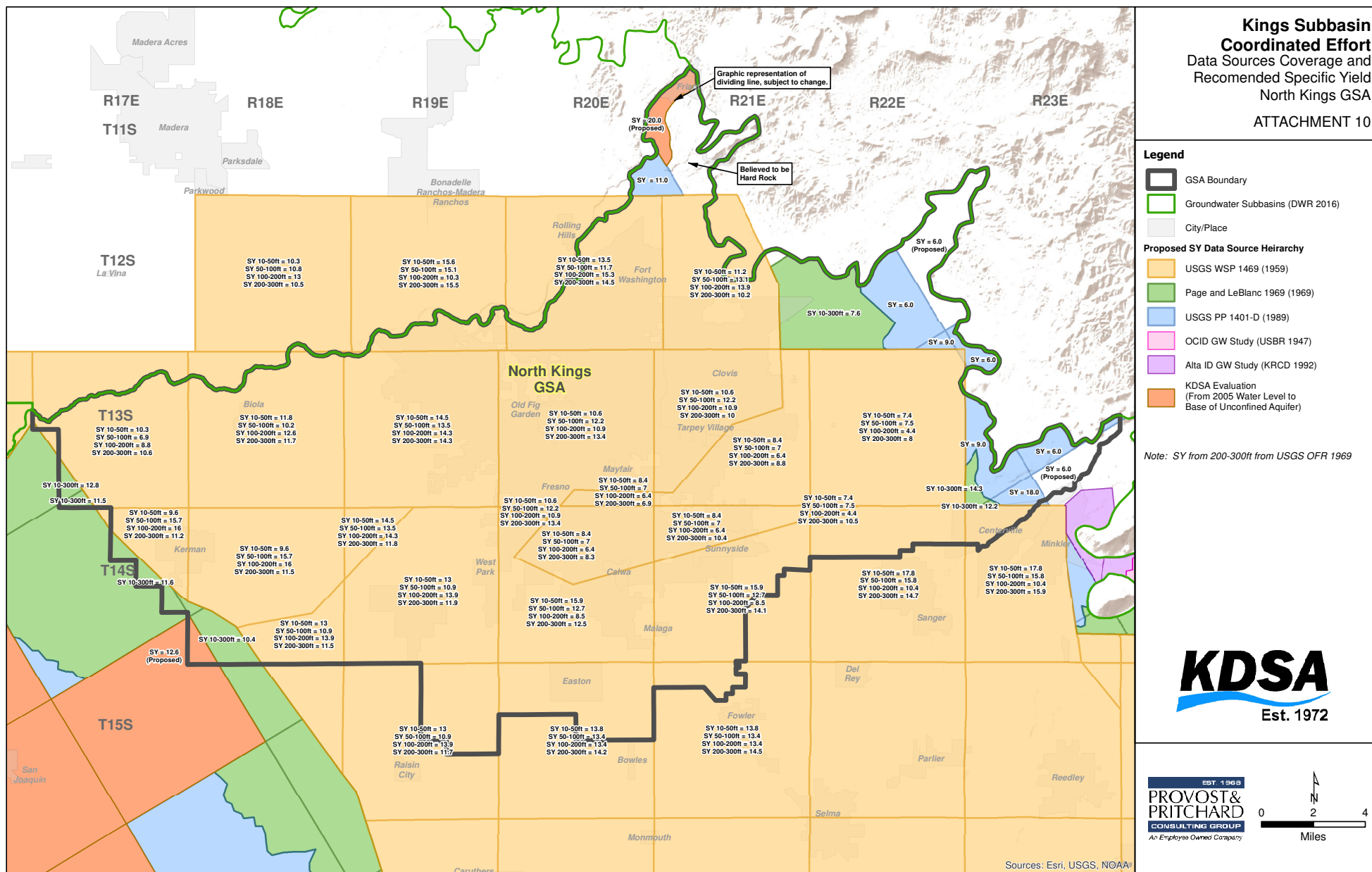
North Fork Kings GSA, Data Sources and Recommended Specific Yield



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Attachments 10

North Kings GSA, Data Sources and Recommended Specific Yield



Attachments 11

KDSA, Memorandum on Friant area Specific Yield Estimates

REACH ALONG SAN JOAQUIN RIVER BELOW FRIANT

For the alluvium along the San Joaquin River between Friant and the confluence of Little Dry Creek, a subsurface geologic cross section from a KDSA report of November 2012 on the Beck Ranch was used. This cross section essentially shows three reaches. The upper reach, extending from near Friant to the south end of the Beck Ranch, is predominantly underlain by cobbles and gravel, having an estimated specific yield of 25 percent. The middle reach, extending from the south end of Beck Ranch to the north end of Ball Ranch, is underlain primarily by sand and gravel, with an estimated specific yield of 20 percent. The southernmost reach, along Ball Ranch near and south of Little Dry Creek, is underlain by alternating layers of cobbles and gravel, sand, and clay. The average specific yield of these deposits is 14 percent. Combining the three reaches, the average specific yield in the reach below Friant is 20 percent.