Appendix E:

Memos from Technical Advisory Committee Members

MEMORANDUM

To: Joseph Sax, Esq.
From: Dr. Steven Bachman, Member of Technical Advisory Committee
Subject: Arizona Technical/Judicial Discussions on Jurisdictional Surface Water and Suggested Tests for Jurisdictional Waters in California
Date: August 15, 2001

I have had a chance to review the Arizona Supreme Court cases and the recommendations from the Arizona Department of Water Resources (ADWR) and I would like to make some comments. I would also like to make some suggestions on how parts of the Arizona discussions could be incorporated in California in a test for what is jurisdictional surface water.

The ADWR treatise[1] starts with descriptions of the geology of groundwater basins and overlying streams in Arizona. The Arizona geologic premises are important in understanding their tests for jurisdictional surface water. Much of their description of streams and underlying groundwater basins are applicable in California. However, California has a much broader range of types of groundwater basins and therefore more ranges in surface water/groundwater interactions. Largely because it, is positioned on the edge of a plate boundary California has a range of different structural settings that also control the groundwater basins. Because of this, there are some statements in the Arizona work that do not apply to California.

For instance, there is the assumption in Arizona that there is an erosional inner alluvial valley in most basins that is filled with "younger alluvium". California streams and rivers do not necessarily follow this assumption. In California, many river systems are constructional – that is the river deposits have built-up on top of previous sediments. Good examples of this are the areas in California where levees are required to control higher flows in the streams, because the streams are very close to surrounding surface elevations. Therefore, anything in the Arizona treatise that discusses this younger alluvium and this incised geometry are probably not applicable to the general case in California.

Another example of a difference between Arizona and California is the general statement that confined aquifers are rare in the Arizona example[2]. In California,

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[1] Technical Assessment of the Arizona Supreme Court Interlocutory Appeal Issue No.2 Opinion, ADWR, 1993.
[2] Ibid, p.16

confined aquifers are found in many areas and constitute a large or perhaps even a majority percentage of the groundwater basins from which groundwater is extracted. California groundwater basins may consist of complex layering of both nonmarine and marine sediments that form multiple aquifers and confining layers.

Despite these differences, I found that the Arizona work was thoughtful and is definitely useful in our deliberations for California. Some of the specific statements made by ADWR are especially useful for us. Arizona has historically tried to use some of the same approaches as California in defining the underflow directly related to surface stream flow. One of these concepts is that subsurface water flowing beneath a surface stream within channels with known "bed and banks" is considered jurisdictional surface water. ADWR stated that,

> "In the ideal, subflow can be visualized as just another part of the stream that lies out of view below the surface. As part of the stream, it also has distinct bed and banks which define its extent. This ideal concept of subflow actually does exist in narrow bedrock canyon streams where both the surface and subsurface components of the stream are contained within hardrock boundaries. But as these bedrock canyons descend from the mountains, the valleys become alluvial valleys between mountain ranges, where the subterranean component of streams becomes unbounded."[3]

> "A physical basis to identify the boundaries of the subterranean component of streams in alluvial valleys does not exist."[4]

The statement in the Arizona treatise that the "bed and banks" criteria only apply in narrow stream canyons, to which I agree, is something that is extremely important to our discussions. It suggests that the "bed and banks" criteria in California should be only a portion of a test to determine whether subsurface water may be jurisdictional. Once a stream has emerged into a valley underlain by a groundwater basin, additional tests are necessary to identify portions of the subsurface water beneath the stream that may be jurisdictional. Arizona case law has taken a restrictive view on this jurisdictional water,

> "The Court (Arizona Supreme Court) makes clear that water in aquifers which are not known underground water courses cannot be classified as subflow. This includes water which has left the known subterranean course and percolated into a nearby aquifer, as well as water in a nearby aquifer which is percolating toward the stream. The Court also makes clear its belief that these known subterranean courses are not as wide as the entire alluvial valley, reaffirming the principle announced in *Southwest Cotton* that 'subflow is found within, or immediately adjacent to, the bed of the surface stream itself.'"[5]

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[3] Ibid, p.38
[4] Ibid, p.91
[5] Ibid, p.39-40

The difficulty in identifying jurisdictional subsurface water in a groundwater basin, away from narrow canyons, is what Arizona has been grappling with:

> "The law appears to require that in alluvial valley streams, an artificially narrow bed and banks be established for the underground flow so that subflow can be approached as a distinct hydrologic entity. From a hydrologist's viewpoint, however, it is not possible to ascertain a distinct hydrologic entity unless artificial criteria are first established." --- "A technical view of subflow in alluvial valley stream situations, then, is not a physical distinction of the hydrologic system, but a certain threshold of interference with the stream."[6]

The Arizona Supreme Court set some limits in identifying jurisdictional water, including comments that,

> "- subflow is not a scientific, hydrological term"[7]

> "Tributary aquifers are those waters which infiltrate their way through the adjoining ground to some surface water course or other body of surface water. These waters differ from the [sub]flow of surface streams in the fact that they have not yet reached the channels of the water courses to which they are tributary."[8]

> "That part of the floodplain alluvium which qualifies as "subflow," beneath and adjacent to the stream, must be part of the geologic unit where the flow direction, the water level elevations, the gradations of the water level elevations and the chemical composition of the water in that particular reach of the stream are substantially the same as the water level, elevation and gradient of the stream."[9]

Thus, groundwater flowing towards the stream that will eventually flow into the stream was excluded from jurisdiction, as was any groundwater that differed in gradient, elevation, and chemistry from the stream. These criteria were among those suggested to the State Board by ACWA in previous testimony and written documents. ADWR approached the problem by proposed several possible tests for jurisdictional waters in alluvial valleys, including:

1) An analytical method to assess streamflow interference from pumping wells by applying pumping rate, length of pumping, distance from the stream, and local aquifer properties;
2) A flow net method that determined at what distance from a stream the groundwater gradients curved in the direction of the stream, within which distance the groundwater was potentially subflow of the stream;

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[6] Ibid, p.41
[7] 198 Ariz. 330, 9 P.3d 1069, p.6
[8] Ibid, p.7
[9] Ibid, p.9

3) A "younger alluvium" method wherein the alluvium filling the erosional inner alluvial valley of a stream was considered to be hydrological interrelated to the stream; and

4) A numerical method using a groundwater flow model.

ADWR considered that the analytical method was the most scientific and the best system, but felt that the Court might not agree.

SUGGESTED TESTS FOR JURISDICTIONAL WATERS IN CALIFORNIA

For California, a combination of some of the techniques suggested in the Arizona treatise might be most effective. The only technique that is not useful in California is the use of the term "younger alluvium" to define the areas where there may be surface and sub-surface groundwater interactions. The reason for this as stated earlier is that California basins rarely have this incised stream valley containing younger alluvium. As an example, along the Santa Clara River in Ventura County there is alluvium of progressively older age buried as deeply as 15,000 feet beneath the river. Trying to define which portion of this alluvium is "younger alluvium" would be an impossible task.

When a stream flows from the "bed and banks" criteria of a bedrock canyon into an alluvial basin, there are several criteria that can be applied directly to determine if there is the possibility that any adjacent subsurface water is jurisdictional. These criteria can be organized into a series of tests. Using the series of tests, a portion of the subsurface water can be systematically eliminated as having no potential for interaction with surface waters. We are then left with a smaller subset of situations where subsurface water may be jurisdictional. This technique is similar to that suggested by ADWR in eliminating the "easy cases."

The hydrologic tests that I suggest start with the most obvious and progress through less obvious and more technically difficult. Ultimately, when we are left with a subset of areas of subsurface water that may be jurisdictional, then a different type of test needs to be applied. This type of test is what we discussed in the last TAC meeting, and which is referred to as the analytical test by ADWR. This analytical test requires that a threshold of effect be established, beyond which the subsurface water is considered to be jurisdictional. This threshold is strictly a policy decision – there is no technical basis to set the threshold higher or lower. This fact bothered the Arizona Supreme Court, which felt that a threshold sounded arbitrary. What a technical analysis will be able to offer is to show the effects of choosing different thresholds before a final decision is made by the State Board – how large an area will be included as jurisdictional subsurface water in typical basins by choosing different thresholds, and how many wells might be affected by selecting different thresholds.

<u>Sequential Tests</u>

Test 1. Bed and Banks – In areas where a stream is contained within narrow bedrock canyons in which the streambed occupies most of the canyon bottom, the historic "bed and banks" test can be used. In this case, the banks of the buried portion of the stream alluvium are most likely to be the bedrock edges of the canyon. It should be noted that scale is important here, and that the width of these bedrock canyons is on the order of hundreds of feet, rather than miles. In this case, the likely presumption is that all of the subsurface water within the bedrock "banks" is flowing with the stream and is jurisdictional.

Test 2. Hydraulic Continuity – As the stream flows across a groundwater basin within an alluvial valley, subsurface water below and adjacent to the stream can only be flowing with the stream if there is hydraulic continuity between the stream and the subsurface water. If there is an unsaturated zone that separates the stream from the subsurface water, the subsurface water is presumed to be percolating groundwater. Likewise, if there is a confining layer that separates the stream from the subsurface water, the subsurface water is presumed to be percolating groundwater. If there is hydraulic continuity, then the subsurface water must be subjected to Test 3. [Note – the specific scientific evidence for hydraulic continuity can be detailed at a later time.]

Test 3. Gradient and Flow Direction of Subsurface Water – For subsurface water that is in hydraulic continuity with an adjacent stream, the gradient and accompanying flow direction of the subsurface water is then compared with the gradient and flow direction of the stream. Unless these gradients and flow directions substantially coincide, the subsurface water is presumed to be percolating groundwater. If they coincide, then the subsurface water must be subjected to Test 4. [Note – the specific criteria for "substantially coincide" can be detailed at a later time. I think that it should be different from ADWR's "flow net" criteria.]

Test 4. Chemistry and Age of Waters – For subsurface water that has passed Tests 2 and 3, the chemistry and age of the subsurface water are compared to the stream. If the chemistry of the subsurface water differs significantly from the stream, then the subsurface water is from a different origin or has traveled a path substantially different from the adjacent stream and is therefore presumed to be percolating groundwater. If the age of the subsurface water indicates that the water has been in the subsurface for longer than 5(?) years, then the subsurface water is presumed to be percolating groundwater. If the subsurface water is similar in chemistry to the stream and the subsurface water has been in the subsurface for less than 5(?) years, then the subsurface water must be subjected to Test 5. If there is insufficient information on the chemistry and age of the waters, then the subsurface water must be subjected to Test 5. [Note – the specific criteria for "differs significantly" can be detailed at a later time.]

Test 5. Analytical Test – For subsurface water that has passed Tests 2, 3, and 4, a final analytical test will be performed to determine the effect that pumping a well drilled into the subject subsurface water would have on the adjacent stream. The analytical test will calculate the percentage of stream water drawn into a well at any specified distance from the stream, given a specified pumping time and pumping rate. There will need to be a policy decision on what effect on the stream will be the threshold for determining State Board jurisdiction over the subsurface water. Once this threshold is established, then the extent of jurisdictional subsurface water adjacent to a particular stream can be determined. The extent of State Board jurisdiction will change along the stream as the aquifer parameters that are part of the analytical test vary along the stream. [Note – the specific analytical test can be detailed at a later time.]

Alternatives to Analytical Test – There may be other available information and models that can be applied in lieu of the analytical test. These might include detailed measurements and studies indicating the degree of connection between the subsurface water and the stream, or a numeric groundwater flow model (such as MODFLOW) that simulates interactions between groundwater and streams. In these cases, local petitioners could use these alternatives in lieu of the analytical test.

Subject: **RE: Thoughts on GW/SW technical advisory committee issues**
Date: Tue, 4 Sep 2001 14:29:13 -0700
From: Steve Bachman <steveb@unitedwater.org>
To: 'Karen R Burow' <krburow@usgs.gov>, kcustis@dfg.ca.gov, Steve Bachman <steveb@unitedwater.org>, chauge@water.ca.gov, Dpurkey@westworldwater.com
CC: saxj@mail.law.berkeley.edu, PMurphey@waterrights.swrcb.ca.gov

Karen,
I was very interested in your comments. Let me think about them. To keep the discussions going, I am in the process of putting technical criteria with the potential tests that I suggested in my memo. That way, we have a target to shoot at.
Steve

-----Original Message-----
From: Karen R Burow [mailto:krburow@usgs.gov]
Sent: Friday, August 31, 2001 3:06 PM
To: kcustis@dfg.ca.gov; steveb@unitedwater.org; chauge@water.ca.gov; Dpurkey@westworldwater.com
Cc: saxj@mail.law.berkeley.edu; PMurphey@waterrights.swrcb.ca.gov; Karen R Burow
Subject: Thoughts on GW/SW technical advisory committee issues

August 31, 2001

To: Technical Advisory Committee,
SWRCB project for review of permitting authority over appropriations of ground water classified as subterranean streams and the SWRCB's implementation of those laws.

From: Karen Burow, TAC member

Please find below some thoughts following Steve's memo dated August 15.

I agree that California has a wider range of "characteristic" stream settings than Arizona. The entire southern half of Arizona is characterized as part of the Basin and Range province, whereas California is divided into 8 different provinces, just to give you an idea of the range of geomorphic characteristics. Regarding the classification of "younger alluvium"- there is previous work in California in which younger (Holocene) alluvium has been mapped and described both on the surface and subsurface. For example, Davis and others (1959) mapped the San Joaquin Valley. At this point, however, whether the sediments surrounding the stream are younger or older alluvium is irrelevant in my mind (see comment 2 below). I also agree with Steve that we have significant confined aquifers- and I would think that pumping from confined aquifers would not have significant influence on streams in most cases.

I am uncomfortable with the notion of delineating a "subterranean stream" as though the water flowing underground along with the stream was separate somehow from the surrounding ground water. For example, given the same set of stream characteristics, a single well pumping intermittently at 500 gpm may not significantly affect a stream, whereas a set of three wells pumping at 1,500 gpm each over long time periods may affect the stream regardless of whether the aquifer near the stream fit the characteristics of gradient or water quality or "younger alluvium". Significant amounts of pumping can reverse the natural gradients (not to mention that gradients near the stream can change as a result of seasonal or climatic changes). Therefore, from a purely technical standpoint, I don't think one can delineate a true "zone of influence" around a stream (whether the water is flowing exactly along the stream path or not) in the absence of consideration for the quantity of streamflow and the individual capacity of the well(s) and length of pumping (so called time-volume analysis). Then the determination comes down to a policy decision on what levels of interference are acceptable, as Steve has noted.

Perhaps it would be possible to use some type of ratio between streamflow, pumping capacity, and pumping frequency, within selected stream/aquifer settings to screen out some of the less significant cases and then apply the more quantitative tests. The types of stream/aquifer characteristics I can think of to characterize stream settings could include: hydraulic gradients, hydraulic conductivity of the sediments, juxtaposition of hydrogeologic units (bedrock/alluvium interface, for example), gaining/losing portions of streams, and seasonal variation in streamflow and hydraulic gradients. The only problem is that this could take a significant amount of time to characterize all the different types of hydrogeologic settings in California.

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September 14, 2001

From: Kit Custis
Senior Engineering Geologist
Dept. of Conservation

To: Department of Fish and Game

This memo has my thoughts on the proposal by Steven Bachman, e-mail to Joe Sax on 8/15/01, regarding tests for classifying groundwater in California. The five tests that Mr. Bachman proposes seems to not replace the current "bed and banks" test, but add four additional tests. All of which must be passed before ground water becomes jurisdictional. This does not seem to be progressive but rather regressive, making it essentially certain that no ground water in California will be jurisdictional. At the end of this memo, I will suggest a methodology that might be used by the State Water Resources Control Board (State Board) to determine whether a well(s) may impact stream flows.

I am in agreement with Mr. Bachman regarding the difference in geologic setting between Arizona and California. The Arizona methodology that Mr. Sax asked us to comment on was for the Gila River Basin, located in the southwestern portion of the state. The Gila drains from just south east of Phoenix to the Colorado River at Yuma. As I discussed with DFG staff before, this area of Arizona has Quaternary geologic history that created a distinct difference between the "older alluvium" and the "younger alluvium" that is typically found in the Basin and Range deserts of California, Nevada, Utah and Arizona. The Arizona DWR staff were trying to take advantage of this distinct geologic difference since it is often readily visible in the field. The older alluvium is generally cemented together with carbonate making it difficult to dig and forms steep slopes, whereas the younger alluvium are uncemented sands and gravels in the active river channel. The diversity of California's geology make the use of a "young" versus "old" formation type distinction meaningless in a statewide application.

Mr. Bachman's memo discusses at some length the issue of "bed and banks" related to defining a subterranean stream and the connection to surface water. He agrees with Arizona's DWR statement that the only "bed and banks" criteria only apply to narrow stream canyons, presumably these narrow canyons are underlain by bedrock. Again the issue is on geology setting. For Arizona these headwater canyons are underlain by "hard rock," the type varies, but the permeability of the material is from fractures not pores. While hard, fractured bedrock is common in California headwater areas, uncemented sandstones are also possible. For example, the Santa Margarita Sandstone in the Santa Cruz area is Miocene-Pliocene in age, which range from 23 to 2 million years ago, although this formation is likely younger than 10 million years. It is still mostly uncemented and is a good yielding aquifer. Streams that flow in incised canyons within the Santa Margarita SS are connected hydraulically with the formation, and the concept of canyon "bed and banks" is invalid.

The recent Garrapata decision by the State Board (Decision 1639, "Garrapata Decision") has a long discussion in the issue of fracture flow feeding a stream. Mr. Bachman and

Arizona DWR ignore the issue of fracture permeability when determining "bed and banks" in bedrock canyons. A rock mechanics technical report that I have has a graph showing the equivalent permeability of fractured rock. For example, a rock with an open fracture 0.1 cm wide (1 millimeter) spaced once every meter, has an equivalent permeability of 0.1 cm/sec. While this does not seem like much, it is roughly equivalent to the permeability of a clean, gravely sand. While most fractures are not continuously open, the bedrock often has many interconnecting fractures that can transmit a lot of water, and it is the coalescing of fractures that one looks for when trying to place a well in bedrock to maximize yield. Thus, it is possible that a well in bedrock adjacent to a stream can be diverting surface water through the fracture system. I will talk about this issue again with the discussion of Bachman's test 1 methodology.

The Garrapata Decision also makes a point that the "bed and banks" does not have to be interconnected with a surface stream (section 3.3.1). This is a really important issue because it breaks the requirement of a direct linkage between surface water and ground water. As I interpret the Garrapata Decision, ground water that begins as "percolating" water can become "subterranean" flow if it moves in a subsurface channel defined by "bed and banks" that are impermeable relative to the channel materials. Four of the five tests proposed by Mr. Bachman go directly to the issue of showing that the water was derived substantially from surface water alone and if it was ever "ground water" then it is non-jurisdictional. The State Board seems to be saying that test of that nature are "immaterial" to the legal classification of ground water.

Bachman's Test 1 is the classic "bed and banks," but he qualifies it with the need to be a "narrow" bedrock canyon in which the steam occupies "most" of the canyon bottom. All of these undefined qualifiers make the test much more difficult to pass. This goes directly to the fear that the "banks" can be miles from the stream, bringing much of the ground water into the State Board's jurisdiction. I don't agree that a well a thousand feet, ("order of hundreds of feet") from a stream can't have an impact on surface water. It depends on the pumping rate and the hydrogeologic setting. I don't think that a codified fixed distance can ensure that the State Board will take jurisdiction over all wells that withdraw water from a subterranean stream, thus impacting the aquatic ecosystem. The State Board's determination that no interconnection is necessary is also violated with this new test and definition of "bed and banks." The State Board's statement in the Garrapata Decision doesn't seem to require the test of "narrow" and "most of canyon bottom."

Bachman's Test 2 attempts to address the issue of direction of stream flow with the presumption that subsurface water "below and adjacent to the stream" can only be flowing with the stream if there is "saturated" hydraulic continuity between the surface and subsurface waters. The State Board's issue of not needing to be directly adjacent has been discussed before. This test proposes that if there is an unsaturated zone, of unspecified thickness and duration, then the ground water is percolating and the hydraulic continuity or connection with surface water is broken. Here we begin the issue of pedigree and the need to have a direct and definable "saturated" pathway between surface and subsurface waters. The concept that the presence of an unsaturated zone breaks the hydraulic continuity between surface water and ground water is inaccurate. First there is the issue of how long and to what extent the unsaturated zone occurs. Seasonal and long-term fluctuation is water table and variations in sediment type can result in temporary unsaturated zones. To measure the thickness of the unsaturated zone, you typically measure the elevation of the water table relative to the streambed, but this does not address the "unsaturated" characteristics of the soils between the surface and ground water. That is, at what rate and direction does the unsaturated zone ground water flow? Surface water does move from the stream bottom downward through an unsaturated zone, but the head difference between the stream and underlying water table does not influence of the rate of infiltration. That does not mean that pumping of ground water doesn't impact surface waters. If a greater unsaturated zone is created by lowering the water table, then more surface water can infiltrate into the subsurface thereby reducing the surface water flows. Mojave River's Alta transition zone is a case in point. The ground water basin in the transition zone needs to be "full" to allow the surface water to move down stream. So the presence of a thick unsaturated zone is known to impact surface water flow directly. I think it is predictable that should the presence of an unsaturated zone mean that the groundwater is not under water rights jurisdiction, then there will be purposeful pumping to create and maintain the unsaturated zone. In other words the more the wells pump, the less jurisdiction the State Board will have over the impacts.

Bachman's Test 3 is an additional qualification on the "saturated" hydraulic continuity requiring that the "gradient and flow direction" of the ground water be essentially the same as adjacent stream. Here the State Board's determination, stated in the Garrapata Decision, that ground water doesn't need to be interconnected with surface water seems to nullify this requirement for flow and gradient. Mr. Bachman's test would require that gradient and direction of ground water "substantially coincide" with surface waters, presumably the interconnected, adjacent waters. This test ignores the concept of gaining and losing streams where the flow direction is towards or away from the stream. In the case of a gaining stream, nearby pumping may divert water that normally flows to the stream. Why would the test of gradient and direction have relevancy when the well is creating the both? Is the test run when there are no wells pumping and is it done at different times of the year? How long must the pumping be stopped because recovery of groundwater gradient and flow direction will not be instantaneous? Because the gradient of ground water is commonly much less than that of surface waters, what level of gradient agreement is needed to establish that they "substantially coincide?" This test also ignores the issue of the hyporheic zone where surface water may enter the stream bed, travel for some distance underground and then re-enter the stream. Because this test has no specifics on how to measure the gradient and flow direction, there is no standard for measuring differences. Closely spaced mini-piezometers along streams can show that there are substantial changes over short distances in gradient and direction along streams as a result of changes in hydraulic conductivity and layering. Are these differences sufficient to prove the lack of interconnection between surface water and ground water? I think that the gradient and flow direction test is inappropriate because of the natural variation that occurs between interconnected surface and ground waters and the influence that pumping can have on the parameters.

Bachman's Test 4 is a geochemical test that is done following passage of test 2 and 4. Here the true genetics of the ground water are measured. The presumption is that differences in surface and ground water chemistry means that they are not hydraulically interconnected. Here, the State Board's determination stated in the Garrapata Decision, that an adjacent interconnection is not necessary also seems to nullify this requirement. If waters can flow through a ground water aquifer before entering a subterranean channel, then the chemistry can be allowed to be different. This test also has a requirement for "significant" differences without specifying what chemicals, what analytical tests and what level of differences are significant. This test does not account for natural changes in chemistry that occur because of a change in oxygen level between surface and groundwater. Changes in the redox potential can have a significant impact on water chemistry, even in surface water bodies, but it does not mean that they is not hydraulically interconnection. This test makes no exceptions for extraneous sources of "pollution" or chemicals that could substantially alter the chemistry of either water body. The test does not account for mixing of chemistry and interaction between natural inorganic and organic chemicals. Will the test be run at the well head, and how long must the well run before a sample is taken and why? The test seems to imply that the pumping of the well will cause an instantaneous discharge of surface waters, when the hydraulics of a pumping well will require some time for water from the stream to reach the well and it is likely there will always be a blending of groundwater and surface water resulting in a changed chemistry.

The second geochemical test is one to determine the "age" of the water. Mr. Bachman suggests that waters that have been in the subsurface longer than 5 years be considered percolating. Here the mixing and chemical change issues are similar to the general chemistry discussed above. There is an additional issue of the type and accuracy of age dating water. No specific test methodology is proposed, but the test seems to argue that presently available analytical methods can distinguish between waters of a few years in age. While I'm not familiar with a method that can achieve this level of accuracy and precision, I have some concerns since most methods have matrix interferences and outside pollutants that significantly contribute to uncertainty. What happens if the test method can not distinguish the age of water within a few years? What about mixing impacts? Can changes in chemistry due to rising ground water to the surface cause interferences? Finally, when should the sample be taken?

Bachman's Test 5 is the final test, should the other 4 be passed. This test is most relevant to the issue of impacts of a well on diversion of surface water flows. This test would require a hydrogeologic analysis of the well's potential hydraulic impact on the stream. The State Board would have to set a level of significance threshold that when exceeded the well's pumping would be jurisdictional. This test is most closely related to DFG's desire to determine State Board jurisdiction based on the impacts of a well on the aquatic ecosystem. The test leaves out a few issues such as when and how to conduct the test. Is the test solely a numerical exercise or is there are requirement to conduct a pumping well test with measurement of stream impacts? Also, the test assumes that the stream impacts will be adjacent to the pumping well. The impacts may be distant from the wells when the pumping extracts water that would recharge the downstream surface flows. Mr. Bachman proposes that that the State Board's jurisdiction change with the hydrogeologic (aquifer) parameters. I suspect that a variable jurisdiction criteria could not be implemented. The jurisdictional criteria for the State Board should be consistent and predictable.

Given the above discussion, I don't recommend that DFG agree with any of these test except possibly a modification of test 5, the pumping impact test. As DFG stated at the Professor Sax's public meeting in Sacramento, the test for State Board jurisdiction over a well should be based on the potential impact of the pumping on the aquatic stream ecosystem. Any test devised should take into account that the protester (DFG for example) does not have to be an expert in groundwater engineering to raise the State Board's level of concern. Direct observations of impacts to surface water flows and the similarity of a site with other tested sites, should suffice to begin at least a monitoring program. There is an issue in that the State Board seems to feel that they can only ask for monitoring if there is a water rights permit. Based on my experience working for the State and Regional Boards, they can require monitoring if there is evidence of impacts to water quality and beneficial uses. It would be important to get a monitoring procedure in place so that data can be collected to document the potential impact. If DFG is the protester, then they should have a say in the design and implementation of the monitoring program.

Conclusion

As I noted several times in this memo, the current perception is that ground water has a distinct heritage and that ground water that cannot be proven to be derived *directly* from the *adjacent* surface waters is by default percolated and the impacts from pumping are not jurisdictional. Three of the five test proposed by Mr. Bachman are designed to determine the ground water's heritage or pedigree and should the water flunk any one of the five tests, then it is not jurisdictional. This approach ignores the fact that pumping of wells can and do have an impact on surface water flows, water quality and beneficial uses and that impact is not always on the stream reach directly adjacent to the well or made solely of water taken from the stream. Unless the State Board is willing to address the issue of surface water diversion from ground water pumping and the impacts on beneficial uses, the addition of five tests over the current one test ("bed and banks") is a step backwards to achieving a workable policy that protects water rights and stream habitats.

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October 15, 2001,

Professor Joseph Sax
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Joe:

Here are some of my reflections regarding the legal classification of ground water beneath streams.

1. **Bed and Banks**
   I agree with Steve Bachmans statement that "in areas where a stream is contained within narrow bedrock canyons in which the streambed occupies most of the canyon bottom, the historic `bed and banks' test can be used." This would apply to perennial and ephemeral streams in hard rock terrains draining into alluvial basins. This also would apply to channels incised in pediments within the alluvial basin covered by a veneer of unconsolidated deposits.

2. **Edges or Margins of alluvial basins – all perennial streams and the average downstream limit of ephemeral streams**
   No confined groundwater should be considered. The proof of subterranean flow should be the configuration of the water table beneath the streams. The groundwater contours beneath the stream should point in the general downstream direction. The chemistry of the ground water should be nearly identical to the chemistry of the overlying stream. The age of the ground water should not be a consideration because most of the recharge enters near the basin margin and forms wave trains as the ground water moves in a down basin direction. There is a train of annual recharge waves moving in a down basin direction.

3. **Size of stream recharge area**
   To estimate the size of a recharge area beneath a stream, I'm leaning toward the use of the contour direction and 45 degree tangent lines diagrammatically shown on page 76 of the Arizona DWR report dated December 15, 1993. Where a stream meanders across the full width of the flood plain, between the first flood plain terraces, perhaps the edges of the terraces could be used.

4. **Volume of water extracted from stream recharge**
   Here I would use the Jenkins Equation which is a graphical solution to the Theis Equation. I believe a threshold value of 50 percent depletion is too high. 20 percent depletion seems more realistic to me.

I hope these thoughts assist you in your deliberations.

MEMORANDUM

To: Joseph Sax, Esq.
From: Dr. Steven Bachman, Member of Technical Advisory Committee
Subject: Expanded Discussion of Tests for Jurisdictional Groundwater
Date: October 18, 2001

I would like to expand on the series of tests for jurisdictional surface water that I suggested in mid-August. The rationale for these tests was explored in the August 15 memo, and need not be repeated here. Instead, I would like to examine in more detail the specific information that would be evaluated in each of the tests. Some of this information is technical, so I have circulated this memo to technical experts for comment and have incorporated those comments.

Tests for Jurisdictional Waters in California

When a stream flows from the "bed and banks" criteria of a bedrock canyon into an alluvial basin, there are several criteria that can be applied directly to determine if there is the possibility that any adjacent subsurface water is jurisdictional. These criteria can be organized into a series of tests. Using the series of tests, a portion of the subsurface water can be systematically eliminated as having no potential for interaction with surface waters. We are then left with a smaller subset of situations, where subsurface water may be jurisdictional, to which the final test (Test 5) is applied.

It should be noted that when the term "subsurface water" is used here to generically describe all water found beneath ground surface; the term "groundwater" is used only in its jurisdictional sense when it has been determined that subsurface water is percolating groundwater.

Sequential Tests

Test 1. Bed and Banks – In areas where a stream is contained within narrow bedrock canyons in which the streambed occupies much of the canyon bottom, the historic "bed and banks" test can be used. In this case, the banks of the buried portion of the stream alluvium are either the bedrock edges of the canyon or the incised edge of older sediments. It should be noted that scale is important here, and that the width of these bedrock canyons is no greater than hundreds of feet, rather than miles. In this case, the presumption is that all of the subsurface water within the bedrock "banks" is flowing with the stream and is jurisdictional, unless Tests 2 through 5 indicate otherwise.

Criterion 1a. Canyon width – The width of the canyon is narrow, with the active channel of the stream occupying greater than 20% of the width of the canyon. If not, then the subsurface water must be subjected to Test 2.

Criterion 1b. Canyon sediments – The saturated sediments filling the canyon were deposited by the stream and the morphology of these buried sediments reflects the present stream depositional system. If not, then the subsurface water must be subjected to Test 2. If criteria 1a and 1b are met, the subsurface water is presumed to be jurisdictional. However, if there is additional evidence available that suggests that Tests 2 through 5 may indicate that the subsurface water is not be jurisdictional, this information should be applied.

<u>Test 2.</u> <u>Hydraulic Continuity</u> – As the stream flows across a groundwater basin within an alluvial valley, subsurface water below and adjacent to the stream can only be flowing with the stream if there is hydraulic continuity between the stream and the subsurface water. If there is an unsaturated zone that separates the stream from the subsurface water, the subsurface water is percolating groundwater. Likewise, if there is a confining layer that separates the stream from the subsurface water, the subsurface water is percolating groundwater. If there is hydraulic continuity, then the subsurface water must be subjected to Test 3.

Along some streams, groundwater levels fluctuate such that continuity is variable along the stream. This would lead to alternating areas of jurisdiction. In addition, not all reaches of the stream may have sufficient information to determine the below criteria. Some technique for generalizing the condition would need to be used.

Criterion 2a. Saturation – Saturation and hydraulic continuity are indicated by subsurface water levels adjacent to the stream that are equivalent to or higher than the level of the base of the streamflow. If subsurface water levels are lower than the base of the streamflow, then the subsurface water is not in hydraulic continuity with the stream and is therefore percolating groundwater. Some reaches of a stream may be in hydraulic continuity with subsurface water only during wet conditions (either seasonally or during wet portions of a climatic cycle). For the purpose of determining jurisdictional waters, the stream and subsurface water must have been in hydraulic continuity for at least 6 months of the base year. The base year is defined as the median streamflow year of the immediately preceding 15 years.

Criterion 2b. Confining layer – If a confining layer separates the subsurface water from the surface stream, then the subsurface water is percolating groundwater. Evidence for the confining layer must be lithologic, reinforced by hydrologic data. The lithologic evidence must indicate that low conductivity sediments overlie the aquifer in question, as determined by drillers' logs and/or geophysical logs. These low conductivity sediments must be present in sufficient areal extent to hydraulically separate the aquifer from the surface stream.

Additional evidence of a confining layer is indicated by hydrologic data from wells and aquifer tests. If water levels in wells perforated beneath the confining layer are at a higher elevation than the top of the aquifer, this is further evidence that the subsurface water is confined and not in hydraulic continuity with the stream.

Multiple aquifer systems may underlie the surface stream. These may all be confined aquifers, or there may be an upper unconfined aquifer underlain by one or more confined aquifers. It is only in an unconfined aquifer where there is the possibility that any subsurface water could be jurisdictional.

Test 3. Flow Direction and Gradient of Subsurface Water – For subsurface water that is in hydraulic continuity with an adjacent stream, the gradient and accompanying flow direction of the subsurface water is then compared with the gradient and flow direction of the stream. Unless these gradients and flow directions substantially coincide (subsurface water flowing with the stream), the subsurface water is percolating groundwater. If they coincide, then the subsurface water must be subjected to Test 4.

Criterion 3a. Flow direction – The flow direction of the subsurface water is determined from a map of contoured subsurface water level elevations. These contours should represent water levels measured in wells during the portion of the year when pumping is minimized. As many wells as possible in reasonable proximity to the stream should be measured to carry out this test. The flow direction of the subsurface water is perpendicular to the water level contours at any point in the basin. The flow direction of the subsurface water adjacent to the stream is compared to that of the stream. The flow direction of the subsurface water is considered to substantially coincide with the flow direction of the stream if they vary in azimuth by no more than 20°.

The direction of a stream may vary significantly along any reach, especially if the stream is following a meandering course. The least-squares method of straightening out these variations documented by the Arizona Department of Water Resources[1] would be an appropriate method to determine the direction of the stream.

[1] Technical Assessment of the Arizona Supreme Court Interlocutory Appeal Issue No.2 Opinion, 1993, Appendix B.

Criterion 3b. Flow gradient – The flow gradient of the subsurface water may be important in some instances to assist in identifying percolating groundwater. This will have to be applied on a case-by-case basis.

Test 4. Chemistry and Age of Waters – For subsurface water that has passed Tests 2 and 3, the chemistry and age of the subsurface water are compared to the stream. If the chemistry of the subsurface water differs significantly from the stream, then the subsurface water is from a different origin or has traveled a path substantially different from the adjacent stream and is therefore percolating groundwater. If the age of the subsurface water indicates that the water has been in the subsurface for longer than 5 years, then the subsurface water is percolating groundwater. If the subsurface water is similar in chemistry to the stream and the subsurface water has been in the subsurface for less than 5 years, then the subsurface water may or may not be jurisdictional and must be subjected to Test 5. If there is insufficient information on the chemistry and age of the waters, then the subsurface water must be subjected to Test 5.

Criterion 4a. Chemistry of waters – The chemistry of the subsurface and surface waters must be substantially the same for the subsurface water to be jurisdictional. Two methods of comparison can be used: general mineral chemistry and isotopic chemistry.

General mineral chemistry, which is a typical laboratory suite of analyses, is a common method of typing waters. There are generally 15 to 20 separate minerals and ions tested in this suite. Stream water may vary somewhat in chemistry with varying flow rate, and the chemistry of subsurface waters may vary somewhat from one sample period to another. For the purpose of this test, the surface and subsurface waters must have overlapping ranges in composition for all general mineral analyses when all samples collected over the most recent 10-year period are considered; if not, then the subsurface water is percolating groundwater. If there were fewer than three analyses conducted over the most recent 10-year period for either the subsurface water or the stream, then the chemistry data are considered insufficient.

Various isotopes give information about the origin of the source water for the stream or the recharge for the subsurface water. Samples from both the stream and the subsurface must have isotopic compositions that overlap within the statistical errors of the analytical method; if not, then the subsurface water is percolating groundwater.

Criterion 4b. Age of subsurface water – There are several methods for evaluating the age of the subsurface water (the length of time the water has been in the subsurface, not in contact with the atmosphere). Water traveling with the stream moves between the subsurface and surface as the stream flows over sediments that vary in hydraulic conductivity; more or less water flows at the surface depending upon the geometry and conductivity of these underlying sediments. If the age of the water is sufficiently old (5 years or greater), meaning that it hasn't risen to the surface in some time, then it is percolating groundwater and not part of the overall flow of the stream.

Test 5. **Analytical or Aquifer Test** – For subsurface water that has passed Tests 2, 3, and 4, a final analytical or aquifer test will be performed to determine the effect that pumping a well drilled into the subsurface water would have on the adjacent stream. An analytical test will calculate the percentage of stream water drawn into a well at any specified distance from the stream, given a specified pumping time and pumping rate. There will need to be a policy decision on what effect on the stream will be the threshold for determining State Board jurisdiction over the subsurface water. Once this threshold is established, then the extent of jurisdictional subsurface water adjacent to a particular stream can be determined. The extent of State Board jurisdiction will change along the stream as the aquifer parameters that are part of the analytical test vary along the stream. [Note - the specific analytical test can be detailed at a later time.]

An alternative test would be to use an aquifer test from the well in question to determine the degree of connection the pumping well has with streamflow. Such a test would involve monitoring water levels in the pumping well over a specified period of time, as well as monitoring water levels in adjacent monitoring points. Standard analyses of the water level drawdown in the well and monitoring points can determine whether the cone of depression in the water levels from the pumping well has intersected the stream and the relative amount of stream water that is being pulled towards the well. [The specific criteria will be detailed later.]

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Registered California Hydrogeologist HG 219
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1059 Via Verona Drive
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December 6, 2001

Joseph G. Sax
1150 Street, #12
San Francisco, CA 94109-9103

Joe:

Here are some of my thoughts on streams and ground water in alluvial basins.

SIZE OF THE STREAM RECHARGE AREA

1. If a stream reach is long and straight it should be the size of the stream. (See figure 1A).
2. If the stream is meandering it should be related to the size of the meander belt on each side of the stream. (See figure 1B).
3. If the stream meanders across the entire width of the first flood plain terrace it should be the distance between the terraces. (See figure 1C).

WHEN SHOULD A WELL BE CONSIDERED AS EXTRACTING WATER FROM THE STREAM DISCHARGE AREA?

1. When the well extracts 20 percent of its annual flow from the stream recharge area (use the Jenkins Method and P.G.& E. receipts).
2. If the well is less than 1000 feed from the stream recharge area it must be further scrutinized.
3. If the well creates a drawdown of 0.20 or more at the edge of the recharge area, additional tests must be made, i.e. is it pumping 20 percent or more of its annual yield from the stream recharge area.
4. If all the well screens are located beneath a clay layer 1.0 foot or more thick (as ascertained from an E log) then the well will not be considered as drawing water from the stream discharge area.
5. Wells may adjust their discharges to avoid being regulated.

1A

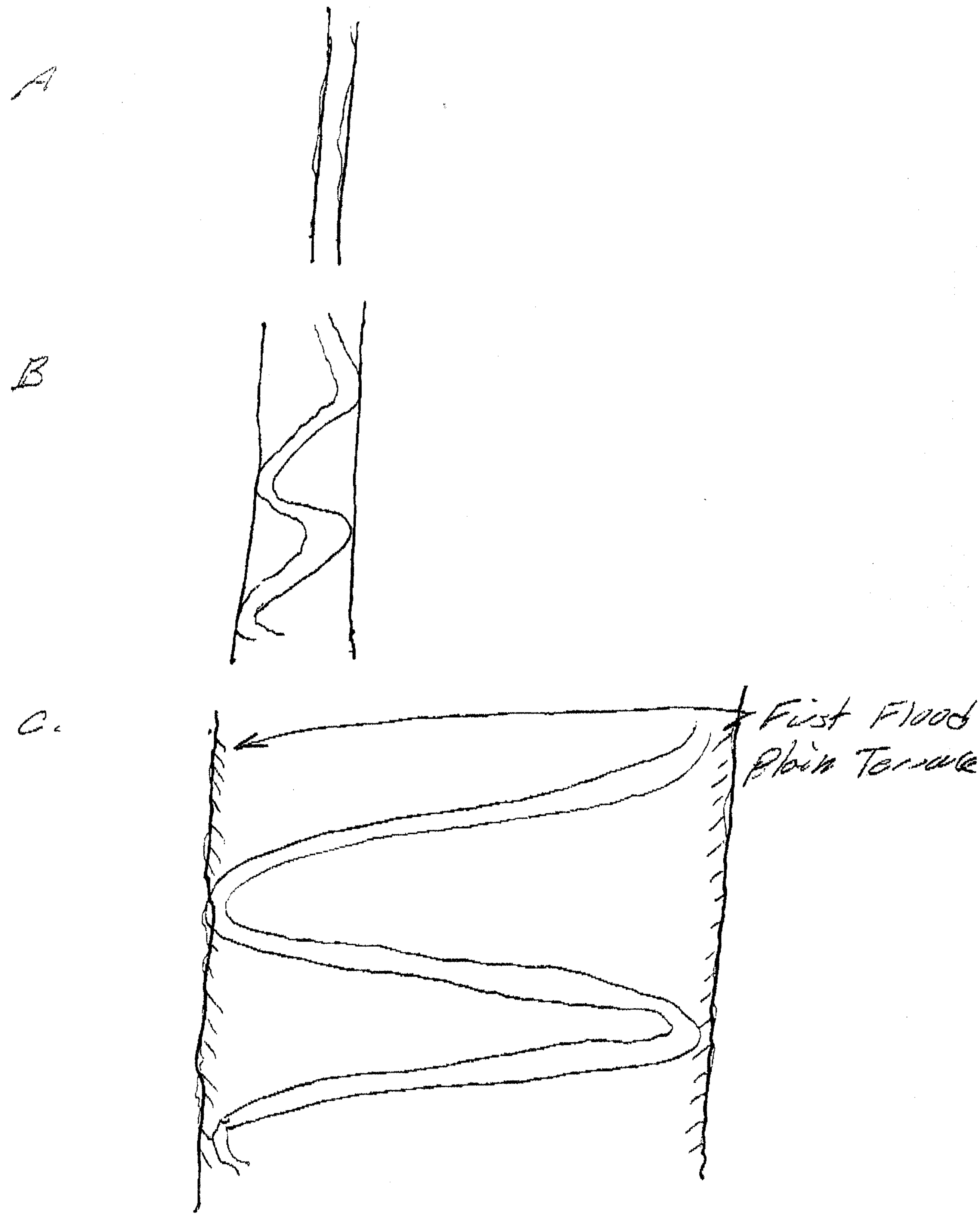

Figure-1 Size of Stream Recharge Areas. (Sizes in Red)

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December 7, 2001

To: Technical Advisory Committee Members: Carl Hauge, Karen Burow, David Purkey, Steve Bachman, Kit Custis, Jerry Behnke

From: Joe Sax

Re: Proposal re: quantifiable criteria

I have now received from Jerry Behnke, as was agreed on at the most recent committee meeting, a suggested draft for a response to the question posed to me: "Can quantifiable criteria be established to implement the legal test? What are the quantifiable criteria.."

I have rewritten it a bit, and am sending it to you for comments and suggestions. I have tried to follow the essentials of Jerry's note to me, and hope I haven't misstated or confused his proposal.

PLEASE PROVIDE YOUR COMMENTS, SUGGESTIONS, ETC. TO ALL COMMITTEE MEMBERS, AND TO ME, VIA E-MAIL. JERRY HAS NO E-MAIL ADDRESS; HIS FAX # IS (530) 898-5234. I AM EAGER TO MOVE ALONG ON THIS AS QUICKLY AS POSSIBLE AND WILL APPRECIATE YOUR RESPONSES AS SOON AS YOUR SCHEDULES ALLOW.

Best holiday greetings to all!

Quantifiable Criteria Test

When the Board is asked to determine whether a well is jurisdictional under Water Code § 1200, the following approach should be used:

1. First determine if the well is 1,000 feet or less from the stream recharge area.[1] If not, it will be presumed not to be jurisdictional. If it is , further inquiry is required, as follows.

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[1] Definition of "stream recharge area": (1) If the stream reach is long and narrow, the stream itself within its bed is the stream recharge area, as shown illustratively in figure A, attached. (2) If the stream meanders, the meander belt on each side of the stream is the stream discharge area, as shown illustratively in figure B, attached. (3) If the stream meanders across the entire width of the first flood plain terrace, the distance between the terraces is the stream discharge area, as shown illustratively in figure C, attached.

2. If the well is screened entirely beneath a clay layer 1.0 foot or more thick (as ascertained from an E log), then the well will be presumed not to be jurisdictional.
3. If the well is not screened entirely beneath a clay layer 1.0 foot or more thick (as ascertained from an E log), then the well is to be tested using a piezometer at the edge of the groundwater mound to determine if the well creates a drawdown of 0.20 feet or more at the edge of the stream recharge area. If the wells does not create a drawdown of 0.20 feet or more at the edge of the stream recharge area, then it will be presumed not to be jurisdictional.
4. If the wells does create a drawdown of 0.20 feet or more at the edge of the stream recharge area, then a determination shall be made, using the Jenkins Method, whether the well extracts 20 percent or more of its annual flow from the stream recharge area. If it does not extract 20 percent or more of its annual flow from the stream recharge area, it will be presumed not to be jurisdictional. If it does extract 20 percent or more of its annual flow from the stream recharge area, it will be determined to be jurisdictional, provided however:

A. That a well owner may adjust discharges to reduce them below the 20 percent level, and if so, the well shall be treated as not jurisdictional so long as discharges remain below that level.

B. That any well owner may have performed individual well tests, . to determine actual well impacts, and to rebut any of the foregoing presumptions that have led to a determination that a well is jurisdictional. The costs of any such tests shall be borne by the well owner.

C. That the SWRCB, on its own initiative or upon request by any interested person, may in its discretion have performed individual well tests, to determine actual well impacts, and to rebut any of the foregoing presumptions that have led to a determination that a well is, or is not, jurisdictional. The costs of any such tests shall be borne by the SWRCB.

Explanatory Notes

The numbers utilized in these proposed quantitative criteria necessarily involve judgments on the part of technically knowledgeable experts.
The 1,000 foot distance has been selected because in setting observation wells in pump tests, experience shows that in water table situations, drawdown is near zero at that distance. This experience has been confirmed by modelling.
The use of an 0.20 foot drawdown was chosen because the threshold value for measurement is about 0.10 foot. That number was doubled to provide some leeway in favor of well owners, in measuring actual drawdown.
Experience suggests that where is a well is screened beneath a clay layer at least 1.0 foot thick, the well is unlikely to be recharged to any significant extent from the stream.

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p.s. I cannot send the attachment with stream sketches by e-mail. I am faxing it to all.

Mr. Joseph L. Sax
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Fax (415) 346-6240

Joe:

Some more thoughts

1. How to determine the minimum acceptable depth to a clay layer having a thickness of 1.0 foot or greater.

   Obtain water level measurements nearest the well being considered. The clay layer should be a least 70 feet below the ~~(illegible)~~ lowest measured water table nearest the well in question, see Figure-1

2. Where well densities are high and a Collective drawdown cone results a study conducted by local, ~~Stat~~ State or federal agencies should be ~~conducted~~ undertaken to determine what actions should be ~~taken~~ considered to eliminate or minimize the impact on the recharged ground water.

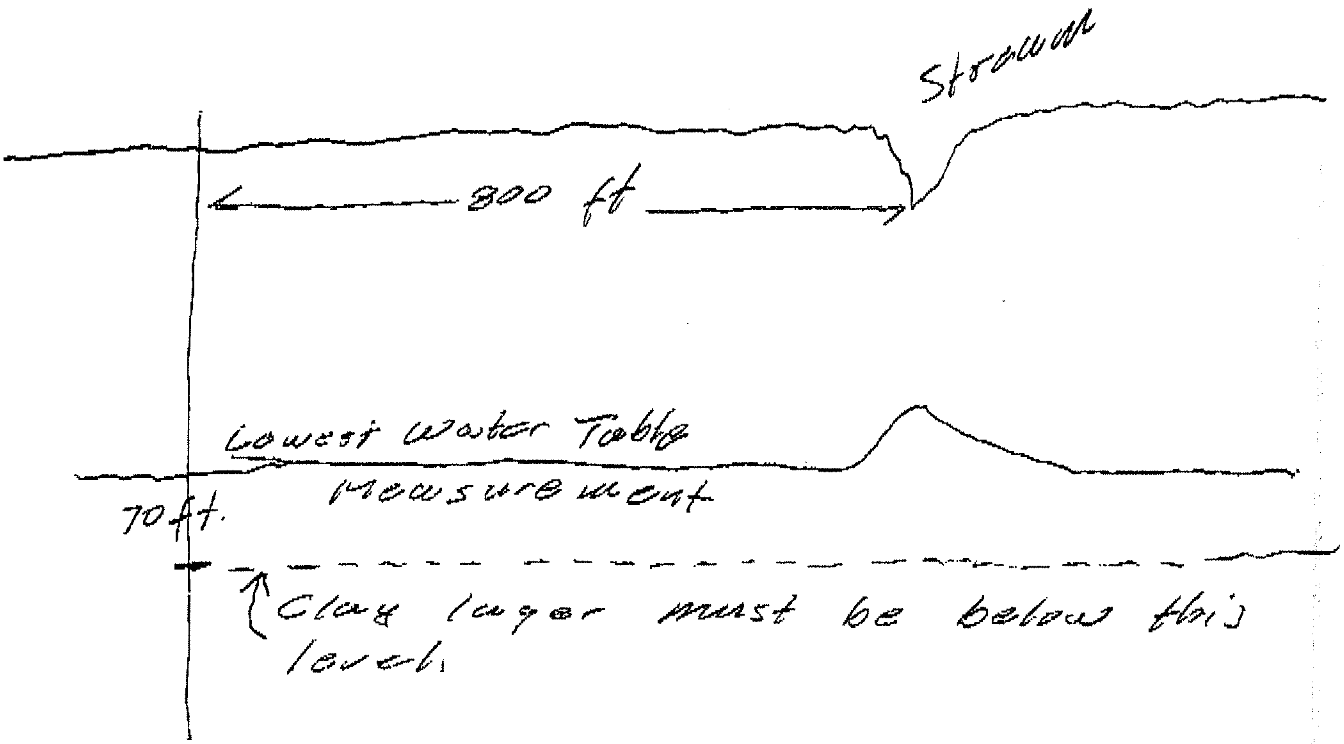

Figure -1 Minimum Depth Location
For a ~~1.0 foot of~~ clay layer having a
thickness of 1.0 foot or greater

Subject: Test of various criteria using real basin data
Date: Tue, 11 Dec 2001 16:56:58 -0800
From: "Steven Bachman" <smkbachman@worldnet.att.net>
To: <saxj@law.berkeley.edu>
CC: <chauge@water.ca.gov>

I just wanted to give you an update on the work that Carl Hauge and I did yesterday. As per the last meeting, we took a real basin with substantial surface water and groundwater data and applied a variety of potential tests that have been suggested. I am putting together a little PowerPoint slide show of what this looked like and where the problems were. One conclusion that we reached was that it would certainly be easier to have some type of initial brightline that would focus future efforts in areas near the surface water and would eliminate uncertainty for most groundwater users. Could further evaluation of jurisdiction within the brightline be for new wells only -- this would effectively grandfather existing wells and eliminate chaos over water rights for existing wells. The average life of a well varies between 20 and 40 years in California, so the issue would come up sequentially in the State as older wells fail and new wells need to be drilled.

Carl and I both have quite a few comments on the criteria that you received and incorporated in your tests. We don't think that they are workable without modifications and will supply comments shortly.

An issue came up at the semi-annual ACWA meeting two weeks ago. I made a report to the Groundwater Committee on what we've done in the technical committee (Board member Silva was there to listen and add comments on the process after the Board receives your recommendation). The issue was whether an overlying groundwater pumper who is determined to be pumping jurisdictional water would be considered to have a riparian surface water right. If so, would the pumper have to own property along the stream or would any overlying property owner who was pumping jurisdictional water be a riparian user without regard to the position of his surface property relative to a stream? There was disagreement among the attorneys present on the answer to this.

Subject: Re: Technical Advisory Committee - response to Jerry Behnke's proposal
Date: Wed, 19 Dec 2001 10:47:54 -0800
From: "Karen R Burow" <krburow@usgs.gov>
To: saxj@mail.law.berkeley.edu, chauge@water.ca.gov, dpurkey@westworldwater.com, kcustis@consrv.ca.gov, steveb@unitedwater.org
CC: "Karen R Burow" <krburow@usgs.gov>, PMurphey@waterrights.swrcb.ca.gov

Re: Memo dated December 7, 2001 on proposed quantifiable criteria

I think the approach outlined by Jerry Behnke is generally reasonable. Please find my comments below.

1. Although this "first pass" to relieve from jurisdiction does not account for the volume of water pumped from the well and the coinciding streamflow, I think that a distance of 1,000 feet is probably reasonable.

2. In general, I wouldn't expect a 1-foot clay in a streambed to be continuous. I think that most clays are going to be overbank deposits which are not laterally continuous, and an erosional stream could incise any extensive clay beneath it. Therefore, I suggest the criteria be based on the same type of distance criteria as above (only as screened depth below the streambed). I'll throw out a proposed depth of 50 ft.

3. and 4. seem reasonable.

****
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"Paul Murphey"
<PMurphey@waterrights.swr
cb.ca.gov>
10/19/2001 01:51 PM

To: <kcustis@consrv.ca.gov>, <steveb@unitedwater.org>, <krburow@usgs.gov>, <chauge@water.ca.gov>, <dpurkey@westworldwater.com>
cc: "Erin Mahaney" <EMahaney@exec.swrcb.ca.gov>, <saxj@mail.law.berkeley.edu>, "Lewis Moeller" <LMOELLER@waterrights.swrcb.ca.gov>, "Vicky Whitney" <VWHITNEY@waterrights.swrcb.ca.gov>
Subject: Technica Advisory Committee Meeting

A Technical Advisory Committee meeting to discuss the legal classification of groundwater will be held at the Cal/EPA Building in Sacramento on November 2nd at 10:00 am. The meeting will be held in Room 1730 which is at the west end of the 17th floor. Call Paul Murphey at (916) 341-5435 if you need further information or directions.

December 28, 2001

To: Mr. Joseph L. Sax
1150 Lombard St., No. 12
San Francisco, CA 94109-9103

From: Kit H. Custis
DOC-Division of Mines and Geology
1027 10th Street, 4th Floor
Sacramento, CA 95814

Subject: Response and Comments to December 7, 2001 Technical Advisory Committee Memo

The quantifiable criteria tests proposed in the December 7 memorandum can help in determining whether a well is diverting surface water flows, but several of the test assumptions need more clarification to develop the intent of these tests. In addition, several of the test criteria deal more with policy and procedure rather than just technical methodology. That is, they specify test cutoff values, who shall perform and evaluate these tests, and the conditions where testing will be allowed. I think that the issues of what volume of stream diversion is significant to the protection of water rights and public trust resources, what agency(s) shall conduct testing and how these tests fit into the broader scope of water law is better left to the policy committee. Leaving the technical committee to discuss whether a particular set of tests is feasible and how to obtain the policy goals. I have included some general comments in the first part of this memorandum and have additional comment specific to each test in the second portion.

An example of the criteria needing more clarification is the relationship between tests No. 3 and 4. Are these two test compatible, do they measure different levels of impact? Does 0.20 feet of drawdown occur before or after 20 percent of the well's discharge comes from the stream? The order they are given implies that if the drawdown is less than 0.20 feet then it can be assumed that the volume of the well's water coming from a stream is also less than 20 percent. However, the footnote suggest that they are not connected as the 0.20 feet of drawdown is based on the ability to take an accurate measurement. Does this make technical sense? Will 0.20 feet of drawdown always occur before the 20 percent limit is reached?

* * *

Can a non-SWRCB agency, such as DFG, pay for a well-stream interaction pump test and have the SWRCB order it done as specified under 4C? What are the conditions or types of protest that the SWRCB would need to order a stream-well interaction pump test? Does the SWRCB have to make a finding to order such a test, if so, are the quantifiable criteria test in this memorandum the only criteria or are there others, such as impact to habitat? All of these questions are "policy" issues, but they are imbedded into the "quantifiable criteria test."

I recommend that any quantifiable criteria test be established with a clear statement of how the test is intended to fulfill the goal of determining which wells are pumping ground water that results in a diversion of surface waters to the extent that it is deemed detrimental. A statement of intent is needed to provide a context for interpreting the results that are likely going to be somewhat ambiguous given the diversity of California's geology and hydrology that a simple test is trying to measure. Remembering that there is a significant problem in studying surface water-ground water interactions because the evidence is not readily visible, the hydraulics are complex and dynamic, the impacts can be felt over a broad area with no single point of diversion from the stream, and because of the time delay between pumping and impact.

Two of the quantifiable criteria presented in the December 7, 2001 memorandum have clear goals and are workable with some modification and a general statement of intent of the tests. One test, No. 1, is the use of a somewhat arbitrary distance from a stream recharge area to define jurisdiction assuming some range of pumping conditions. The test setback distance should be define based on what level of pumping is considered insignificant to the stream, including the issue of cumulative impacts. If the SWRCB can establish a policy on what level of stream diversion is not significant, then a technical committee can define a setback given an assumed set of hydrogeologic conditions. A clear statement of the assumed conditions is needed to allow for varying the setback when the site-specific conditions vary significantly.

The second feasible test is No. 4, which is based on the issue of acceptable impact. That is what percentage of the well's water comes from the stream. While I'll discuss this test in more detail below, I think the test should be modified so that the diversion is referenced to the condition at the stream rather than at the well. Rather that setting a standard for well production percentage, I recommend that a duel standard at the stream include maximum instantaneous stream depletion, such as cubic-feet-per-second loss, and maximum total volume diverted, such as acre-feet. The use of stream diversion standards allows for adjustment to meet individual stream needs and allow for easier adjustment of pumping condition to meet the standards (see examples in Jenkins' 1970 USGS paper). Also, these two standard are similar to surface water permit requirements for maintaining minimum by-pass flows and allocating a maximum annual surface water diversion.

The following are specific comments and recommendations regarding the four quantifiable criteria tests given in the December 7, 2001 memorandum. I have also included some suggestions on other criteria that could be implemented.

1. The distance criterion for jurisdiction, 1,000 feet from the stream recharge area, is what was generally agreed to at our last meeting. The criteria for identifying the stream recharge area given under footnote 1 can become problematic without some specification of flood frequency. Many regulations now specify a flood plain based on flood frequency, i.e. 100-flood zone. Without specifying a flood frequency it is likely there will be a lot of debate about what terraces defines the flood plain intended in this test. I have seen that this type of definition has become a major issue with timber harvest regulations because the regulations tie the cut zones to the flood plain. I have participated recently in field discussions where an elevation difference of a foot between two flood plains was the focus of heated debate between numerous state and federal agencies and the landowner. What was a stake in this discussion was whether the landowner would be allowed to cut the timber in the flood plain or be required to set it aside for habitat. I would not recommend creating another regulation that does not clearly define its intent. Instead, I recommend using a flood stage criterion. Although the determination of a flood stage, which can be used to define the stream recharge area, is not a simple task, it is a well-known methodology and can give a consistent application of what was intended. The three cases shown in the memorandum's figure C can be used to clarify the intent and may help to readily define the stream recharge area without the requirement for a flood stage study.

   There is another issue regarding using a 1,000-foot width for all wells. In our last technical meeting there was a discussion of using a different width for agricultural and municipal wells since they pump much more water and have a correspondingly greater impact on an aquifer and aquatic ecosystem. I have attached three tables showing the impact of a large well at 1,000 feet and 3,000 feet from a stream. These tables are based on Jenkins' method. At the closer distance, the well extracts about 20 percent of its flow from the stream in approximately 8 days where as at the greater distance it takes 75 days to reach the same level of stream depletion, Table 1 versus Table 2. The total volume of water taken from the stream also varies with the duration of pumping. I will provide more detail on the issues of stream depletion rate and total volume of depletion below in my discussion of test No. 4. Table 3 calculates the stream depletion when the well's pumping rate significantly increased from 500 gallons-per-minute (gpm) to 3,000 gpm and all other parameters remain the same as Table 2. Table 3 shows is that the percentage of well water taken from the stream does not vary with the pumping rate, but is controlled by the aquifer hydraulics and the distance between the well and stream, which Jenkins' calls the stream depletion factor, sdf.

I recommend that the "stream recharge area" definition be modified to "the channel area lying between the channel belt width delineated by the water surface associated with the 100-year return period flood event." The three cases specified can be given as examples of how to determine the extent when a channel condition clearly confines the flow and there is a desire to minimize the effort and costs in defining the channel belt width. If there is a major dispute about the boundary or the importance of a particular terrace in restricting groundwater recharge, then the 100-year criteria can be used to more accurately define the stream recharge area. For many incised reaches it is clear from field inspection that the channel contains all but the largest flood events and there would be no need to calculate the 100-year flood. For those reaches where the channel braided or there is a large broad flood plain the stream recharge area is much more difficult to identify the flood stage can be calculated is a well known engineering analysis and may already be done for some area.

I also recommend that two criteria be established for setback distance from the stream recharge area, one for small producers and one for large. The differences between these two types of groundwater producers and the exact setback distances need to be worked out. We need to give criteria for large versus small pumping, using both instantaneous pumping rates and long term total stream diversion yield. With these numbers, Jenkins' model, or something like it, can be run to establish the setback non-jurisdiction distance. In any case, it is important that the assumptions be clearly stated so that deviations can be recalculated.

2. Test No. 2 uses a 1-foot clay layer criterion that has been used in many state regulations to remove wells whose hydraulic connection to the stream would not cause a significant impact. All of these existing regulations assume that the presence of a clay layer means that it is sufficiently continuous both in thickness and laterally in extent to provide the desired protection. Based on my experience working with both the State Water Board and the Regional Water Boards, I think the assumption that the clay bed continuity can be assumed based on a single sampling point is not well founded. There are geologic settings where the clays are deposited as thick, laterally continuous layers, such as ancient lake beds, but in the alluvial environment that underlies much of California's rivers, these clays interfinger with more permeable materials, are often cut by meandering channels, such that their lateral continuity can't be universally assumed. In fact, while I was at the Central Valley Regional Water Quality Control Board I was the case officer for a contaminated well study in the San Joaquin Valley where the discharger's consultant submitted a ground water model to demonstrate how shallow contaminated groundwater under the influence of a pumping municipal well migrated over a 10-year period through a 100-foot thick clay layer to pollute a lower aquifer. If a 100-foot clay is susceptible to being penetrated during a short time period due to a pumping well, then the "impermeability" of a 1-foot

clay shouldn't be automatically assumed. There is also the issue that the only identifier for the clay layer an e-log. While I agree that down-hole logging is one of the best tools for subsurface interpretation, many of the existing wells do not have such a log. Are these wells exempt from jurisdiction or included by default?

I would recommend moving this test into item No. 4 where it can be used whenever there is evidence that the clay layer is sufficiently continuous to restrict stream-aquifer interconnection. The presence of a continuous clay layer can used as part of the determination of a well's potential impact.

3. Assuming that test No. 2 remains, then test No. 3 adds a requirement to measure drawdown at the "edge of the groundwater mound." The criterion doesn't specify where along the edge the point shall be measured or how to calculate the location of the edge of mound. I assume that the intent is to measure changes in water table independent from the recharge "mounding" beneath a stream. There are several conditions that create a recharge "mound" beneath a stream that produce very different mound shapes. Bouwer (1978) lists three general conditions (A, B, and C; page 268) with two subsets for condition A. These conditions result in very different mound edge distances away from the stream. The edge of the mound is dependant upon subsurface hydrogeologic conditions not just the stream recharge area boundary. Test No. 3 requires that a piezometer be installed at the mound edge for measurement of the water table, but the edge may not be known without first drilling the well. Thus, this test may require an investigation of the mound behavior before the piezometer well can be placed and tested.

   While the concept of measuring changes in the water table adjacent to the stream recharge area does help to address the question of hydraulic influence of the well's pumping, it raises several questions that I think need to be addressed to get a better understanding of the intent and design of test No. 3.

   - Is the piezometer location at the mound's edge lying along a line perpendicular between the well and the stream recharge area?
   - Is the piezometer location along the stream at a distance other than the shorted between the well and the edge of the mound?
   - What happens if the well lies within the "mound?"
   - What happens when landownership or other property restrictions prevent the piezometer from being placed in the ideal location?
   - Is this piezometer test, the only acceptable test?
   - Does the well's pumping history and/or the stream's flow history matter?
   - What impact will fluctuations in water table caused by variations in winter/spring runoff flows that recharge the aquifer?
   - When should the well's drawdown effect be measured, winter or summer?
   - What happens if the stream changes from a gaining to a losing stream during the year?

- Are gaining stream even jurisdictional?
- If a stream is "disconnected" from the underlying aquifer because of a thick vadose zone, it this test still a valid measure of impact?
- If the piezometer is placed at a point that lies along the shortest distance between the well and the edge of recharge mound, is it reasonable to assume that half the stream losses will occur upstream and half downstream?
- What if the impact to the stream is not directly adjacent to the well? How will this test address the significance of this impact?
- Does 0.20 feet of drawdown in the water table equal 20 percent or less of the well's flow? If not, how does this test fit with test No. 4?
- How are long term fluctuations in stream flow dealt with?
- In test No. 4, there is supervision by a state agency (DWR is suggested) for that test. Is there supervision for test No. 3? If so, by whom, and when, before or after the test is made?
- The costs of installing a piezometer may be prohibitive for small well owners, does that mean they skip test No. 3 and go directly to No. 4?
- Are all four of Bouwer's mounding conditions possible for "jurisdictional" groundwater? If not, which ones are jurisdictional and which are not?

Given that test No. 3 is more difficult to implement and to understand its meaning than either tests No. 1, No. 2 or No. 4. I recommend not using this as a "yes or no" jurisdiction test, but reserve test No. 3 for use in test No. 4, if the information is compelling in demonstrating a level of no significant impact.

4. As discussed above, test No. 4 is conceptually a workable quantifiable criteria test for determining jurisdiction, but it needs some clarification of the intent. My understanding is that the SWRCB has jurisdiction over surface water diversions. I assume that the issue regarding the SWRCB's jurisdiction over ground water is how to determine when a well diverts sufficient surface water such that the well's pumping is considered to have a detrimental impact on the rights of other surface water diverters, public trust resources or other beneficial uses of the surface waters of the State. Test No. 4 tries to establish a quantifiable level of significance based on the well's pumping volume. Specifically, a well can extract no more than 20 percent of its annual flow from the stream. There are a few problems with the use of the well as the point to measure impact and with the use of only total annual pumped volume. First, the point of diversion is the stream not the well. Putting exclusive emphasis on the well's impact seem misplaces. Second, the significance of 20 percent of a well's annual yield on the flows in the stream is unspecified and not consistent. If a well pumps annually 1 acre-foot or 1,000 acre-feet, the criterion is still 20 percent, resulting in a difference of 0.2 versus 200 acre-feet pumped from the stream, respectively. The significance to the stream of diverting these different volumes is not considered in test No. 4. Third, a comparison of Table 2 and 3 shows that increases in pumping can have a dramatic impact on instantaneous stream depletion and total volume

depleted even though the percentage of well water coming from the stream remains the same.

There is another major issue regarding the timing of the pumping. The significance of the impact from a surface water diversion changes greatly from winter to summer. Generally, the summer low flows are the most critical for a stream, although there can be other critical periods depending on the resources in the aquatic ecosystem. By using only the well's annual yield as a measure of the potential impact, significant seasonal impacts will be ignored.

I have attached Table 5, which shows the stream flows on the Gualala River as an example of the complexity of surface flows. I'm using this data because I have ready access to it and it is similar to other coastal northern California streams. This data demonstrates how the use of an annual average masks the potential seasonal impacts of diverting surface flows, in particular, diverting during summer months. Wells used for irrigation will likely increase pumping during the summer months and decrease during winter. Table 5 shows that winter diversion of a few cubic-feet-per-second may not be significant to the total stream flow, but that same level of diversion can be significant in the summer months. Especially, when pumping from other wells along the stream reach are combined. Table 5 also shows the annual variation in surface flows that makes selection of the appropriate regulatory flow a complex process. As proposed, Test No. 4 doesn't account for the seasonal variation in stream flow or directly address the potential impacts to the stream or aquatic ecosystem.

There is also the issue of residual stream depletion after the pumping stops. Jenkins (1970) showed that the residual stream losses can be as great as that during pumping. The effect of residual stream depletion can be estimated using the method of superposition. That is, assume the well continues to pump and an imaginary well at the same location recharges the aquifer at the same rate as the pumping well, but with an offset in the pumping start time. The rate and volume of stream depletion is the difference between the pumping and recharge wells. Because the residual stream depletion is significant, shouldn't the 20 percent standard be reduced to account for residual depletion?

Table 4 is attached to show the effects of residual depletion. Results in Table 4 can also be calculated using Table 1 and the method of superposition. For example, if pumping stops after 200 hours the instantaneous stream depletion rate is 0.229 cfs and the total stream depletion volume is approximately 1.5 ac.-ft. To find out what the stream impact is 200 hours after pumping stops, the values at 200 hours are subtracted from the values at 400 hours of pumping. At 200 hours after pumping stopped, the instantaneous stream depletion rate is still 0.184 cfs (0.413 - 0.229) and the total depleted volume is now approximately 5.48 ac.-ft (6.982 - 1.507). These residual losses are not minor difference over those of the pumping period. In fact, the instantaneous depletion rate is still approximately 80 percent of the rate when pumping stopped, and over 2.5 times as much water is taken from the stream after pumping stopped than during pumping. Also, the peak instantaneous stream depletion rate occurs after pumping stops. In Table 4, peak instantaneous stream depletion rate occurs 2 days into the residual period.

Recommendations in test No. 4 parts A, B and C are really policy issues that have technical implementation criteria. Test No. 4A allows the well owner to adjust the pumping to minimize stream diversion to a level below 20 percent to avoid jurisdiction. The test doesn't indicate how this reduction would be reported, documented or enforced without a permit (a policy issue). Jenkins' 1970 USGS publication on his stream depletion model goes through several scenarios where the pumping rate and timing are adjusted to meet specific criteria.

A critical difference between test No. 4A and Jenkins' examples is that he assumed that the maximum allowable depletion rate from the stream was specified, both as an instantaneous rate (acre-feet-per-day) and/or cumulative discharge for a particular growing period (acre-feet for a 150 day period). Jenkins then demonstrated how his model can be used to design a pumping rate and schedule to meet these restrictions. Since test No. 4 does not require any limits on total pumping yield or instantaneous stream diversion rate, I'm not certain that just reducing the pumping rate as specified in the test will change the impact on the surface water flows.

I have included in Tables 1, 2 and 3 calculations for different pumping scenarios and the estimated stream depletion rates using Jenkins' model. The hydraulic and pumping characteristics model are typical for a irrigation well. Table 1 shows stream depletion for a well located 1,000 feet from the stream pumping at a rate of 500 gpm. The 20-percent stream depletion is achieved after approximately 8 day of pumping with approximately 1.5 acre-feet of total water diverted from the stream. Table 2 show the same well/aquifer hydraulics except that now the well is 3,000 feet from the stream. 20-percent stream depletion is achieved after approximately 75 days, but the total stream diversion is now 13.6 acre-feet. The instantaneous depletion rate upon reaching the 20-percent cutoff is the same for both cases 0.229 cfs. Table 3 shows what happens when the pumping rate is increased for Table 2's scenario. The time to achieve the 20-percent yield is the same, approximately 75 days, but the total stream diversion is significantly increased to approximately 81 acre-feet, and the instantaneous stream depletion rate is increased six fold to approximately 1.38 cfs.

These examples show why it is important to set the well pumping standard based on the stream depletion rate and total allowable surface water diversion not just on a percentage of the well's annual pumping rate.

Test 4B allows the well owner to conduct a pumping test to demonstrate the level of impact.

there should be some standard for what type of demonstration is needed, what data are acceptable, and who can perform this type of test. The cost of a pump test can be significant, particularly if a piezometer(s) is necessary (see test No. 2 requirement). There might be a phased testing effort depending on the well type, well yield and potential impacts. A small well for domestic use might only need a specific capacity test that can be performed by the driller that installs the well. Based on this simple test data and some general hydrogeologic assumptions, the small well's impact can be estimated and a diversion criteria set. For larger wells, the pumping test may need to be more involved, especially if the effects of clay layers need to be determined.

Test 4C allows the SWRCB to conduct a well test under the supervision of DWR. I'm not sure whether this is a quantifiable test or just a statement of policy. The SWRCB may already have authority to conduct such a test. Are other parties also be allowed to conduct a pump test under the SWRCB authority as part of a water rights protest or complaint? For example, DFG has been willing to conduct and pay for pump tests on wells where they have filed a water rights complaint. In any case, the SWRCB should have the authority to evaluate and measure the potential impacts from a pumping well and to set diversion limits based on those studies and other water rights and public trust doctrines.

I recommend that standards for both the maximum allowable instantaneous stream depletion rate and the maximum allow total stream withdrawal during the period of most critical flows, likely summer months, be used to establish acceptable pumping rates and schedules. I also recommend clarification of the types of well tests that are allowable to demonstrate pumping impacts. These test criteria should allow for variation depending on the potential for impact and the need for detailed data.

Conclusion and Summary

1. The quantifiable criteria tests as written in the December 7, 2001 memorandum would lead to very few wells being determined to be jurisdictional to the SWRCB. As such, the criteria are too narrow and would eliminate from SWRCB jurisdiction wells that draw water and have a significant impact on a stream.

2. Rather than using a fixed setback distance from a stream recharge area, the SWRCB should at the outset make a policy determination regarding:

    a. Maximum allowable stream depletion rate (adjusted for seasons), and

b. Maximum allowable total stream withdrawal (adjusted for seasons).

These determinations should be made based on the assumption that SWRCB should take jurisdiction over those wells that impact the surface flow of a stream or aquatic ecosystem. The SWRCB could use a process similar to the creation of Basin Plans throughout the state to set these rates for each watershed or stream.

3. Test No. 2 is not scientifically defensible in the light of the differing hydrogeologic conditions for clay layers in California and it should not be used as a jurisdiction test in and of itself, but as additional information towards making the determinations set forth in 2a and 2b above.

4. Implementation of test No. 3 is too complex to consistently implement. The use of a single value for the change in water level is not likely to assess seasonal variations in stream-aquifer interaction. Test No. 3 should not be used as a jurisdiction test in and of itself, but as additional information towards making the determinations set forth in 2a and 2b above.

5. Test No. 4 should not be based on a percentage of the annual well yield, but should be based on impact to the stream. As discussed above, instantaneous rate and total volume of stream depletion increases in proportion to an increase in pumping rate while the percentage of the total water pumped from the stream remains the same. Thus, the percent pumped test would create a standard that results in a wide variation of impact to streams and aquatic ecosystems. Any standard for SWRCB's ground water jurisdiction should account for seasonal variations in stream flows and seasonal consequences from diversion of surface water.

6. Test No. 4 should be performed by the SWRCB, not the DWR. It would be an inappropriate delegation of authority to give DWR the authority to do the well testing, rather that SWRCB. State law should be modified to make it clear that SWRCB, and its personnel, have the authority to access property for the purpose of performing such a test to determine if a well is jurisdictional.

Department of Fish and Game Proposal

The Department of Fish and Game proposes that the SWRCB take jurisdiction of wells whose pumping diverts surface water flows above an allowable maximum instantaneous rate of stream depletion and above a maximum allowable total stream withdrawal which are adjusted for seasonal variations in surface water flow impacts to aquatic ecosystems and public trust resources. Due to the diversity of California's environment, the allowable maximum depletion rate and volume for streams may vary. Once maximum allowable diversions are established, a setback for a presumption of SWRCB jurisdiction, in feet from the stream recharge area, can be established.

If a well is outside of the jurisdiction setback, then the burden of proof is on the protestant to show that the well's pumping is still detrimental to stream flow, aquatic ecosystems and public trust resources. SWRCB must have the authority to collect hydrogeologic and well pumping information as well as perform pumped well tests necessary to evaluate the well's impacts and SWRCB's jurisdiction. (This authority may require a change in California law).

If a well is within the setback distance, then there is a presumption of jurisdiction and an application must be filed. SWRCB could use Jenkins' model (or an equivalent) to estimate the well's impacts on surface water flows, aquatic ecosystems and public trust resources, and to establish permit requirements and restrictions. As stated above, SWRCB must have authority to collect hydrogeologic and well pumping information including performing pumped well testing.

cc: Technical Advisory Committee
Diana Jacobs, Deputy Director, Department of Fish and Game
Nancee Murray, Staff Counsel, Department of Fish and Game

Table 1
Stream Depletion from Well
(Jenkins, 1968; Walton, 1984)

Project: California Ground Water
Well: Sample Well
Date:
Investigator:

75	= Hydraulic conductivity aquifer, ft/day
561.1	= Hydraulic conductivity of aquifer, gpd/ft^2
100	= Thickness of aquifer, ft
56,108	= Transmissivity of aquifer, gpd/ft
0.2	= Storativity
1000	= Distance from well to line of effective recharge (stream), ft
500	= Constant pump rate, gpm
1.1140	= Constant pump rate, ft^3/sec
26.667	= Stream depletion factor, sdf, days

Pumping time, hrs	Pumping time, days	Stream Depletion Rate, cfs	Stream Depletion Rate, gpm	Total Volume Pumped ac.ft	% of Total Well Pumping	Stream Depleted Volume, cu.ft	Stream Depleted Volume, ac-ft.
24	1.00	0.000	0.13	2.2	0.0	3	0.000
48	2.00	0.011	4.91	4.4	1.0	350	0.008
72	3.00	0.039	17.51	6.6	3.5	2,412	0.055
120	5.00	0.114	51.24	11.0	10.2	15,532	0.357
200	8.33	0.229	102.95	18.4	20.6	65,660	1.507
224	9.33	0.258	116.00	20.6	23.2	86,752	1.992
248	10.33	0.285	127.99	22.8	25.6	110,253	2.531
272	11.33	0.310	139.04	25.0	27.8	135,969	3.121
400	16.67	0.413	185.55	36.8	37.1	304,142	6.982
448	18.67	0.443	199.01	41.2	39.8	378,225	8.683
1,800	75.00	0.750	336.64	165.7	67.3	3,502,414	80.404
2,880	120.00	0.823	369.44	265.2	73.9	6,576,494	150.976
4,320	180.00	0.875	392.75	397.7	78.5	10,991,331	252.326
8,760	365.00	0.945	424.21	806.5	84.8	25,634,672	588.491

Table 2

Stream Depletion from Well

(Jenkins, 1968; Walton, 1984)

Project: California Ground Water
Well: Sample Well
Date:
Investigator:

75	= Hydraulic conductivity aquifer, ft/day
561.1	= Hydraulic conductivity of aquifer, gpd/ft^2
100	= Thickness of aquifer, ft
56,108	= Transmissivity of aquifer, gpd/ft
0.2	= Storativity
3000	= Distance from well to line of effective recharge (stream), ft
500	= Constant pump rate, gpm
1.1140	= Constant pump rate, ft^3/sec
240.000	= Stream depletion factor, sdf, days

Pumping time, hrs	Pumping time, days	Stream Depletion Rate, cfs	Stream Depletion Rate, gpm	Total Volume Pumped ac.ft	% of Total Well Pumping	Stream Depleted Volume, cu.ft	Stream Depleted Volume, ac-ft.
24	1.00	0.000	0.00	2.2	0.0	0	0.000
48	2.00	0.000	0.00	4.4	0.0	0	0.000
72	3.00	0.000	0.00	6.6	0.0	0	0.000
120	5.00	0.000	0.00	11.0	0.0	0	0.000
200	8.33	0.000	0.07	18.4	0.0	13	0.000
224	9.33	0.000	0.17	20.6	0.0	35	0.001
248	10.33	0.001	0.33	22.8	0.1	81	0.002
272	11.33	0.001	0.57	25.0	0.1	166	0.004
400	16.67	0.008	3.65	36.8	0.7	2,057	0.047
448	18.67	0.013	5.61	41.2	1.1	3,826	0.088
1,800	75.00	0.229	102.95	165.7	20.6	590,943	13.566
2,880	120.00	0.353	158.66	265.2	31.7	1,740,361	39.953
4,320	180.00	0.461	207.11	397.7	41.4	3,873,215	88.917
8,760	365.00	0.631	283.19	806.5	56.6	12,803,638	293.931

Table 3
Stream Depletion from Well

(Jenkins, 1968; Walton, 1984)

Project: California Ground Water
Well: Sample Well
Date:
Investigator:

75	= Hydraulic conductivity aquifer, ft/day
561.1	= Hydraulic conductivity of aquifer, gpd/ft^2
100	= Thickness of aquifer, ft
56,108	= Transmissivity of aquifer, gpd/ft
0.2	= Storativity
3000	= Distance from well to line of effective recharge (stream), ft
3000	= Constant pump rate, gpm
6.6840	= Constant pump rate, ft^3/sec
240.000	= Stream depletion factor, sdf, days

Pumping time, hrs	Pumping time, days	Stream Depletion Rate, cfs	Stream Depletion Rate, gpm	Total Volume Pumped ac.ft	% of Total Well Pumping	Stream Depleted Volume, cu.ft	Stream Depleted Volume, ac-ft.
24	1.00	0.000	0.00	13.3	0.0	0	0.000
48	2.00	0.000	0.00	26.5	0.0	0	0.000
72	3.00	0.000	0.00	39.8	0.0	0	0.000
120	5.00	0.000	0.00	66.3	0.0	0	0.000
200	8.33	0.001	0.44	110.5	0.0	75	0.002
224	9.33	0.002	1.01	123.7	0.0	210	0.005
248	10.33	0.004	1.96	137.0	0.1	489	0.011
272	11.33	0.008	3.41	150.3	0.1	998	0.023
400	16.67	0.049	21.87	221.0	0.7	12,342	0.283
448	18.67	0.075	33.69	247.5	1.1	22,956	0.527
1,800	75.00	1.376	617.71	994.3	20.6	3,545,658	81.397
2,880	120.00	2.121	951.93	1,590.9	31.7	10,442,163	239.719
4,320	180.00	2.769	1,242.65	2,386.4	41.4	23,239,292	533.501
8,760	365.00	3.786	1,699.16	4,839.0	56.6	76,821,828	1,763.587

Table 4

Residual Stream Depletion from Well

(Jenkins, 1968; Walton, 1984)

Project: California Ground Water
Well: Sample Well
Date:
Investigator:

75	= Hydraulic conductivity aquifer, ft/day
561.1	= Hydraulic conductivity of aquifer, gpd/ft^2
100	= Thickness of aquifer, ft
56,108	= Transmissivity of aquifer, gpd/ft
0.2	= Storativity
1000	= Distance from well to line of effective recharge (stream), ft
500	= Constant pump rate, gpm
1.1140	= Constant pump rate, ft^3/sec
200.0	= Total Pumping time, hrs
8.3	= Total Pumping time, days
18.4	= Total Volume pumped, ac.ft.
26.667	= Stream depletion factor, sdf, days
1.507	= Total Volume depleted during pumping, ac.ft

Time Since Pumping Stopped, hrs	Time Since Pumping Stopped, days	Total Time Since Pumping Started, hrs	Total Time Since Pumping Started, days	Stream Depletion Rate, cfs	Stream Depletion Rate, gpm	Depletion as % of Total Pumping Rate	Volume Depleted Since Pump Stopped, cu.ft	Volume Depleted Since Pump Started, ac.ft
24	1.00	224.0	9.33	0.258	115.87	23.2	86,749	1.991
48	2.00	248.0	10.33	0.274	123.08	24.6	109,903	2.523
72	3.00	272.0	11.33	0.271	121.53	24.3	133,557	3.066
120	5.00	320.0	13.33	0.239	107.42	21.5	177,841	4.083
200	8.33	400.0	16.67	0.184	82.60	16.5	238,481	5.475
224	9.33	424.0	17.67	0.170	76.49	15.3	253,783	5.826
248	10.33	448.0	18.67	0.158	71.02	14.2	267,972	6.152
272	11.33	472.0	19.67	0.147	66.11	13.2	281,162	6.455
400	16.67	600.0	25.00	0.105	47.06	9.4	338,376	7.768
448	18.67	648.0	27.00	0.094	42.10	8.4	355,510	8.161
1,800	75.00	2,000.0	83.33	0.0177	7.93	1.6	546,557	12.547
2,880	120.00	3,080.0	128.33	0.0093	4.16	0.8	596,038	13.683
4,320	180.00	4,520.0	188.33	0.0052	2.34	0.5	631,934	14.507
8,760	365.00	8,960.0	373.33	0.0019	0.84	0.2	681,188	15.638

Table 5

SOUTH FORK GUALALA RIVER NEAR ANNAPOLIS
USGS Station #1467500

MEAN MONTHLY FLOW
Water Years 1951 - 1971 and 1991 - 1994
(Units in cfs, NR = no record)

Water	Month																	Yield
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Min	Max	Avg	Total		(ac-ft)
1951	NR	NR	1,343	1,420	1,280	747	98	159	28	12	4	2	NR	NR	NR	NR		NR
1952	21	312	2,343	2,111	1,140	905	167	89	34	17	7	4	4	2,343	596	7,150		14,183
1953	4	18	1,847	2,501	135	481	362	163	53	19	9	7	4	2,501	466	5,597		11,101
1954	14	343	270	2,165	863	843	983	109	40	14	25	11	11	2,165	473	5,680		11,267
1955	15	375	782	588	147	83	658	135	33	13	5	4	4	782	237	2,839		5,631
1956	6	88	3,060	2,367	1,650	273	102	78	27	11	5	5	5	3,060	639	7,671		15,216
1957	38	24	15	482	1,039	943	309	660	103	24	9	90	9	1,039	311	3,735		7,408
1958	736	225	577	1,322	4,407	870	1,256	98	61	20	9	6	6	4,407	799	9,587		19,016
1959	7	20	22	1,134	1,533	164	88	33	14	4	3	36	3	1,533	255	3,057		6,064
1960	11	8	13	510	1,713	1,188	188	78	31	13	6	5	5	1,713	314	3,765		7,467
1961	8	87	979	586	1,586	1,034	172	68	30	9	5	4	4	1,586	381	4,569		9,062
1962	6	266	417	260	2,385	1,023	119	52	21	11	5	6	5	2,385	381	4,572		9,067
1963	434	71	560	663	1,144	643	1,401	152	47	21	11	7	7	1,401	430	5,154		10,223
1964	37	879	146	820	150	135	56	32	18	8	4	3	3	879	190	2,285		4,533
1965	22	481	2,276	1,589	273	162	955	118	44	18	10	6	6	2,276	496	5,954		11,810
1966	7	461	544	1,312	906	448	151	51	22	12	6	2	2	1,312	327	3,922		7,780
1967	1	556	1,028	1,909	390	905	866	159	77	21	8	5	1	1,909	494	5,925		11,753
1968	13	36	338	972	1,043	632	124	52	21	9	9	7	7	1,043	271	3,256		6,458
1969	24	61	1,284	2,677	1,798	488	240	66	31	12	5	4	4	2,677	558	6,690		13,270
1970	15	25	1,445	4,152	613	314	73	33	14	3	2	2	2	4,152	558	6,691		13,272
1971	8	395	2,259	1,357	132	858	244	72	29	11	5	4	4	2,259	448	5,375		10,661
1991	NR	NR	NR	NR	NR	NR	NR	NR	12	5	2	1	NR	NR	NR	NR		NR
1992	13	22	NR	183	NR	NR	182	45	20	11	3	2	NR	NR	NR	NR		NR
1993	12	16	NR	NR	NR	NR	337	196	197	42	14	6	NR	NR	NR	NR		NR
1994	5	21	NR	NR	NR	117	61	35	12	NR	NR	NR	NR	NR	NR	NR		NR
Minimum	1	8	13	183	132	83	56	32	12	3	2	1						
Maximum	736	879	3,060	4,152	4,407	1,188	1,401	660	197	42	25	90						
Average	63	208	1,026	1,413	1,159	603	383	114	41	14	7	9						