RIVERS THAT DEPEND ON AQUIFERS

DRAFTING SGMA GROUNDWATER PLANS WITH FISHERIES IN MIND

A GUIDEBOOK FOR USING CALIFORNIA'S SUSTAINABLE GROUNDWATER MANAGEMENT ACT TO PROTECT FISHERIES

CUEL | CENTER ON URBAN ENVIRONMENTAL LAW
AT GOLDEN GATE UNIVERSITY SCHOOL OF LAW

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CONTENTS

I. A HIDDEN CONNECTION

SGMA GROUNDWATER PLANS, SURFACE FLOWS AND FISHERIES

IN CALIFORNIA, SURFACE WATERS HAVE HISTORICALLY BEEN REGULATED AS IF THEY WERE UNCONNECTED TO GROUNDWATER. YET IN REALITY, SURFACE WATERS AND GROUNDWATER ARE OFTEN HYDROLOGICALLY CONNECTED. MANY OF THE RIVERS THAT SUPPORT FISHERIES SUCH AS SALMON AND TROUT ARE HYDROLOGICALLY DEPENDENT ON TRIBUTARY GROUNDWATER TO MAINTAIN INSTREAM FLOW. THIS MEANS THAT WHEN THERE IS INTENSIVE PUMPING OF TRIBUTARY GROUNDWATER THE RESULT CAN BE REDUCTIONS IN INSTREAM FLOW AND DAMAGE TO FISHERIES.

For this reason, stakeholders concerned about adequate instream flows for fisheries in California's rivers, streams and creeks need to be effectively engaged in the implementation of California's Sustainable Groundwater Management Act (SGMA).

Many of the rivers that support fisheries such as salmon and trout are hydrologically dependent on tributary groundwater to maintain instream flow. This means that when there is intensive pumping of tributary groundwater the result can be reductions in instream flow and damage to fisheries.

Consider the Scott River in Northern California, part of the larger Klamath River Basin. Nearby groundwater contributes to the Scott River. When high volumes of groundwater are extracted from nearby wells, it depletes the Scott River's instream flow with adverse impacts on salmon and steelhead trout. As discussed further in Section VI of this guidebook, this has led to litigation over the application of California public trust law to groundwater extraction affecting Scott River instream flows, and efforts to use SGMA to ensure that groundwater pumping near the Scott River is compatible with the instream flow needs of fisheries. Situations similar to the Scott River surface and groundwater basin are unfolding throughout California.

On a statewide basis, how pervasive is the effect of groundwater pumping on surface water flows? Research by Maurice Hall of the Environmental Defense Fund, utilizing the California Department of Water Resources Central Valley Groundwater Surface Flow Model, provides us with some sense of the magnitude of the problem. In a May 2018 presentation, Hall reported:

> What the model showed us is that early in the 1900s, 1940s and 1950s, the Sacramento River received a net inflow from the groundwater of something like 1 million acre feet a year...Since that time, the groundwater levels have gone down, and the amount of water that has flowed into the Sacramento River from the surrounding groundwater has gone down accordingly to the point that when we were doing this modeling around 2010, it appeared that on average, the Sacramento River lost just about as much as it gained from the surrounding groundwater in the valley floor. This is the Sacramento River and all of its tributaries upstream of the Sacramento...So the net effect over that period is there was roughly on average 900,000 acre-feet per year less water showing up in the Sacramento River at Sacramento." (Hall and O'Brien).

SGMA was enacted in 2014. Pursuant to SGMA, by June 2017 a groundwater sustainability agency was required to be designated for each groundwater basin in California. Each groundwater sustainability agency in high and medium priority basins must prepare and adopt a Groundwater Sustainability Plan (SGMA Groundwater Plan) by 2020 if the basin is deemed to be in a critical state of overdraft or 2022 for all remaining high and medium priority basins. Each SGMA Groundwater Plan must detail how the groundwater basin will be managed to avoid overdraft conditions and, importantly for fisheries, to avoid adverse impacts on hydrologically connected surface waters.

Although groundwater sustainability agencies and fishery stakeholders recognize that the groundwater-surface water connection needs to be addressed in SGMA Groundwater Plans, at present there is limited guidance on how to do this. That is, what are the specific types of information, modeling, monitoring, and pumping provisions that should be included in SGMA Groundwater Plans to ensure that groundwater extraction does not cause significant adverse impacts on fisheries? The purpose of this guidebook is to provide such guidance.

There are five key take-aways from this guidebook.

First, when dealing with the impacts of groundwater pumping on surface flows that support fisheries, the temporal focus is different than when dealing with efforts to manage groundwater as a reliable supply for agricultural or residential use. With fisheries, the necessary temporal focus is on whether groundwater extractions impacting instream flow occur when fisheries have specific flow demands, not whether the groundwater table can be maintained *on average* at "sustainable" or "safe" levels over the long-term.

what are the specific types of information, modeling, monitoring, and pumping provisions that should be included in SGMA Groundwater Plans to ensure that groundwater extraction does not cause significant adverse impacts on fisheries?

Second, when it comes to evaluating the impacts of the groundwater pumping on fisheries, the lateral location of wells can matter. This is because pumping of groundwater wells often creates a cone of depression around the wellhead, and this cone of depression can result in aquifers that once contributed to surface waters becoming aquifers that drain surface waters

and reduce instream flows. By contrast, the particular lateral location of groundwater wells is not as important to evaluating the potential overdraft of aquifers. Rather, from a groundwater supply perspective, what is most pertinent is the total amount of groundwater pumped from the aquifer, which is a function of the number of wells, the depth of the wells, and the pumping rates for the wells.

Third, while the temperature of water in aquifers is not usually relevant to determining safe yield or preventing overdraft, such water temperatures may be relevant in terms of impacts on fisheries and surface stream habitat. This is because many fisheries (such as salmon and steelhead) require colder instream temperatures that can be affected by the temperature of groundwater that is tributary to surface streams that support such fisheries.

Fourth, the existence of complete data about surface stream flows, surface flows needed to support fisheries, and the precise dynamics of the groundwater-surface water connection is not a pre-requisite to effectively addressing surface water impacts in SGMA Groundwater Plans. SGMA calls for such plans to be based on the *best available science*, not perfect information. Groundwater sustainability agencies can make hydrologically credible assumptions about the impacts of groundwater pumping on instream flows in nearby surface waterways, use regression models to determine flows in a particular river reach based on existing flow data upstream and downstream of the reach, and gain a general understanding of fishery needs based on existing data and scientific literature. Thus, while additional monitoring may provide useful data to improve how SGMA Groundwater Plans can prevent adverse impacts on surface flows and fisheries from groundwater pumping, the absence of complete data is not a proper basis for groundwater sustainability agencies to omit or defer the inclusion of substantive provisions to protect fisheries in SGMA groundwater plans.

Fifth, surface water flows that support fisheries are subject to California public trust law (discussed in Section V of this guidebook), as are extractions from groundwater that reduce surface water flows that support fisheries. This means that, when it comes to groundwater that is tributary to surface waters that support fisheries, it is not simply a question of whether SGMA Groundwater Plans are consistent with SGMA. It is also a question of whether groundwater pumping allowed in such plans is consistent with California public trust law.

This guidebook explains how these take-aways can be incorporated into the substantive and procedural aspects of SGMA Groundwater Plans to ensure that such plans are protective of fisheries. Although the focus of this guidebook in on fisheries, the information and analysis contained herein may also be useful in drafting those portions of SGMA Groundwater Plans that address the more general question of how groundwater pumping can affect surface water flows even when fisheries are not the primary concern.

II.

THE CONNECTION HAS BEEN THERE ALL ALONG

CALIFORNIA WATER LAW TERMINOLOGY AND HYDROLOGIC REALITY

SGMA IS PART OF THE LARGER BODY OF CALIFORNIA WATER LAW, WHICH HAS DEVELOPED ITS OWN SET OF TERMS AND DISTINCTIONS. ONE OF THE KEY DISTINCTIONS IN CALIFORNIA WATER LAW IS BETWEEN SURFACE WATER AND GROUNDWATER.

In California, surface water use is regulated pursuant to the twin doctrines of riparian water rights and appropriative water rights. Since 1914 all appropriative water rights are issued by the State Water Resources Control Board (State Water Board). Use of groundwater in California, however, is subject to a different set of legal doctrines – overlying and non-overlying groundwater rights – and generally is not subject to the appropriative permitting authority of the State Water Board. The exception to this rule is that the State Water Board has asserted permitting authority over certain "subterranean" waters located in close proximity to surface waters, although the precise scope and limits of this permitting authority over such "subterranean" waters has been subject to longstanding debate.

In 2002, the late Professor Joseph Sax, a leading authority on California water law, completed a report assessing the permitting authority of State Water Board over groundwater and subterranean waters. Professor Sax's 2002 report, *Review of Laws Establishing the SWRCB's Permitting Authority over Appropriations of Groundwater Classified as Subterranean Streams and the SWRCB's Implementation of Those Laws*, included the following analysis that provides a useful framework for evaluating the ways SGMA Groundwater Plans should consider impacts on surface waters:

> My analysis reveals that the legislative purpose [of granting the State Water Board permitting authority over subterranean water in close proximity to surface waters] was to protect the permitting authority of the permitting agency's jurisdiction over surface stream adjudications by preventing unpermitted taking of groundwater that appreciably and directly affects surface stream flows. The concern was essentially to close a loophole that would have been left if any taking of water from a subsurface location would leave the permitting agency powerless in the face of wells or tunnels that were effectively underground facilities for withdrawing stream water.
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> ...
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> My conclusion is that the legislation was designed to create an impact test (impact of pumping on surface stream flows) rather than seeking to identify a physical entity with a specific shape despite the conventional "subterranean stream" language the law picked up from the old treaties. I conclude that a test designed to identify appreciable and direct impact of groundwater diversion on surface streams represents a more faithful implementation of the legislative purposes than any catalog of physical characteristics.

The "impact test" described by Professor Sax in 2002 was intended to define the reach of the State Water Board's permitting authority over groundwater pumping and was based on the premise that to effectively regulate surface water the State Water Board needed permitting authority over pumping that directly reduced surface water flows. Professor Sax's reasoning and proposed "impact test" apply with equal force in the context of SGMA Groundwater Plans, only in a different way. For a SGMA Groundwater Plan to effectively regulate groundwater resources, it must include information that explains the surface-groundwater interaction at pumping locations, addresses how this interaction affects fish that are present, and set forth measures to mitigate adverse impacts.

The "impact test" described by Professor Sax in 2002 was intended to define the reach of the State Water Board's permitting authority over groundwater pumping and was based on the premise that to effectively regulate surface water the State Water Board needed permitting authority over pumping that directly reduced surface water flows.

The "impact test" described by Professor Sax is consistent with the approach taken by the California Supreme Court in its 1909 decision in the case of *Hudson v. Dailey*. As noted water rights attorney Kevin O'Brien explained in a May 2018 presentation, in *Hudson v. Dailey* the California Supreme Court held that when groundwater is tributary to surface waters the two sources need to be viewed as a "common supply." O'Brien explains:

> Mrs. Hudson sued the groundwater pumpers and basically said, I'm riparian, I have a paramount right, you groundwater pumpers, you have to curtail. And the California Supreme Court ultimately said no, in this situation these are overlying landowners and they have overlying rights, you are a riparian and you have a riparian right, so you essentially stand on equal footing from a water rights standpoint, and we're going to take all that groundwater and surface water and put it together and we're going to determine water rights as a common supply.
>
> So while California does have separate water rights systems for groundwater and surface water, I think this concept of the common supply rule is going to be more and more prominent as we move forward and will remain relevant to issues that will arise under SGMA." (Hall and O'Brien)

In his 2002 law review article, titled We *Don't Do Groundwater; A Morsel of California Legal History*, Professor Sax also noted the fairness considerations involved by requiring surface water diverters to comply with bypass flow requirements for fisheries but allowing groundwater extraction to occur with no regard for bypass flow impacts:

> While California has a system in place that averts crisis and system collapse, it continues to suffer a variety of dysfunctional results growing out of a system that is at odds with hydrologic reality. One example that has drawn a good deal of attention recently arises from assertions that groundwater pumpers are depriving streams of water needed to meet downstream environmental flow requirements, even though regular surface water users are meeting the bypass flow requirements that have been imposed on them.

In this sense, SGMA's mandate to address the impacts of groundwater pumping on surface waters is not really new from a conceptual or policy standpoint. Professor Sax's 2002 report for the State Water Board made clear that it has long been understood and recognized that groundwater pumping can reduce surface flows, and as early as 1909 the California Supreme Court acknowledged that there were times when groundwater and surface water formed a "common supply." Moreover, Professor Sax's 2002 law review article recognized that it was fair that groundwater pumpers impacting surface water flows be subject to bypass flow requirements just like direct surface water diverters. Under SGMA, this interconnection and these common supply and fairness concerns must now be addressed explicitly and meaningfully in SGMA Groundwater Plans.

III.

PICTURING THE CONNECTION

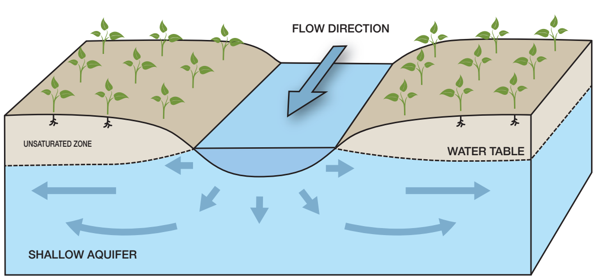
AQUIFERS, GAINING STREAMS/LOSING STREAMS AND FLOWS FOR FISHERIES

TO UNDERSTAND THE POTENTIAL IMPACT OF GROUNDWATER PUMPING ON SURFACE WATERS AND FISHERIES, IT IS HELPFUL TO FIRST PICTURE THE WAYS THAT GROUNDWATER AND SURFACE WATER CAN INTERACT, AND TO BECOME FAMILIAR WITH SOME OF THE COMMON TERMINOLOGY USED TO DISCUSS THESE INTERACTIONS.

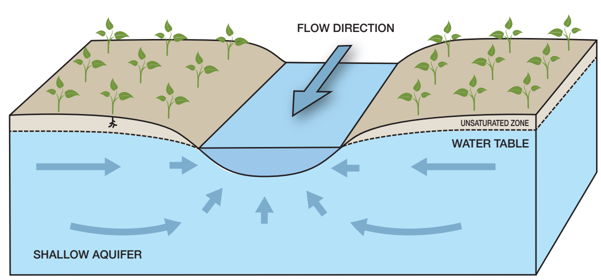
One of the key conceptual distinctions involved in groundwater-surface water interaction is the distinction between "gaining streams/reaches" and "losing streams/reaches." A gaining stream/reach is a stream/reach that receives water from subterranean aquifers. Or put another way, with a gaining stream/reach groundwater discharge contributes to surface flows. In contrast, a losing stream/reach is a stream/reach where surface flows are lost or drained into an aquifer. Or put another way, with a losing stream/reach surface waters flow into the aquifer.

Whether a surface stream/reach is a "gaining stream/reach" or a "losing stream/reach" depends on the respective elevations of the groundwater and surface water involved. This means that the status of surface water as a "gaining" stream/reach" or a "losing" stream/reach is not static or fixed but is subject to intra- and interannual variation. That is, during a period when the groundwater table in an aquifer is higher and surface flows are lower, the surface water may be gaining; but during a period when the groundwater table in an aquifer is lower and surface flows are higher, the surface water may be losing. During periods when there is simultaneously intensive groundwater pumping (e.g., in late summer when irrigation needs are highest) and reduced surface flows, a gaining stream/reach can become a losing stream/reach.

B. LOSING STREAM



A. GAINING STREAM



(USGS Circular 1376)

It is also important to understand that, along a particular surface watercourse, there may be some reaches where it is a gaining stream and other reaches where it is a losing stream. Whether the reach is gaining or losing depends on the proximity of and connection between the groundwater and surface water, and the respective elevations of the groundwater table and the surface water.

the concept of gaining streams/ reaches and losing streams/reaches presents particular challenges for developing hydrologic models, water budgets, monitoring programs, and pumping provisions in the context of SGMA Groundwater Plans.

As discussed further in this guidebook, the concept of gaining streams/reaches and losing streams/ reaches presents particular challenges for developing hydrologic models, water budgets, monitoring programs, and pumping provisions in the context of SGMA Groundwater Plans.

In addition to the question of gaining and losing streams/reaches, when it comes to fisheries there is also the question of how the relative contributions of surface water and groundwater affect fish habitat parameters. For instance, a critical component of salmon and steelhead habitat is water temperature. These are coldwater fish (for instance Chinook salmon eggs incubate most successfully at temperatures below 55 degrees Fahrenheit and experience increased mortality and negative sub-lethal effects as water temperatures rise). Importantly, instream temperatures tend to rise when ambient air temperatures rise (e.g., late summer) and whenever ambient conditions allow increased sunlight penetration (e.g. unshaded areas). Even when higher ambient air temperatures tend to raise the temperature of surface waters, the temperature of groundwater tends to remain stable and cooler. Therefore, if groundwater is tributary to surface waters, the influx of cooler groundwater tends to keep instream surface waters cooler, a dynamic that is particularly important for coldwater fish in late summer/early fall when ambient air temperatures tend to be warmer.

As another example, anadromous fish such as salmon and steelhead migrate downstream at particular times of the year and their need for surface flows is more acute during these seasonal migration periods. To protect and restore spring and fall runs of salmon and steelhead, the State Water Board has conditioned water rights on bypass flow requirements and restrictions on diversions for certain water year types.

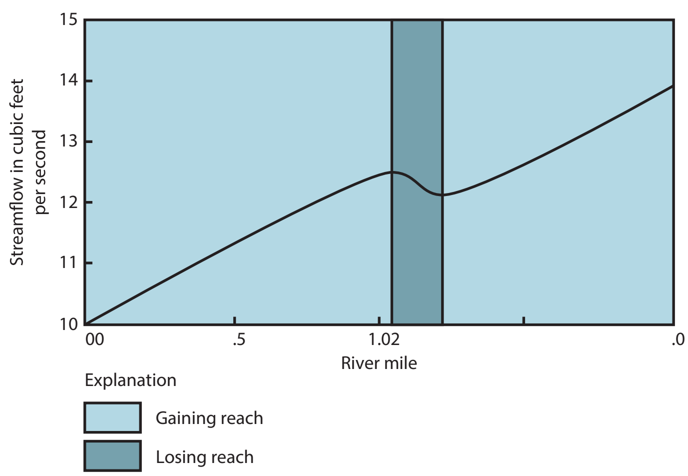
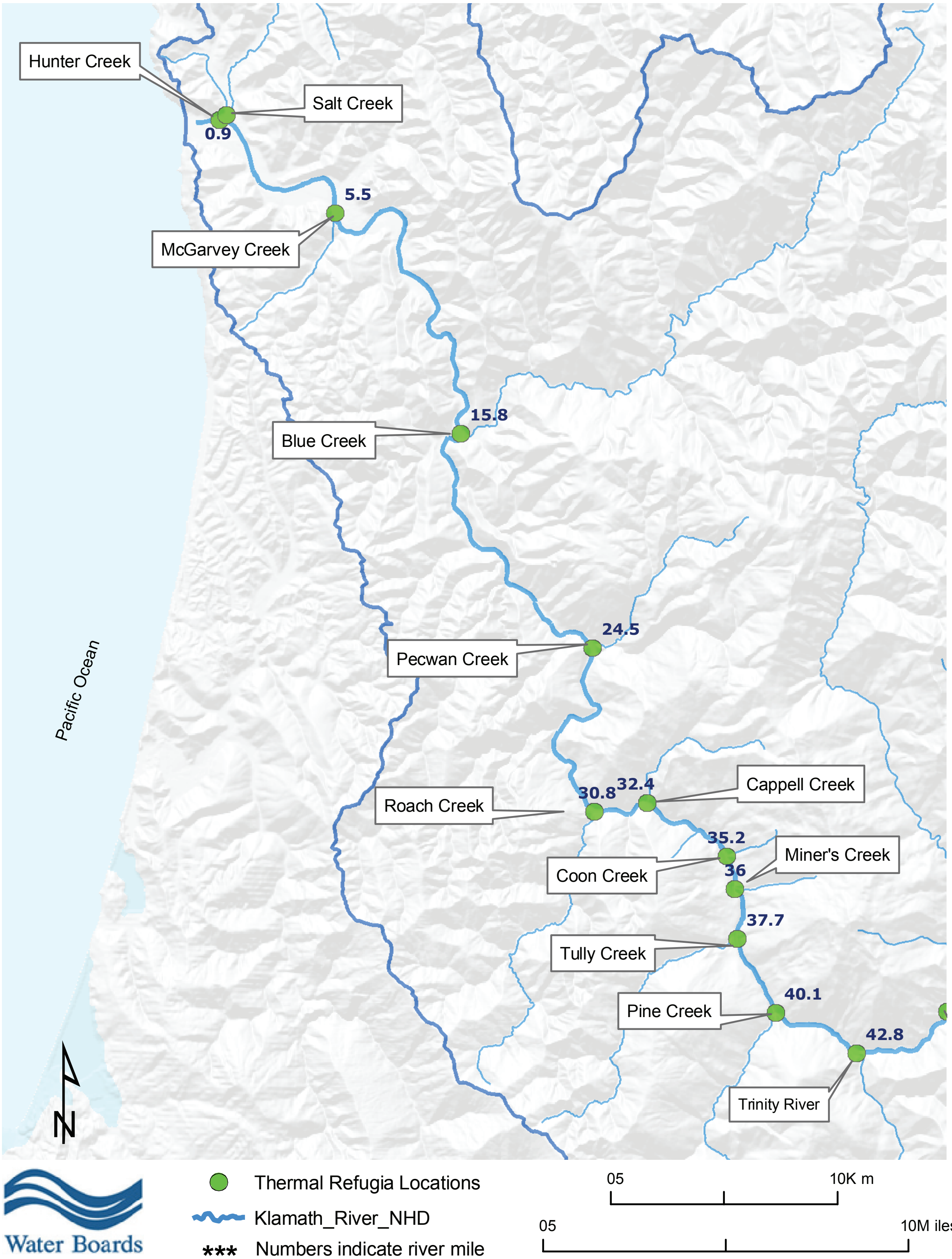


Figure 4.
Streamflow increases along the gaining reaches of a river and streamflow decreases along the losing reaches of a river when there is no direct surface-water runoff to the river.
(USGS Circular 1376)



Source, North Coast Regional Water Quality Control Board.

As a final illustration, to escape warm summer and early fall temperatures on the mainstem of larger surface waters such as the Klamath River, migrating salmon and steelhead often retreat from the exposed mainstem into smaller, shaded tributary creeks until mainstem temperatures have declined. In this way, fish use tributary creeks as "coldwater refuges" (sometimes also referred to as "thermal refugia") to escape warmer mainstem waters.

However, these tributaries only provide suitable refugia for fish migrating during summer/early fall if flows are sufficient to maintain connectivity with the mainstem so fish do not become isolated from or trapped within the creeks. Connectivity between the mainstem and coldwater refuges can be lost due to increased groundwater pumping near tributary creeks in the late summer/early fall (a period of high irrigation demand) when groundwater pumping can transform a gaining reach into a losing reach and turn tributary creeks into isolated ponds.

groundwater sustainability agencies need to consider specific habitat needs and timing in developing SGMA Groundwater Plans that effectively regulate groundwater pumping to prevent impacts to fish. This requires robust hydrologic models, water budgets, monitoring, and groundwater pumping provisions that consider the biological and physical needs of fish.

As discussed further in this guidebook, in terms of assessing the impacts of groundwater pumping on fisheries, groundwater sustainability agencies need to consider specific habitat needs and timing in developing SGMA Groundwater Plans that effectively regulate groundwater pumping to prevent impacts to fish. This requires robust hydrologic models, water budgets, monitoring, and groundwater pumping provisions that consider the biological and physical needs of fish. The good news is that there are tested and readily available methods to address these factors related to the groundwater-surface water connection and fisheries impacts, and to incorporate these factors into SGMA Groundwater Plans. To do this effectively, groundwater sustainability agencies will need to understand both the spatial and temporal impacts that groundwater pumping has on instream flows, as well as the instream conditions protective of fish species in their basin.

One of the best resources for how to analyze and model groundwater pumping-surface water flows interactions in SGMA Groundwater Plans is the 2012 United States Geological Survey Circular 1376, titled *Streamflow Depletion by Wells – Understanding and Managing the Effects of Groundwater Pumping on Streamflow (USGS Circular 1376). USGS Circular 1376* provides a catalog of scientifically-accepted programs and methodologies that can be used to determine the impact of groundwater pumping on surface stream flows, which in turn can be relied upon to manage groundwater pumping to avoid significant adverse impacts on surface stream flows and the fisheries that depend on such flows. As *USGS Circular 1376* explains at the outset:

> One of the primary concerns related to the development of groundwater resources is the effect of groundwater pumping on streamflow. Groundwater and surface-water systems are connected, and groundwater discharge is often a substantial component of the total flow of a stream. Groundwater pumping reduces the amount of groundwater that flows to streams and, in some cases, can draw streamflow into the underlying groundwater system. Streamflow reductions (or depletions) caused by pumping have become an important water-resource management issue because of the negative impacts that reduced flows can have on aquatic ecosystems.
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> ...
>
> [B]ecause precipitation rates, pumping rates and other hydrologic stresses vary with time, it is possible for a particular stream reach to switch from a gaining to a losing condition or from a losing to a gaining conditions from one period of time to the next.

USGS Circular 1376 provides guidance on ways to model and quantify groundwater pumping-surface water flow interactions:

The most common way to describe streamflow depletion has been to report the changes in the instantaneous flow rate of the stream, which is expressed in units of volume of streamflow per unit of time, such as cubic feet per second .... A related approach is to report the rate of streamflow depletion as a fraction of the pumping rate of the well, which is a dimensionless quantity .... These two approaches are illustrated in figure B-1, where rates of streamflow depletion are shown for a pumping rate of 1.0 M/gal/d at a well located 250 feet from a stream. The streamflow depletion that results from pumping the well is shown in units of cubic feet per second, which is the unit most often used in reporting streamflow.

...

More commonly ... pumping schedules vary with time, either in response to changing water supply demands or for the maintenance and overall operation of the water supply system. Pumping schedules can vary on an hourly and daily basis response to short-term fluctuations in demand and over longer-term cycles in response to factors as seasonal and annual climate variability and irrigation demands.

USGS Circular 1376 goes on to explain why traditional groundwater management concepts, such as "safe yield" and "overdraft avoidance," may not be appropriate benchmarks for determining groundwater pumping's impacts on surface flows and fisheries. This is because the concepts of "safe yield" and "overdraft avoidance" focus on a particular variable – maintaining the groundwater table over the long-term. The groundwater management objectives of "safe yield" and "overdraft avoidance" do not capture the seasonal or year-to-year (e.g. drought) impacts of groundwater pumping on surface stream flows, in which the periodic/short-term combination of low surface flows and increased groundwater pumping can have devastating adverse impacts on fisheries. As *UGGS Circular 1376* notes: "[t]here has been a tendency in parts of the United States to view groundwater development in an

The groundwater management objectives of "safe yield" and "overdraft avoidance" do not capture the seasonal or year-to-year (e.g. drought) impacts of groundwater pumping on surface stream flows, in which the periodic/short-term combination of low surface flows and increased groundwater pumping can have devastating adverse impacts on fisheries.

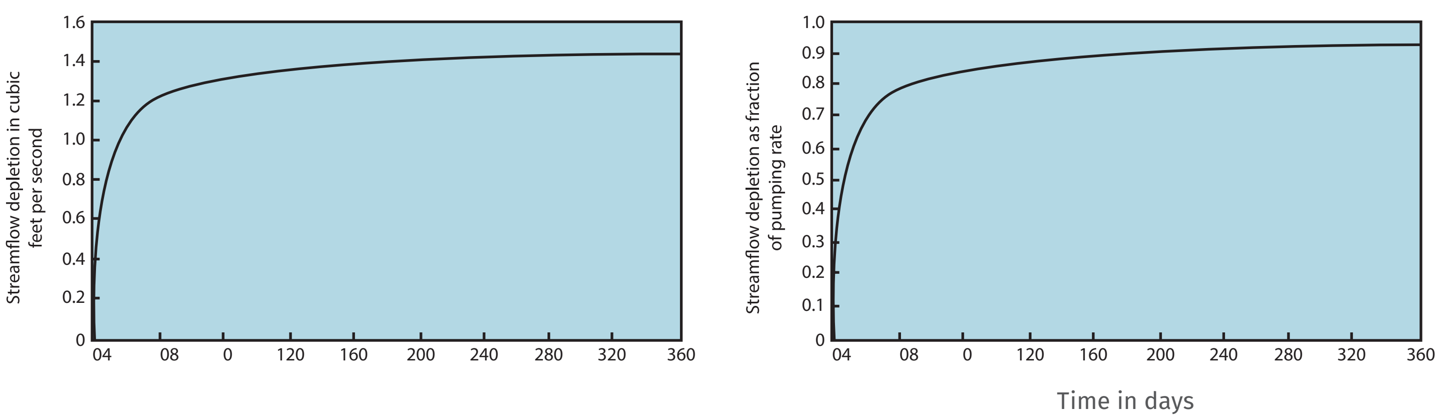

Figure B–1. Streamflow depletion resulting from pumping at a well located 250 feet from a stream. The well is pumped at a rate of 1 million gallons per day (about 1.55 cubic feet per second). In graph A, streamflow depletion is expressed as a rate, in cubic feet per second; in graph B, depletion is expressed as a fraction of the pumping rate at the well, which is a dimensionless quantity. (USGS Circular 1376) aquifer to be 'sustainable' or 'safe' when the overall rate of groundwater extraction does not exceed the long-term average rate of recharge to the aquifer."

Given SGMA's mandate that groundwater plans evaluate and address impacts on fisheries, not just long-term maintenance of the aquifer, we need to rethink what "sustainable" and "safe" groundwater pumping means.

there are programs, methodologies, and software available that allow groundwater sustainability agencies to address the correlation between reduced surface water flows and impacts on fisheries in SGMA Groundwater Plans.

Fortunately, there are programs, methodologies, and software available that allow groundwater sustainability agencies to address the correlation between reduced surface water flows and impacts on fisheries in SGMA Groundwater Plans. For instance, in the case of surface stream flow and temperature impacts on salmon, many agencies and fishery scientists in California now rely on SALMOD software, which was initially developed by the United States Geological Survey in 1994 to address stream flow impacts on salmon in the Klamath River-Trinity River watershed in Northern California. As explained in a 2004 article by USGS Fishery Biologist John M. Bartholow, titled *Modeling Chinook Salmon with SALMOD on the Sacramento River, California*:

> SALMOD is a computer model that simulates the dynamics of freshwater salmonid populations. The conceptual model was developed using fish experts concerned with Trinity River Chinook restoration (Williamson et al. 1993). The model's premise is that egg and fish mortality are directly related to spatially and temporally variable micro- and macrohabitat limitations, which themselves are related to the timing and amount of streamflow and other meteorological variables. Habitat quality and capacity are characterized by the hydraulic and thermal properties of individual mesohabitats, which are used as spatial "computation units" in the model. The model tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of local water temperature.

In addition to SALMOD, California water managers and fishery biologists also sometimes rely on the Interactive Object-Oriented Simulation Model (IOS Model) to evaluate the impact of surface water flows

and surface water temperatures on fisheries such as salmon and steelhead. In a 2012 article by Steven C. Zung et al, titled *Application of a Life Cycle Simulation Model to Evaluate Impacts of Water Management and Conservation Actions on an Endangered Population of Chinook Salmon*, the authors explain how life cycle models like the IOS Model work:

> Life cycle models utilize available time-series data as well as values taken from laboratory studies or other sources to parameterize model relationships, thereby utilizing the greatest amount of data available to dynamically simulate responses of populations across multiple life stages to changes in environmental variables or combinations of environmental variables at specific times and locations.

Moreover, in cases where groundwater pumping is causing surface waters to go dry altogether, reliance on SALMOD and the IOS Model is not needed to determine that there are significant adverse impacts on fisheries otherwise present in these areas. The complete disappearance of surface waters to groundwater pumping, by itself, renders these dried-out surface water reaches unsuitable for fish (because fish need water) and results in a loss of connectivity for fish in the portions of the watershed downstream and upstream of the dried-out reaches.

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The availability of SALMOD and the IOS Model, which enable groundwater sustainability agencies to model the effects of reduced surface stream flow and changes in surface stream temperatures on fish, makes it difficult for groundwater sustainability agencies to credibly claim that it is not feasible or too speculative to meaningfully address the impacts of groundwater pumping on fisheries in SGMA Groundwater Plans.

IV. FRAMING THE CONNECTION UNDER SGMA

STATUTE, REGULATIONS AND GUIDANCE

UNDER SGMA, GROUNDWATER SUSTAINABILITY AGENCIES ARE REQUIRED TO PREPARE GROUNDWATER SUSTAINABILITY PLANS THAT ESTABLISH THE WATER BASIN SETTING AND DESCRIBE HOW THE AGENCY WILL MANAGE AND USE GROUNDWATER "IN A MANNER THAT CAN BE MAINTAINED DURING THE PLANNING AND IMPLEMENTATION HORIZON WITHOUT CAUSING *UNDESIRABLE RESULTS*." (SGMA SECTION 10721, SGMA REGULATION 350.4) IN ADDITION TO DEPLETION OF GROUNDWATER SUPPLY OR STORAGE AND DEGRADATION OF WATER QUALITY, THE DEFINITION OF "UNDESIRABLE RESULT" INCLUDES "DEPLETION OF INTERCONNECTED SURFACE WATER THAT HAVE SIGNIFICANT AND UNREASONABLE ADVERSE IMPACTS ON BENEFICIAL USES OF THE SURFACE WATER." (SGMA SECTION 10721) FISHERIES PROPAGATION, REARING, AND/OR MIGRATION ARE DESIGNATED BENEFICIAL USES IN MOST BASINS.

A. SGMA Statutes and Regulations

Under SGMA, groundwater plans must contain certain elements, including but not limited to:

1. basic information about the groundwater sustainability agency administering the plan and the area covered by the plan;
2. description of the water basin setting and geographic area covered by the plan;
3. description of existing and planned water resource monitoring and management programs and how implementation of such programs may limit operational flexibility;
4. description of any conjunctive use programs in the basin;
5. description of land use elements relevant to the basin, including how implementation of the plan may change the water supply assumptions within those plans;
6. any additional elements (e.g., replenishment of groundwater extractions, coordination with state and federal agencies, impacts on groundwater dependent ecosystems) the groundwater sustainability agency deems appropriate. (SGMA, Section 10727.4, SGMA Regulations 354.2, 354.4, and 354.8)

The basin setting is one of the key elements of a SGMA Groundwater Plan. The setting serves "as the basis for defining and assessing reasonable sustainable management criteria and projects and management actions." (SGMA Regulation 354.12) For this reason, an accurate description of the setting – including data gaps and areas of uncertainty – is critical to the success of any plan.

As part of defining the basin setting, each groundwater sustainability agency is required to develop a hydrogeologic conceptual model based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin. (SGMA Regulation 354.14) In addition, the conceptual model must describe the current and historical groundwater conditions in the basin, including:

1. groundwater elevation data;
2. estimates of the change in groundwater storage annually and cumulatively;
3. any saltwater intrusion conditions;
4. groundwater quality issues that may affect the supply and beneficial uses **(including fisheries)** of groundwater;
5. extent, cumulative total, and annual rate of any land subsidence;
6. "[i]dentification of **interconnected surface water systems within the basin and an estimate of the quantity and timing of depletions of those systems**";
7. " identification of groundwater dependent ecosystems within the basin...." (SGMA Regulation 354.16, bold added)

The identification of interconnected surface water systems and estimates of the quantity and timing of depletions are important to understanding the effects of groundwater pumping on fisheries. There are certain types of information and data that can serve as the foundation for developing hydrologic models and water budgets to understand groundwater-surface water interaction in a given basin, and these hydrologic models and water budgets can then serve as the foundation for the adoption of groundwater pumping provisions to prevent depletion of surface water flows and prevent associated adverse impacts on fisheries.

Given that SGMA represents the first time groundwater will be comprehensively regulated in California, the statute anticipates there will be gaps in existing monitoring data and understanding of the ground and surface water interconnection. The statute adopts a "best available science" standard for information relied upon in developing SGMA Groundwater Plans. "Best available science" is defined as "the use of sufficient and credible information and data, specific to the decision being made and the time frame available for making that decision, that is consistent with scientific and engineering professional standards of practice."(SGMA Regulation 351)

Under SGMA, the quest for improved and more complete underlying data on groundwater pumping impacts on surface water flows and fisheries (which can be obtained through additional monitoring) is not a valid justification for delaying or avoiding the adoption of thresholds and groundwater pumping conditions in a SGMA Groundwater Plan to avoid the "undesirable result" of "depletions of interconnected surface water."

In the context of SGMA Groundwater Plans, there may be stakeholders that will resist the inclusion of specific and quantitative limits on groundwater pumping to avoid surface stream depletion based on the claim that there is incomplete data to support such limits. This line of reasoning does not square with SGMA's grounding in "best available science," or with the obligation of groundwater sustainability agencies to adopt thresholds for groundwater pumping to prevent continuing depletion of surface streams and to prevent continuing harm to fisheries based on the information and data that are available. Under SGMA, the quest for improved and more complete underlying data on groundwater pumping impacts on surface water flows and fisheries (which can be obtained through additional monitoring) is not a valid justification for delaying or avoiding the adoption of thresholds and groundwater pumping conditions in a SGMA Groundwater Plan to avoid the "undesirable result" of "depletions of interconnected surface water."

Groundwater models such as MODFLOW and IWFM can help bridge some of the gaps in existing data. Indeed, reliance on such models has become standard in the management of groundwater systems, and will be key to implementing SGMA. Groundwater models serve as simplified versions of real-world systems. Such models can provide an improved conceptual understanding of the system, including the essential and relevant processes and properties influencing the system. They support decision-making by facilitating the exploration of alternative management actions and, when calibrated appropriately, can forecast short- and long-term changes to the groundwater system resulting from management actions or changing environmental conditions.

As noted in a 2016 article by Tara Moran of the Stanford University Water in the West program, titled *Projecting Forward – A Framework for Groundwater Model Development Under the Sustainable Groundwater Management Act*:

> Groundwater models in California are developed using predominantly two model codes. Of the respondents that reported model codes, the [United States Geologic Survey's] MODFLOW and [California Department of Water Resources'] IWFM model codes account for more than 95 percent of the reported groundwater models used across the state. The consistency in model codes used across the state may aid in groundwater model coordination efforts under SGMA.

B. Best Management Practices for SGMA Groundwater Plans

In December 2016, DWR published a series of Best Management Practices (BMPs) to assist in the preparation of SGMA Groundwater Plans. Some of these BMPs addressed techniques and considerations related to how plans can prevent groundwater pumping causing significant and unreasonable depletion of interconnected surface waters.

An important component of the basin setting is the water budget, which is defined in the *DWR Modeling BMP* as "an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored." (*DWR Modeling BMP*) The *DWR Modeling BMP* further provides:

> The water budget shall quantify the following, either through direct measurements or estimates based on data:
>
> 1. Total **surface water** entering and leaving a basin by water source type.
> 2. **Inflow** to the groundwater systems by water sources type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and **surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.**
> 3. **Outflows** from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, **groundwater discharge to surface water sources**, and subsurface groundwater outflow. (bold added)

In a similar vein, the *DWR Water Budget BMP* provides:

> Another important water budget consideration is stream depletion due to groundwater pumping. In basins with interconnected surface water systems. If inflows (recharge) to the basis remain fixed while the amount of groundwater extraction increases, the increased volume of groundwater extraction, while initially resulting in a decline in the volume of aquifer storage, will eventually be balanced by decreases in the groundwater flow to springs, gaining streams, groundwater-dependent ecosystems or in increase in discharge from losing streams. Shallow production wells in close proximity to surface water systems commonly capture flow directly from the surface water system through induced recharge. Stream depletion associated with pumping wells further removed from surface water systems is more commonly the result of the indirect capture of groundwater flow that would otherwise have discharged to the surface water system sometime in the future. In both situations, streamflow depletion will continue until a new equilibrium between the outflow associated with groundwater extraction and the inflow from surface water depletion is established.

The *DWR Water Budget BMP* continues:

> The transition from storage depletion to stream depletion will affect water budget accounting over time...In many basins, stream depletion due to groundwater extraction will continue for decades prior to reaching a new equilibrium. Because of this transitional process, a water budget based on “average conditions” will not reflect this slow and progressive change. It is also important to recognize that water budget accounting during the early stages of groundwater basin development will have different storage and basin outflow values than water budget for a later time period, when the basin is approaching equilibrium...To accurately identify and evaluate the various inflow and outflow components of the water budget, it is important to adequately characterize the interaction between surface water and groundwater systems through sufficient monitoring of groundwater levels and streamflow conditions.

The *DWR Water Budget BMP* cautions:

> In basins with interconnected surface water systems or complex spatial and temporal variations in water budget components, quantifying and forecasting streamflow depletion and other water budget components may be extremely difficult without the use of a numerical groundwater and surface water model.

The *DWR Water Budget BMP* states:

> In addition to the lateral and vertical basin boundaries, the water budget accounting takes into consideration the exchange of water between subsystems within the hydrologic cycle. Figure 4 is a generalized schematic illustrating the potential interaction between water budget components and the surface water systems and groundwater system for a groundwater basin or management area.

The *DWR Water Budget BMP* instructs:

> Water budget components associated with the river and stream system include the surface water entering (inflow) and leaving the basin (outflow). The inflow and outflow of surface water to the basin is **required to be annually quantified as a total annual volume in acre-feet per year** (af/y) according to the surface water body (name) and the water sources type. (bold added)

In the context of drafting and implementing a SGMA Groundwater Plan, the preparation of a water budget can accurately reveal tensions between objectives, or “undesirable results” as defined under SGMA, such as the potential tension between avoidance of adverse impacts on agriculture of reducing groundwater pumping in late summer/drought years and the reduction of surface flows for fish that can

it may be that for certain times of year (e.g., late summer) or under certain conditions (e.g. drought) the need for groundwater as an irrigation supply may need to yield to the need to maintain adequate surface flows for fisheries.

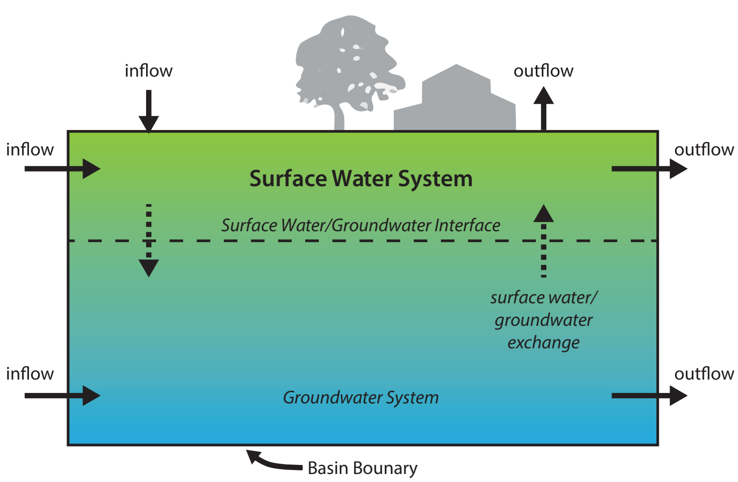

Figure 4

Conceptual Basin Boundary, Surfce Water and Groundwater Systems, and inflows and outflows. (USGS Circular 1376) result from intensive groundwater pumping in late summer/drought years. Disclosing such potential tensions will enable groundwater sustainability agencies and other stakeholders to make informed decisions. For instance, it may be that for certain times of year (e.g., late summer) or under certain conditions (e.g. drought) the need for groundwater as an irrigation supply may need to yield to the need to maintain adequate surface flows for fisheries. A rigorous and robust water budget in a SGMA Groundwater Plan can frame these potential tensions and trade-offs in a way that allows for more informed and transparent decision-making.

A water budget is like a household budget. It accounts for all of the water that enters and leaves your groundwater basin, by category. Your sources of income are inflows, and your expenses are outflows.

Echoing the guidance providedthe DWR BMPs, the Union of Concerned Scientists (in its 2017 publication titled *Getting Involved in Groundwater: A Guide to California's Groundwater Sustainability Plans)* has similarly stated that "water budgets" are an "essential component" of a SGMA Groundwater Plan:

> The water budget is a critical element of a GSP [Groundwater Sustainability Plan]. Water budgets track a variety of important pieces of information and can be used to help estimate a groundwater basin's sustainable yield, the amount of water that can be drawn out without causing an undesirable result...A water budget is like a household budget. It accounts for all of the water that enters and leaves your groundwater basin, by category. Your sources of income are inflows, and your expenses are outflows.

In regard to the groundwater-surface water interconnection, as discussed above, the concepts of "gaining streams/reaches" and "losing streams/reaches" relate to the accounting of "outflows" and " inflows" in water budgets. That is, when a surface watercourse "gains" water from an aquifer this is reflected as an "outflow" in the groundwater basin budget, and when a surface watercourse "loses" water to an aquifer (perhaps as a result of the water table falling due to groundwater pumping) this is reflected as an " inflow" in the groundwater basin budget. The UCS Guide makes clear why the water budgets included in SGMA Groundwater Plans need to include an accurate accounting of the inflow and outflows between aquifers and surface waters.

In addition to the *DWR Modeling BMP and the DWR Water Budget BMP, there is also a DWR BMP on Monitoring Networks and Identification of Data Gaps (DWR Monitoring/Data Gaps BMP).* SGMA requires that each groundwater plan include monitoring protocols to assess progress in meeting the sustainability goals established in the plan. (SGMA Regulations 354.24 and 354.30). Each groundwater sustainability agency must develop a monitoring network capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions and yield representative information about groundwater conditions as necessary to evaluate Plan implementation "along with specific monitoring network objectives." (SGMA Regulation 354.34) Agencies are to report their monitoring data to DWR annually. (SGMA Regulation 354.40)

> The monitoring must be designed to evaluate depletions of interconnected surface water:
>
> to characterize the **spatial** and **temporal** exchanges between surface water and groundwater, and to calibrate and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. The monitoring network shall be able to characterize the following:
>
> 1. **Flow conditions indicating surface water discharge**, surface water heads and **baseflow contribution**.
> 2. **Identifying** the approximate date and location where ephemeral or intermittent flowing streams and rivers **cease to flow**, if applicable.
> 3. **Temporal changes in conditions due to variations in stream discharge and regional groundwater extractions.**

4. Other factors that may be necessary to identify adverse impacts on beneficial uses of the surface water. (SGMA Regulation 354.34, bold added)

Further, each SGMA groundwater plan must include the following information in the description of the monitoring network: "For **each sustainability indicator, the quantitative values for the minimum threshold**, measurable objective and interim milestones that will be measured at each monitoring site or representative monitoring sites established pursuant to Section 354.36." (SGMA Regulation 354.34, bold added) Each description of the minimum thresholds must include:

1. the information and criteria relied upon to establish and justify the **minimum thresholds for each sustainability indicator**. The justification for the minimum threshold shall be supported by information provided in the basin setting, and other data or models as appropriate, and quantified by uncertainty in the understanding of the basin setting.
   ...
6. **Depletions of Interconnected Surface Water:** The **minimum thresholds for depletions of interconnected surface water** shall be the **rate or volume of surface water depletions** caused by groundwater use that has **adverse impacts on beneficial uses of the surface water** and may lead to **undesirable results**. The minimum threshold established for depletions of interconnected surface water shall be supported by the following:

a. The location, quantity and **timing** of depletions of interconnected surface water

b. A description of the **groundwater and surface water model** used to quantify surface water depletion If a numerical groundwater and surface water model is not used to quantify surface water depletion, the Plan shall identify and describe an **equally effective method, tool or analytic model** to accomplish the requirements of this Paragraph." (SGMA Regulation 354.28, bold added)

In terms of implementing these SGMA provisions related to monitoring, the *DWR Monitoring/Data BMP* begins by outlining the following objective: "Information provided in this BMP provides technical assistance to Groundwater Sustainability Agencies (GSAs) and other stakeholders to aid in the development of a monitoring network that is capable of providing sustainability indicator data of sufficient accuracy and quantity to demonstrate that the basin is being sustainably managed. In addition, this BMP is intended to provide information on how to identify and plan to resolve data gaps to reduce uncertainty that may be necessary to improve the ability of the GSP to achieve the sustainability goals for the basin." This BMP further explains: "Groundwater monitoring is a fundamental component of SGMA as each GSP must include a sufficient network that provides data that demonstrate measured progress toward achievement of the sustainability goal for each basin. For this reason, a sufficient network will need to be developed and utilized to accomplish this component of SGMA."

The *DWR Monitoring/Data BMP* goes on to state:

> Monitoring of the **interconnected surface water depletions** requires the use of tools, commonly modeled approaches, to estimate the depletions associated with groundwater extraction. Models require assumptions be made to constrain the numerical model solutions. These assumptions should be based on empirical observations determining the extent of the connection of surface water and groundwater systems, the **timing** of those connections, the flow dynamics of both surface water and groundwater systems, and hydrogeologic properties of the geologic framework connecting these two systems.
>
> The following components should be included in the establishment of a **monitoring network**:
>
> 1. Use existing stream gaging and groundwater level monitoring networks to the extent possible.
>
> 2. **Establish stream gaging along sections of known surface water groundwater connection.**

3. Establish a shallow groundwater monitoring well network to characterize groundwater levels adjacent to connected streams and hydrogeologic properties.

    i. Network should extend perpendicular and parallel to stream flow to provide adequate characterization to constrain model development.

    ii. Monitor to capture **seasonable pumping conditions** in vicinity-connected surface water bodies.

4. Identify and quantify both timing and volume **of groundwater pumping within approximately 3 miles of the stream** or as appropriate for the flow regime. (bold added)

This guidance in the *DWR Monitoring/Data BMP* is particularly relevant in terms of the monitoring networks included in SGMA Groundwater Plans. More specifically, this guidance suggests that when there are known or potential groundwater-surface water interactions, the plan needs to include stream gage monitoring (both for volume and for temperature in terms of fishery-related impacts) of surface waters that may be impacted by groundwater pumping, and such stream gage/temperature monitoring needs to be done on a seasonal rather than annual basis, to account for the ways that seasonal groundwater pumping and season surface flow fluctuations impact and the extent to which groundwater pumping may be depleting surface water flows and impacting surface water temperatures.

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V. THE PUBLIC TRUST CONNECTION

STATUTE, REGULATIONS AND GUIDANCE

IN TERMS OF THE OBLIGATIONS OF GROUNDWATER SUSTAINABILITY AGENCIES TO PREPARE SGMA GROUNDWATER PLANS THAT ADDRESS THE IMPACT OF GROUNDWATER PUMPING ON SURFACE FLOWS AND FISHERIES, THESE OBLIGATIONS MAY BE DEFINED BY A SOURCE OF LAW OUTSIDE OF SGMA AND ITS IMPLEMENTING REGULATIONS – CALIFORNIA PUBLIC TRUST LAW. THE APPLICATION OF CALIFORNIA PUBLIC TRUST LAW HAS BECOME APPARENT AS A RESULT OF RECENT LITIGATION INVOLVING GROUNDWATER PUMPING IN THE SCOTT RIVER BASIN.

As noted in the introduction and described more fully below, there is evidence that groundwater extraction from wells near the Scott River depletes surface flows with adverse impacts on the salmon and steelhead fisheries present. To address this situation, the Environmental Law Foundation (ELF) sued Siskiyou County and the State Water Board in Sacramento County Superior Court (Case No.: 34-2010-80000583) under California public trust law. California public trust law applies to public trust resources (which include fisheries such as salmon and steelhead stocks) and public trust uses (which include non-commercial fishing for salmon and steelhead). In its 2014 ruling, the court held California public trust law applies to groundwater that is tributary to navigable surface waters such as the Scott River that contain public trust resources and support public trust uses. Relying on the California Supreme Court's 1983 *National Audubon* decision concerning the public trust, the court explained:

> The public trust doctrine would prevent pumping directly out of the Scott River harming public trust uses. So too under *National Audubon* the public trust doctrine would prevent pumping a non-navigable tributary of the Scott River harming public trust uses of the river. The court finds no reason why the analysis of *National Audubon* would not apply to the facts alleged here. The court thus finds the public trust doctrine protects navigable waters from harm caused by extraction of groundwater, where the groundwater is so connected to the navigable water that its extraction adversely affects public trust uses. (*ELF v. Siskiyou County*)

The court also held that public trust obligations apply not only to the State Water Board and other state agencies, but also to local governments like Siskiyou County:

> **There is no conflict between authorizing the County to adopt a groundwater management plan, and requiring it to comply with the public trust doctrine**. The public trust doctrine applies when the extraction of groundwater harms navigable waters and the public's use for trust purposes. If the County's issuance of well permits will result in extraction of groundwater adversely affecting the public's right to use the Scott River for trust purposes, the County must take the public trust into consideration and protect public trust uses when feasible. Such a requirement does not conflict with the County's discretion to decide whether or not to implement an overall groundwater management plan. (*ELF v. Siskiyou County*, bold added.)

In addition to the SGMA requirements for how groundwater plans must address the impacts of groundwater extraction on surface waters and fisheries, groundwater sustainability agencies may also be required also take into account California public trust law. Following the 2014 *ELF v. Siskiyou County* decision, it now appears that groundwater sustainability agencies have separate public trust obligations, independent of SGMA, to refrain from approving groundwater pumping that reduces the instream flow of navigable rivers needed to maintain fisheries.

For example, the groundwater sustainability agency designated for the Scott River Valley Groundwater Basin is the Siskiyou County Flood Control and Water Conservation District. Over the next few years the district will be preparing a SGMA Groundwater Plan that covers groundwater wells that are impacting the Scott River's instream flow and salmon fisheries. The district's preparation of the SGMA Groundwater Plan therefore provides an opportunity to see how California public trust law overlies SGMA. Under SGMA, in every basin where groundwater extraction is adversely impacting surface flows and fisheries, the SGMA Groundwater Plan drafting and approval process provides a key opportunity for fishery groups, including fishing and conservation organizations, to press for provisions that give effect the public trust law obligations recognized in the *ELF v. Siskiyou County* case.

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Overlaying the public trust doctrine to implementation of SGMA could enhance the legal obligations of groundwater sustainability agencies in several ways. For example, California public trust law calls for full protection of public trust resources whenever feasible. (*National Audubon*) If it can be demonstrated that it is feasible for groundwater sustainability agencies to develop hydrologic models and water budgets that account for the impacts of groundwater pumping on surface flows and fisheries dependent on such surface flows, the failure of a groundwater sustainability agency to factor these considerations into the hydrologic models and water budgets in a SGMA Groundwater Plan may constitute a violation of California public trust law independent of SGMA's requirements.

As another example, if it can be demonstrated that it is feasible to conduct seasonal surface stream monitoring of flows and temperatures to track the impacts of groundwater pumping on fisheries, the failure of a groundwater sustainability agency to require such seasonal surface stream monitoring in a SGMA Groundwater Plan may constitute a violation of California public trust law independent of SGMA's requirements.

As a final illustration, if it can be demonstrated that it is feasible to adopt thresholds for groundwater pumping that provide for full protection of fisheries from the adverse impacts of groundwater pumping-induced surface stream depletion, the failure of a groundwater sustainability agency to adopt such thresholds may constitute a violation of California public trust law independent of SGMA's requirements.

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VI. LESSONS FOR SGMA FROM THE SCOTT RIVER BASIN & ARIZONA

IN DEVELOPING APPROACHES TO ADDRESS THE GROUNDWATER-SURFACE WATER INTERACTION IN THE CONTEXT OF SGMA GROUNDWATER PLANS, GROUNDWATER SUSTAINABILITY AGENCIES AND OTHER STAKEHOLDERS INVOLVED IN IMPLEMENTING SGMA DO NOT NEED TO START FROM SCRATCH. THERE ARE OTHER REGULATORY SETTINGS, BOTH IN CALIFORNIA AND OTHER STATES SUCH AS ARIZONA, IN WHICH PROVISIONS HAVE BEEN PUT IN PLACE TO HELP PREVENT GROUNDWATER PUMPING FROM REDUCING INTERCONNECTED SURFACE WATER FLOWS AND TO PROTECT FISHERIES DEPENDENT ON SUCH FLOWS. AN OVERVIEW OF HOW THE GROUNDWATER-SURFACE WATER CONNECTION WAS HANDLED IN THESE NON-SGMA REGULATORY SETTINGS MAY PROVIDE POTENTIAL MODELS FOR USE IN SGMA GROUNDWATER PLANS.

A. Scott River Basin

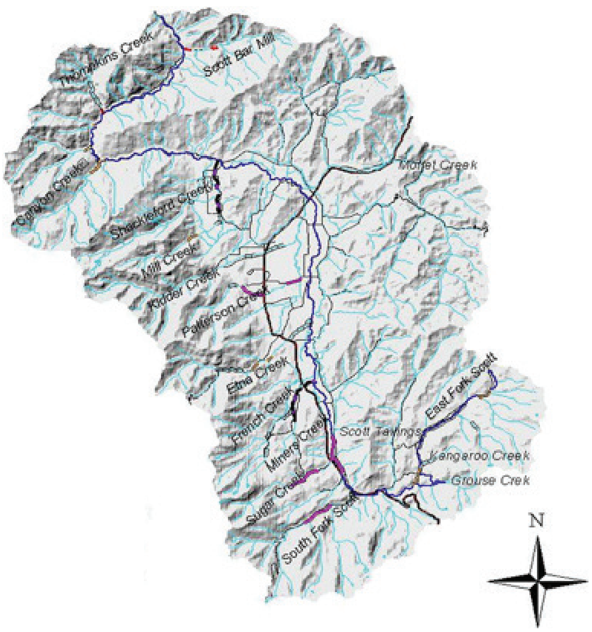
The Scott River Watershed is located in Northern California and is a major tributary of the Klamath River. The Scott River Valley's primary land use is agriculture. It is a good case study for SGMA purposes because, as Aaron Herbert noted in his 2016 study titled *Impact to Anadromous Fish Through Groundwater Extraction*, the Scott River Basin's "water problems typify many of California's structural challenges in managing water: an over-allocated and adjudicated surface water system, an excess of groundwater pumping, the majority of flow volume outside of the growing season, and special status anadromous fish that require water just at the time it is in most demand by people."

The Herbert study noted that there is a strong surface- groundwater interconnection in the Scott River: "[d]uring the dry summer, streamflow in the Scott River system is low and relies almost entirely on groundwater return flow (baseflow) from the alluvial aquifer system underlying Scott Valley. There has been a marked downward trend in surface flows in the last several decades that has been attributed to climate change and increased groundwater pumping."

Water rights to the Scott River were adjudicated in a 1980 court decree. (Scott River Court Decree) The scope of the court decree includes both surface and interconnected groundwater, specifically: "(1) all surface water rights in the Scott River stream system ... (2) all rights to supporting underflow and (3) all rights to groundwater that is interconnected with the Scott River ...." (Scott River Court Decree). The 1980 decree was somewhat prescient in its recognition of the interconnection between groundwater and surface water. It defined "interconnected ground water" as:

> all ground water so closely and freely connected with the surface flow of the Scott River that any extraction of such groundwater causes a reduction in the surface flow in the Scott River prior to the end of a current irrigation season. The surface projection of such interconnected ground water as defined herein is that area adjacent to the Scott River as

delineated on the SWRCB may in the reach from the confluence of Clarks Creek and Scott River to Meamber Bridge. (Scott River Court Decree)



Map of Scott River Watershed (May 2005 Report on Scott River Watershed Adult Coho Spawning Ground Surveys by Siskiyou Resource Conservation District for United States Fish and Wildlife Service)

The court decree allotted interconnected groundwater claimants "that amount of water, by subirrigation or by pumping from ground water interconnected with the Scott River, reasonably required to irrigate the acreage shown opposite their names." (Scott River Court Decree) It documented the location of existing and proposed wells or sumps, and provided that "[a]dditional wells or sumps may be constructed to augment irrigation or to replace subirrigation but must be located at least 500 feet from the Scott River or at the most distant point from the river on the land that overlies the interconnected ground water, whichever is less." (Scott River Court Decree)

Since the issuance of the 1980 court decree, the Herbert study found that the number of wells outside of the designated "interconnected groundwater" has grown steadily over time and groundwater pumping greatly increased. It seems that an unintended consequence of the adjudication of primarily surface water rights was to increase the demand for groundwater.

In addition to supporting agriculture, the Herbert study notes that the Scott River also "provides important habitat for salmonid fish, including spawning and rearing habitat for coho (*Onchorhynchus kisutch*) and fall-run Chinook salmon (*Onchorhynchus tschawytscha*) and steelhead trout (*Onchorynchus mykiss*)." A 2013 report by the University of California at Davis concluded that these fish need adequate flows at low temperatures for spawning in the fall and rearing in the summer. (*2013 UC Davis Report*) In 2014, the National Marine Fisheries Services determined that surface water diversions and increased groundwater extraction have contributed to a decline in suitable salmon habitat in the Scott River Basin. (*2014 NMFS Plan*).

The western tributaries in the Scott River watershed, in particular, provide important anadromous fish habitat. These tributaries are characterized by a strong surface- and groundwater interconnection, and the Herbert study notes are "likely highly sensitive to surface diversions and groundwater extraction. It has been theorized that groundwater pumping on these streams actually draws from surface water, not groundwater based on the relatively stable levels of groundwater storage despite an increase in pumping over the last 30 years."

Due to the conflicts between groundwater pumping and fisheries, there have been several studies regarding the relationship between groundwater and surface flow in the Scott River watershed even prior to the enactment of SGMA and the requirements to describe the basin setting and establish a hydrogeological conceptual model, including the Herbert groundwater conditions study commissioned by the Karuk Tribe, the integrated hydrologic model developed by University of California at Davis, and the water budget developed by Laura Foglia and her colleagues. These efforts may be useful to groundwater sustainability agencies preparing groundwater sustainability plans in basins that support coldwater fisheries.

In 2012, the Karuk Tribe commissioned Aaron Herbert to prepare a high-resolution groundwater model of the Scott Valley for purposes of characterizing valley-wide groundwater conditions and ground and surface water interactions. (Herbert). The model was used to run two scenarios: groundwater at recent levels of use, and groundwater at partial build-out of the existing groundwater capacity.

The modeling analysis in the Herbert study had the following findings:

- Groundwater elevations in winter are minimally affected by long-term pumping. Groundwater elevations in late summer/early fall have been subject to declines on the order of a few feet, depending on location.
- Groundwater declines from pumping tend to be greater in the outlying areas of the basin including upland gulches; similarly, groundwater elevation increases from recharge events may be more pronounced in these areas.
- The Scott River and tributaries can be and have been impacted by increased levels of groundwater pumping. These impacts, termed "stream depletion", involve a combination of a reduction in gains to the stream from groundwater and increased seepage losses from the stream to groundwater, depending on location and time of year.
- Stream depletion can occur from pumping at any location within the Scott Valley; however, the magnitude and timing of impacts to the river or tributaries depends on the amount, duration, location and depth of pumping.
- The model has been applied to generate a stream depletion relationship for the existing basin-wide distribution of pumping which shows that, in composite, increases in groundwater pumping are conveyed to equivalent reductions in streamflow within approximately five years, with the bulk of the impact occurring in the first year or two.
- The simulated net increase in pumping between the "partial build-out" condition (approximately, 1980s) and the "recent" condition (2000) indicates a corresponding stream depletion impact of approximately 16 cfs during the late summer season, July through September. The stream depletion is a change that would be superimposed on surface water flows resulting from the combination of other inflows and outflows, including run-off, ambient stream gains/losses, surface diversion and return flow.
- Higher stream depletion impacts occur during the summer than during the winter/early spring period, reflecting the seasonal occurrence of irrigation pumping.
- The magnitude of stream depletion resulting from an increase in groundwater pumping from "partial build-out" conditions to "recent" conditions is consistent with the observed reduction in baseflow of the Scott River over recent decades, adjusted to account for climate impacts.

The study commissioned by the Karuk Tribe demonstrates that it is feasible to develop a robust hydrologic model and water budget that captures, quantifies and analyzes all of these interactions and impacts.

The findings in the Karuk Tribe study have implications for SGMA Groundwater Plans in at least three important respects. First, the findings reflect how groundwater pumping over an extended period can transform a "gaining stream/reach' to a "losing stream/reach" as the groundwater table falls. Second, the findings reflect how the proximity of groundwater pumping well to streams can impact the effect of the groundwater pumping on surface stream flows. Third, the findings reflect the ways that seasonal grounding pumping during the summer to meet irrigation needs can result in more acute adverse impacts on surface stream flows. The study commissioned by the Karuk Tribe demonstrates that it is feasible to develop a robust hydrologic model and water budget that captures, quantifies and analyzes all of these interactions and impacts.

The utility of the model extends beyond just these findings and can be used to evaluate alternative scenarios that reduce or prevent the adverse effects of groundwater pumping and related effects on fish, which would be considered an undesirable result for purposes of SGMA. Such scenarios could include "recharge ponds, modification of pumping locations or schedules, alternate irrigation application methods or other approaches for increasing aquifer recharge." (Herbert)

to address the absence of complete data about stream-groundwater interaction, the modelers performed a streamflow regression analysis as part of their water budget to provide a basis to estimate the monthly tributary inflows into the Scott Valley based on incomplete sets of measured data.

The second noteworthy study of groundwater-surface water interactions in the Scott River Basin was undertaken by the University of California at Davis Department of Land, Air and Water Resources. This 2013 publication, titled *Scott Valley Integrated Hydrological Model: Data Collection, Analysis and Water Budget (2013 UC Davis Report)* was prepared as a report for submission to the State Water Board and the North Coast Regional Water Quality Control Board. It included "precipitation data analysis, streamflow analysis and modeling, evapotranspiration data analysis and modeling, soils and groundwater data assembly and analysis, land use and topography data analysis, and development and analysis of a soil water budget to estimate field-by-field daily pumping and groundwater recharge in the Scott Valley for Water Years 1991-2011."

The 2013 UC Davis Report developed methods to compensate for incomplete data. Specifically, to address the absence of complete data about stream-groundwater interaction, the modelers performed a streamflow regression analysis as part of their water budget to provide a basis to estimate the monthly tributary inflows into the Scott Valley based on incomplete sets of measured data. More specifically, the UC Davis Report concluded: "We are able to estimate tributary flows with a newly developed statistical model that take advantage of the long-time series of data at the Ft. Jones streamflow gauging station immediately downstream from Scott Valley...the **synthetic dataset generated will be sufficient for purposes of the integrated hydrological model.**" (bold added)

The streamflow regression methodology relied upon in the *UC Davis Report* can be used by groundwater sustainability agencies to address surface water streamflow impacts of groundwater pumping in SGMA Groundwater Plans even when there is incomplete data. This reliance is consistent with SGMA's requirement that water budgets and hydrological models be based on the "best science available" rather than forgoing such analysis altogether due to the absence of some hypothetical complete set of complete data that does not exist.

This approach was also taken in a 2013 paper by Laura Foglia and her colleagues, titled *Coupling a Spatiotemporally Distributed Soil Water Budget with Stream Depletion Functions to Inform Stakeholder-Driven Management of Groundwater-Dependent Ecosystems (Foglia)* The Foglia paper found that initial thinking about the Scott River Basin water budget was off. Although groundwater recharge was initially thought sufficient to offset groundwater pumping and avoid streamflow depletion, the model used in the Foglia paper (which included streamflow regression analysis) showed a net drop in the groundwater table and a net depletion of the streamflow over the course of a year:

> Due to the high streamflows during November through June stream depletion is here only of concern during the summer period. During that period, existing winter and spring recharge is not sufficient to offset summer groundwater pumping effects on stream depletion."

The Foglia paper identified a "range of groundwater management scenarios to broadly bracket options that can serve as a catalyst to direct stakeholder discussions, and to demonstrate the potential range of beneficial impacts from groundwater management on stream depletion." (Foglia) The scenarios included the following:

1. **Increased groundwater storage** of winter and spring streamflow, especially near the Scott River, may significantly decrease the impact of the pumping season on streamflow depletion during the critical summer period.

2. **Groundwater pumping effects in August and July could be further mitigated by transferring groundwater pumping in the most sensitive areas to wells that are some distance away from the Scott River.** This would require water trading and transport infrastructure.

3. Addressing uncertainty about the effective hydraulic conductivity between the stream and the aquifer due to geologic heterogeneity, due to geomorphologic complexity, and the unknown complexity of the flow field between groundwater and the stream is critical to better quantify actual stream depletion impacts. We also found that the soil water budget significantly overestimates currently reported farm irrigation rates in center pivot and wheel-line sprinkler systems, possibly due to significant, but unreported deficit irrigation. Sensitivity analysis yields a measure of uncertainty. More importantly it provides direction for critical field measurement programs and the design of more complex hydrologic models for site-specific assessment and feasibility studies of specific recharge and pumping management projects. (bold added)

In terms of drafting SGMA Groundwater Plans, there are a number of lessons from the Foglia paper. First, placing winter and spring surface stream flows in groundwater aquifers can raise the groundwater table to decrease the impact of summer groundwater pumping on stream depletion. Second, relocating groundwater wells further away from interconnected surface streams may reduce the impacts of groundwater pumping on stream depletion and fisheries. Third, there are field measure programs that can be included as part of the modeling network in SGMA Groundwater Plans that will improve understanding of the effects of groundwater pumping on surface stream depletion.

All three of the studies discussed above reached the same basic conclusion, namely that groundwater pumping in the Scott River Basin can seasonally affect instream flows at a time when flow is needed to support anadromous fisheries:

> [T]he vast majority of wells in the Scott aquifer cause stream depletion in a relatively short time frame in amounts approaching their pumping rates. The materials between the well and stream affect the timing and short-term magnitude of the depletion but appear to suggest nearly of all of the aquifer materials are interconnected to the Scott River
>
> [N]early all of the groundwater in the Scott Valley aquifer is "interconnected" with the surface water systems. The relatively shallow depth of the materials and their hydraulic conductivities facilitate stream depletion. The effects of more distant wells occur over many years and for long periods of time within the year after pumping has ceased. While these effects on anadromous fish are lessened because they mostly cause stream depletion outside of the low flow period, some portion of their depletion does occur during the low flow period. The scale of stream depletion from groundwater extraction, estimated between 16 cfs and 55 cfs during July and August, is significantly less than 235 cfs allocated to the priority 1 users. Yet the use of both systems influences the other: if surface water is unavailable, more groundwater is likely to be pumped, causing less surface water to be available. While the scale of total stream depletion from pumping is much less than the priority 1 allocation, the near equivalent overall estimated groundwater and surface water

relocating groundwater wells further away from interconnected surface streams may reduce the impacts of groundwater pumping on stream depletion and fisheries.

> use (~40,000 – 50,000 acre feet/year for each) suggests the priority 1 allocation is often not met, surface waters are too limited to divert, and therefore compensated for with groundwater pumping. While groundwater extraction may have lesser and slower impacts to the stream during the low flow periods than direct surface water diversions, they are not mutually exclusive actions in the Scott River watershed because not enough surface water is available during the times it is needed. (Herbert)

All three of these studies suggest that anadromous fisheries in the Scott River Basin are vulnerable to these incremental and cumulative impacts of groundwater pumping:

> The over-allocation of surface water creates a baseline of water shortages that makes the Scott River susceptible to disconnection during drought. The overall lack of storage in the watershed also appears to cause a seasonal shift from surface waters to groundwater in the summer. The nature of the aquifer materials means that to shift to groundwater pumping further reduces surface water, even within the season. The preferred habitat of the Coho is also those low gradient areas where the alluvial deposits built up over time to create the aquifer. Some of the western tributaries that have historically gone dry during droughts are intrinsically vulnerable … to minor reductions in streamflow," which can degrade their habitat value. (Herbert)

Some of the modeling methodologies implemented and being refined for the Scott River Basin may be instructive for SGMA groundwater sustainability agencies undertaking to conceptualize their groundwater basins and determine how pumping affects surface water flows and habitat components that are flow-dependent inter- and intra-annually. Interested parties may also cite to these methodologies as a benchmark for what constitutes "best available science."

B. The Arizona Approach

Unlike with California's State Water Board, the Arizona Department of Water Resources has broad statutory authority to regulate groundwater extraction as well as surface water diversions. Arizona has adopted certain approaches to interconnected groundwater-surface water that may be instructive to the provisions in SGMA Groundwater Plans pertaining to the effect of groundwater pumping on surface water flows and fisheries.

There are three concepts used in Arizona that may provide particular guidance for SGMA implementation: delineation of the subflow zone, the cone of depression test, and the use of set-back lines for groundwater management.

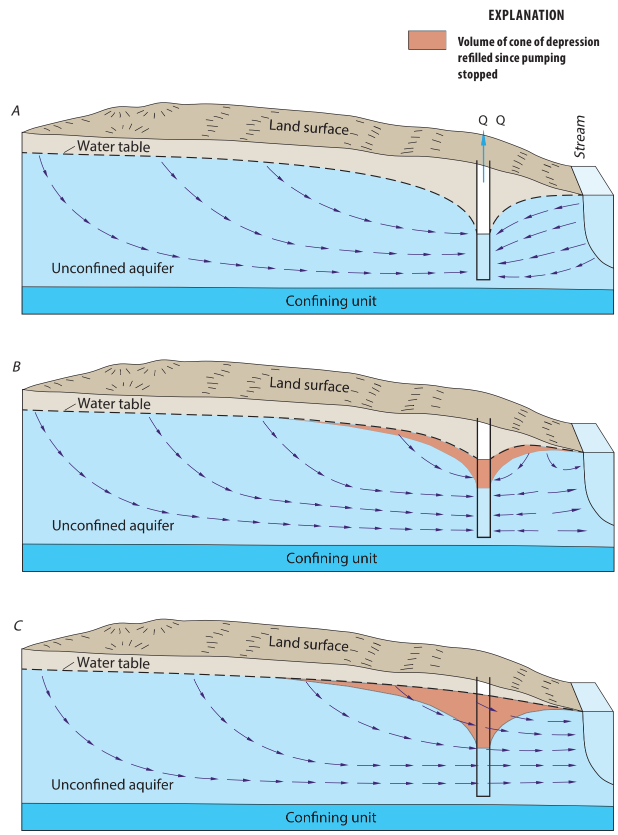
First, Arizona's regulation of groundwater extraction to prevent surface flow depletion is based largely on the determination of what is referred to as the "subflow zone." (*2014 Arizona Subflow Report*) The subflow zone is the area adjacent to or near surface water where there is evidence suggesting that groundwater extraction in this area is resulting in reduced surface water flows. (*2014 Arizona Subflow Report*) In Arizona, the subflow zone is also sometimes referred to as the saturated floodpain holocene alluvium. (*2014 Arizona Subflow Report*). In its *2014 Revised Subflow Delineation Report for the San Pedro River* (*2014 Arizona Subflow Report*) the Arizona Department of Water Resources noted that in addition to existing data correlating groundwater pumping and surface stream depletion, the presence of riparian vegetation near surface waters can help in determining the lateral extent of the subflow zone.

San Pedro River in Arizona (Photo by Harold Malde, Used with permission of The Nature Conservancy)

For instance, in terms of the San Pedro River Basin in Arizona, the *2014 Subflow Report* noted that willow trees and cottonwoods have a shallow root structure and therefore often rely on shallow subsurface groundwater for survival. The presence of such trees and vegetation can thus be useful in mapping the subflow zone. In its consideration of such riparian vegetation to map the subflow zone, the Arizona Department of Water Resource used aerial photography from the United States Department of Agriculture's 2010 Agricultural Imagery Program and satellite imagery from the 2013 World Imagery by ESRI Corporation. (*2014 Arizona Subflow Report*)

The portions of the *2014 Arizona Subflow Report* on trees and vegetation that rely on shallow groundwater also relates to the more general question of groundwater-dependent terrestrial ecosystems. In January 2012, The Nature Conservancy published a comprehensive report on this topic, titled *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans*. Although the question of how SGMA Groundwater Plans should take account of groundwater pumping impacts on such ecosystems is somewhat separate from this guidebook's focus on impacts on fish, it is a question that also merits close attention.

Second, Arizona's Department of Water Resources also regulates groundwater pumping in areas outside of the subflow zones if there is evidence that the groundwater wells' "cones of depression" reached the subflow zone and wells appear to be impacting surface water flows. (*2017 Arizona Cone of Depression Test Methodology*) Identification of the impacts of cones of depression on the surface zone is therefore an additional basis to regulate groundwater pumping in Arizona.



Effects of pumping from a hypothetical water-table aquifer that discharges to a stream (USGS Circular 1376)

Third, based on available data, subflow zone mapping and cones of depression determinations, the Arizona Department of Water Resources has adopted specific numerical "set-back lines" to guide groundwater pumping restrictions. For example, in the case of the San Pedro River Basin, 100-foot and 200-foot set-back lines were established, in reference to proximity to the San Pedro River. Groundwater wells located within the 100-foot set-back line were subject to more stringent pumping restrictions, while groundwater wells located between the 100-foot and 200-foot set-back lines were subject to less stringent pumping restrictions. (*2014 Arizona Subflow Report*)

Arizona's approach may be instructive for SGMA Groundwater Plans in three respects. First, Arizona's "subflow" test suggests that the presence of above-ground trees and vegetation may provide an appropriate basis for determining within a SGMA Groundwater Plan which groundwater wells are likely impacting surface flows and fisheries. Second, Arizona's "cone of depression" criteria may provide an appropriate basis for terms in a SGMA Groundwater Plan calling for relocation of groundwater wells further away from surface streams. Third, the types of set-back lines used in connection with Arizona's San Pedro River basin could be incorporated into SGMA Groundwater Plans to establish minimum thresholds, pumping restrictions and monitoring requirements for groundwater wells located different distances from surface waters.

the types of set-back lines used in connection with Arizona's San Pedro River basin could be incorporated into SGMA Groundwater Plans to establish minimum thresholds, pumping restrictions and monitoring requirements for groundwater wells located different distances from surface waters.

VII. CONCLUSION

GIVING SUBSTANCE TO THE CONNECTION THROUGH SGMA

IN HIS 2002 REPORT TO THE STATE WATER BOARD, PROFESSOR SAX OFFERED THE FOLLOWING OBSERVATION ABOUT CALIFORNIA WATER LAW:

> WATER UNDERGROUND MAY, AT ONE PLACE OR DURING ONE SEASON, SEEP INTO A RIVER THROUGH ITS BANKS (A GAINING RIVER), AND AT ANOTHER PLACE OR TIME SEEP OUT FROM THE BANKS AND INTO THE UNDERGROUND (A LOSING RIVER). IT ALL DEPENDS ON WHETHER THE SATURATED AREA OF THE GROUND IS ABOVE OR BELOW THE RIVER BANK AT THAT POINT.
>
> THE CATEGORIES THAT STATUTES AND JUDICIAL OPINIONS USE, SUCH AS "UNDERFLOW," "SUBFLOW," "SUBTERRANEAN STREAMS," AND "PERCOLATING GROUNDWATER," BEAR LITTLE IF ANY RELATIONSHIP TO THESE GEOLOGICAL REALITIES. INDEED, THESE WATER LAW TERMS ARE GEOGRAPHIC CONCEPTIONS FUNDAMENTALLY AT ODDS WITH SCIENCE'S UNDERSTANDING OF WATER'S MOVEMENTS.

SGMA provides an opportunity to bring California's regulation of water into closer alignment with the "geological realities" noted by Professor Sax, by ensuring that SGMA Groundwater Plans are implemented that effectively prevent groundwater extraction from resulting in surface water depletions and the adverse impacts on fisheries associated with reduced surface water flows. In essence, SGMA Groundwater Plans are a regulatory means to give effect to the guidance provided by the California Supreme Court more than a century ago in its 1909 decision in *Hudson v. Dailey*, to treat groundwater and surface water as a "common supply" when groundwater is tributary to surface flows.

SGMA Groundwater Plans are a regulatory means to give effect to the guidance provided by the California Supreme Court more than a century ago in its 1909 decision in Hudson v. Dailey, to treat groundwater and surface water as a "common supply" when groundwater is tributary to surface flows.

With these fisheries impacts in mind, this guidebook has identified five key take-aways that can help guide the drafting and implementation of SGMA Groundwater Plans:

1. When dealing with the impacts of groundwater pumping on surface flows that support fisheries, the necessary temporal focus is on whether groundwater extractions impacting instream flow take place at the particular times when fisheries need certain levels of instream flow, not whether the groundwater table can be maintained at an average "sustainable" or "safe" level over the long-term.

2. When it comes to the groundwater-surface water connection, the lateral location of wells can matter. This is because pumping of groundwater wells often creates a cone of depression around the wellhead, and this cone of depression can result in aquifers

that once contributed to surface waters becoming aquifers that drain surface waters and reduce instream flows.

3. Although the temperature of water in aquifers is not usually relevant to determining safe yield or preventing overdraft, such water temperatures may be relevant in terms of impacts on fisheries and surface stream habitat. This is because many fisheries (such as salmon and steelhead) require colder instream temperatures, which can be affected by the temperature of groundwater that is tributary to surface streams that support such fisheries.

4. Although additional monitoring may provide useful data to improve how SGMA Groundwater Plans can prevent adverse impacts on surface flows and fisheries from groundwater pumping, the absence of complete data is not a proper basis for SGMA Groundwater Plans to omit the inclusion of substantive provisions to avoid and prevent such adverse impacts until this monitoring takes place.

5. When it comes to groundwater that is tributary to surface waters that support fisheries, SGMA Groundwater Plans need to satisfy the requirements of California public trust law as well as SGMA's requirements.

VIII. REFERENCES

Arizona Department of Water Resources, *ADWR Demonstration Project Report: De Minimis Assessment and Cone of Depression Test Methodology* (2017).

Arizona Department of Water Resources, *Revised Subflow Delineation Report for the San Pedro River* (2014).

Bartholow, John, *Modeling Chinook Salmon with SALMOD on the Sacramento River, California, Hydroecol* (2004).

California Code of Regulations, Title 23, Sections 350 et seq. (SGMA Regulations).

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

California Department of Water Resources, *Best Management Practices for the Sustainable Management of Groundwater: BMP on Monitoring Networks and Identification of Data Gaps* (December 2016).

California Department of Water Resources, *Best Management Practices for the Sustainable Management of Groundwater: Water Budget BMP* (December 2016).

California Water Code, Section 10720 et seq. (SGMA Statute).

Foglia, Laura et al., *Coupling a Spatiotemporally Distributed Soil Water Budget with Stream Depletion Functions to Inform Stakeholder-Driven Management of Groundwater Dependent Ecosystems* (2013).

Hall, Maurice and O'Brien, Kevin, *Sustainable Groundwater Management: Can California Successfully Integrate Groundwater and Surface Water under SGMA?* (May 6, 2018 article posted on Maven's Notebook website reporting on the presentations by Maurice Hall and Kevin O'Brien at the 2018 Anne J. Schneider Memorial Lecture Series).

Herbert, Aaron, *Impacts to Anadromous Fish Through Groundwater Extraction* (2016 study for Karuk Tribe).

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

National Marine Fisheries Service, *Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionary Significant Unit of Coho Salmon* (September 30, 2014).

The Nature Conservancy, *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans* (January 2018).

Sax, Joseph, *Review of Laws Establishing the SWRCB's Permitting Authority over Appropriations of Groundwater Classified as Subterranean Streams and SWRCB's Implementation of Those Laws* (2002 Report to the California State Water Resources Control Board).

Sax, Joseph, *We Don't Do Groundwater: A Morsel of California Legal History*, 6 University of Denver Water Law Review 269 (2002).

Supreme Court of California, *Hudson v. Dailey*, 105 P. 748 (1909).

Supreme Court of California, *National Audubon Society v. Superior Court of Alpine County*, 658 P.2d 709 (1983).

Superior Court for Siskiyou County, *Environmental Law Foundation v. Siskiyou County et al.* (2014 decision in Case No. 34-2010-80000583).

Superior Court for Siskiyou County, *Scott River Adjudication – Decree 30662* (1980).

Union of Concerned Scientists, *Getting Involved in Groundwater: A Guide to California's Groundwater Sustainability Plans* (2017).

United States Geological Survey, *Circular 1376 – Streamflow Depletion by Wells: Understanding and Managing the Effects of Groundwater Pumping on Streamflow* (2012).

University of California at Davis Department of Land, Air and Water Resources, *Scott Valley Integrated Hydrologic Model: Data Collection, Analysis and Water Budget* (April 2013 Final Report to California State Water Resources Control Board and North Coast Regional Water Board).

Zeug, Steven C. et al., *Application of a Life System Simulation Model to Evaluate Impacts of Water Management and Conservation Actions on an Endangered Population of Chinook Salmon*, Spinger Science and Business Media (February 2012).

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