The Water Report™

Water Rights, Water Quality & Water Solutions in the West

In This Issue:

Upcoming Stories:

New Federal Water Policy Initiatives

Public Trust Doctrine

Water Transfers & NPDES Ruling

& More!

AQUIFER STORAGE AND RECOVERY

AN IMPORTANT TOOL FOR WESTERN STATES

PERMITTING DEVELOPMENTS & OPPORTUNITIES IN WASHINGTON

by Chris Pitre, Coho Water Resources, LLC (Seattle, WA)

INTRODUCTION

Aquifer storage and **r**ecovery (ASR) — i.e, the placing of water into an aquifer for later retrieval — is increasingly being used throughout the world as a water resource management tool. *The Water Report* has covered ASR in several previous articles, including TWR issues #8, #74, #91 and #130.

Two of the most important permitting issues in determining the feasibility of an ASR system are the recoverable quantity of water and the allowable changes in water quality resulting from artificial recharge. These factors drive the financial and water system viability of an ASR system.

In Washington State, the Department of Ecology (Ecology) is responsible for both water supply and water quality regulation and oversight. Ecology has recognized ASR as an important water supply management tool since the early 1990's. Yet, only two ASR systems in Washington — the cities' of Walla Walla and Yakima — are fully permitted and operational, with both having received their permits in the past two years. Several other permitted projects are not operating for a variety of reasons.

Over the past decade, obtaining additional water supply by applying for a new water right in Washington State has become nearly impossible. Balancing competing needs for potable and agricultural water supply, while maintaining healthy ecological conditions in the face of climate change, imposes serious constraints on water managers. Court decisions have restricted Ecology's ability to develop mitigation packages, and the general application of "precautionary principles" in the regulatory environment has created frustration and uncertainty for both water managers and regulators. The water balance neutral aspect of ASR is a universally accepted water resource management approach.

This article focuses on the issues of recoverable quantity and allowable water quality changes associated with ASR in Washington State. It addresses both the technical and permitting challenges of these issues as they have unfolded over the past 15 years. The primary difficulties in Washington's ASR permitting process relate to the calculation of recoverable quantity, and the required quality of recharge water as it relates to compliance with Washington's Antidegradation of Groundwater Rule.

These two issues will first be directly discussed including alternative points of recovery (Aquifer Storage Transfer and Recovery or ASTR) and the use of water quality data to evaluate mixing processes. Next, permitting difficulties are reviewed with suggestions for improvements. The article closes with a brief synopsis of ASR projects in Washington State.

ASR

Recharge Water

Factors Required

Recovery & Water Rights

BACKGROUND

An ASR system operates on a cycle of recharge to an aquifer during times of excess water availability, and recovery from the aquifer at a later time during a drier period. This operating cycle can be over varying time frames ranging from seasonal to annual to multi-year. In some cases, daily or weekly cycles of ASR are used. Recharge water is commonly surface water, but may be stormwater, reclaimed water, or water from another aquifer. ASR can provide the benefits of storage without the above-ground footprint and permitting challenges of conventional surface water impoundments. ASR can increase water supply availability and reliability, provide environmental benefits, and be an effective response to climate change impacts on water supply availability. The fortunate conjunction of multiple factors is required in order for ASR to be viable, including: a source of water to recharge; an appropriate aquifer for storage; adequate infrastructure (pre-recharge treatment as needed, transmission system, and recharge/recovery wells); workable economics; and an enabling permitting regimen.

ASR systems are operating in other parts of the United States (e.g., Oregon since 1997, California, the Southwest, and Florida) and around the world (e.g., England, Australia, and Israel). Washington State has an ASR permitting structure in place, and a stated policy that supports and encourages ASR (RCW 90.03.370; WAC 173-157). The State also has provided significant funding to advance projects. However, the permitting process in Washington remains difficult with ongoing regulatory uncertainty and few encouraging precedents upon which to plan projects. Consequently, planners and managers have a difficult time convincing decision makers to commit to ASR projects. The potential benefits of ASR are not being realized in Washington State despite a clear need and projects that are ready to come on line.

RECOVERABLE QUANTITY

An ASR permit is a storage water right to store water underground (RCW 90.03.370). A primary diversionary or withdrawal water right is needed to provide the water to be recharged. If the final purpose of use is different from the primary water right, a secondary use water right is needed for the ASR permit. The functions of the ASR permit are to ensure recharge activities are within the limits of the primary water right and protective of aquifer water quality.

Qr – A Water Balance Variable

"Recoverable quantity" (Qr) as used in this article is a water right parameter. It is the amount of recharged water that should be allowed to be recovered under an ASR permit. Recoverable quantity is properly based on physical water balance considerations. The objective of ASR is to place available water into storage in aquifers, for later recovery when it is otherwise not available. The amount of water that is recoverable depends on the amount of "excess" water, that is, the amount of water that remains in storage at the time of recovery above what would otherwise be in the aquifer if recharge had *not* been conducted. Recovery of the same molecule of water is not required to comply with the intent of the ASR rule. Due to the properties of aquifers — some aquifers hold water well ("tight aquifers"), while others do not ("leaky aquifers") — the recoverable quantity, as a percentage of that which was originally recharged, may differ for each project.

When a project proponent places valuable water into the ground for an ASR program, either under their primary water right or with water that they have purchased, they naturally wish to maximize the quantity of water that can be recovered. Water right holders with a keen awareness of the value of water may initially believe they have a right to recover 100% of water they place into the ground. Conversely, regulators are cautious to not allow more water to be recovered than is legally valid.

Qr – Independent of Water Quality

Artificially recharged water co-mingles with natural recharge and the question of "what water?" is being recovered is often asked. Co-mingling is relevant in the water *quality* context, and irrelevant in the water *quantity* (water right) context.

Recovery of the "same molecule" of water that was recharged is not required to comply with the intent of the water quantity aspect of the ASR rule (i.e., Qr: recoverable quantity). The recovered water, as a percentage of that which was originally recharged, or the same molecule recharged, varies depending on: the configuration of the aquifer; its connection to adjacent aquifers and boundaries; and the physical processes that govern mixing. Water that is not recovered becomes part of an augmented water balance for that aquifer system that may provide benefits to, for example, increased aquifer storage and/or streamflows. From the project proponent's perspective, unrecoverable water increases the marginal cost of an ASR project.

The Water Report
(ISSN 1946-116X)
is published monthly by
Envirotech Publications, Inc.
260 North Polk Street,
Eugene, OR 97402

Editors: David Light
David Moon

Phone: 541/ 343-8504
Cellular: 541/ 517-5608
Fax: 541/ 683-8279
email:
thewaterreport@yahoo.com
website:
www.TheWaterReport.com

Subscription Rates:
$299 per year
Multiple subscription rates available.

Postmaster: Please send address corrections to
The Water Report,
260 North Polk Street,
Eugene, OR 97402

ASR

Tight Aquifers

Tight aquifers hold water well and behave like a storage tank. Tight aquifers in which water levels have dropped significantly due to over-drafting are good candidates for ASR because there has been storage room created to accept recharged water. Examples of tight aquifers include the Columbia River Basalts of the Odessa and Walla Walla areas of Washington, and the Willamette Valley of Oregon. These basalts can be highly productive, supporting individual well yields in excess of 3,000 **g**allons **p**er **m**inute (gpm). These basalts often contain blocks that are bounded by geologic faults that create isolated compartments.

Water from these basalt compartments can be "mined," and water levels lowered by pumping, which demonstrates that they are isolated and do not receive recharge from lateral flow along strata. [Editor's Note: "mining" occurs when more water is withdrawn from an aquifer than is recharged.] Because they are isolated and hydraulically disconnected from adjacent areas, they also will contain water that is recharged without loss to leakage. For example, ASR projects in Oregon for the Tualatin Valley Water District and City of Salem are established in Columbia River Basalts and ASR injection results in stable water level rise that is the result of artificial (not natural) recharge. The Oregon Water Resources Department has permitted these projects with 90-95% recoverable quantities, even in the presence of significant mixing.

"Lost" Water Is Not Lost

Leaky Aquifers

Leaky aquifers, which are more directly connected to adjacent aquifer systems and/or streams, can also play a role in ASR projects in the Pacific Northwest. In these cases, groundwater flow is more dynamic and less like a storage tank. Recharge can increase the amount of groundwater discharge to streams and rivers. In the Walla Walla Valley a surface infiltration project is specifically designed to augment stream flows for environmental enhancement, and the leakage of recharge water back to the river is the desired objective. This project straddles the Washington-Oregon border and operates under a temporary water right from Ecology and limited licenses from the Oregon Water Resources Department. In this case, there is no active recovery or associated downstream water right credits, and so the permit does not stipulate a recoverable quantity. Recognizing the full spectrum of benefits beyond one immediate issue at hand can greatly facilitate the acquisition of funding and project support.

Seasonal Balance

The means of determining the amount of recoverable water are not prescribed in the regulations out of recognition that the recoverable amount varies in relation to the many influencing factors, and that a "one-size-fits-all" approach is not desirable. In the Pacific Northwest, ASR has been pursued by applicants with a responsibility of providing drinking water in the context of seasonal water availability, with artificial recharge occurring in the winter and recovery occurring in the summer. However, recharged water may remain in storage for more than one year before recovery. Therefore, an analysis of the seasonal water balance is needed to understand how ASR recharge interacts with the aquifer system. This is typically conducted through development of a conceptual model, a pilot test and an associated groundwater model or analytical evaluation.

Monitoring

Aquifer Dynamics

Monitoring aquifer water levels is an important element of the pilot test to understanding the system. Aquifer water levels can be a good indicator of the status of aquifer storage and recoverable quantity. However, separating water level responses due to ASR from natural recharge responses and other pumping in the aquifer can be difficult, particularly in aquifers that are pumped for irrigation. Technical work is needed to understand the aquifer dynamics before a determination of recoverable quantity can be made and even then uncertainties may remain. The determination of recoverable quantity requires that Ecology, in consultation with an applicant, evaluate the supporting technical work.

The ABC's of ASR

AGR – Antidegradation of Groundwater Rule: Washington Administrative Code (WAC) 173-200

AR – Artificial Recharge: Includes all forms of artificial recharge to groundwater.

ASR – Aquifer Storage and Recovery: In Washington, recharge through deeper wells and later active recovery through wells.

ASTR – Aquifer Storage Transfer and Recovery. Coined by Dr. Peter Dillon of Australia for recharging stormwater at one location with recovery at a different point.

IPR – Indirect Potable Reuse: Used by California in recharging reclaimed water to groundwater at one point and recovering it a different point. Similar to ASTR.

MAR – Managed Aquifer Recharge: The same as AR.

MUS – Managed Underground Storage: Used by the National Academy of Sciences. Includes ASR and SAR.

SAR – Shallow Aquifer Recharge: In Washington, used by Ecology for recharge from ground surface or subsurface to the vadose zone intended to augment streamflows, and not actively recovered through wells. Used in California and elsewhere for actively recovered water.

ASR

Additional Benefits

For example, the City of Yakima's primary surface water source is reliable in most years, but is curtailed during drought conditions every few years. The City has 60% redundancy in groundwater sources and can only last a few days during peak demand periods operating on groundwater wells. The City explored the use of ASR to permit additional groundwater sources. The intent is to recharge water at several points to the aquifer for recovery when needed at a new well. Computer simulation models of stored groundwater indicate approximately 90% of the recharged water is recoverable within the first year after recharge. The target recharge aquifer is slightly leaky and is predicted to lose water over time, such that approximately 60% of the recharged water remains available for recovery after 10 years (assuming no intervening recovery). The unrecovered water will provide benefits by restoring depleted aquifer storage and ultimately sustain cool baseflows to the Yakima River that is important to improving habitat conditions for salmonids listed for protection under the Endangered Species Act.

Alternative Points of Recovery

California has a specific application of ASR for reclaimed water — referred to as **i**ndirect **p**otable **r**euse (IPR) — in which treated water can be directly injected into a groundwater aquifer. The groundwater can later be pumped out of the aquifer at a different well and either treated further or distributed directly into the drinking water delivery system. One of the first applications of IPR through groundwater replenishment with advanced treated water in California was the Orange County Water District's Water Factory 21, which began providing reverse osmosis treatment of recycled water to prevent seawater intrusion in 1976. Orange County Water District later implemented their Groundwater Replenishment System, which has provided full advanced treated purified water for Orange County since 2008. The Groundwater Replenishment System, which is jointly-funded by the Orange County Water District and the Orange County Sanitation District, has a 70 million gallon per day capacity and produces enough water for nearly 600,000 people. *See* Markus, *TWR* #59. The Los Angeles Department of Water and Power, in collaboration with the City's Bureau of Sanitation, is proceeding with its proposed Los Angeles Groundwater Replenishment Project to increase groundwater recharge using purified, advanced treated recycled water to supplement drinking supplies. The purified water replenishes up to 30,000 acre-feet per year at existing spreading grounds and new injection wells.

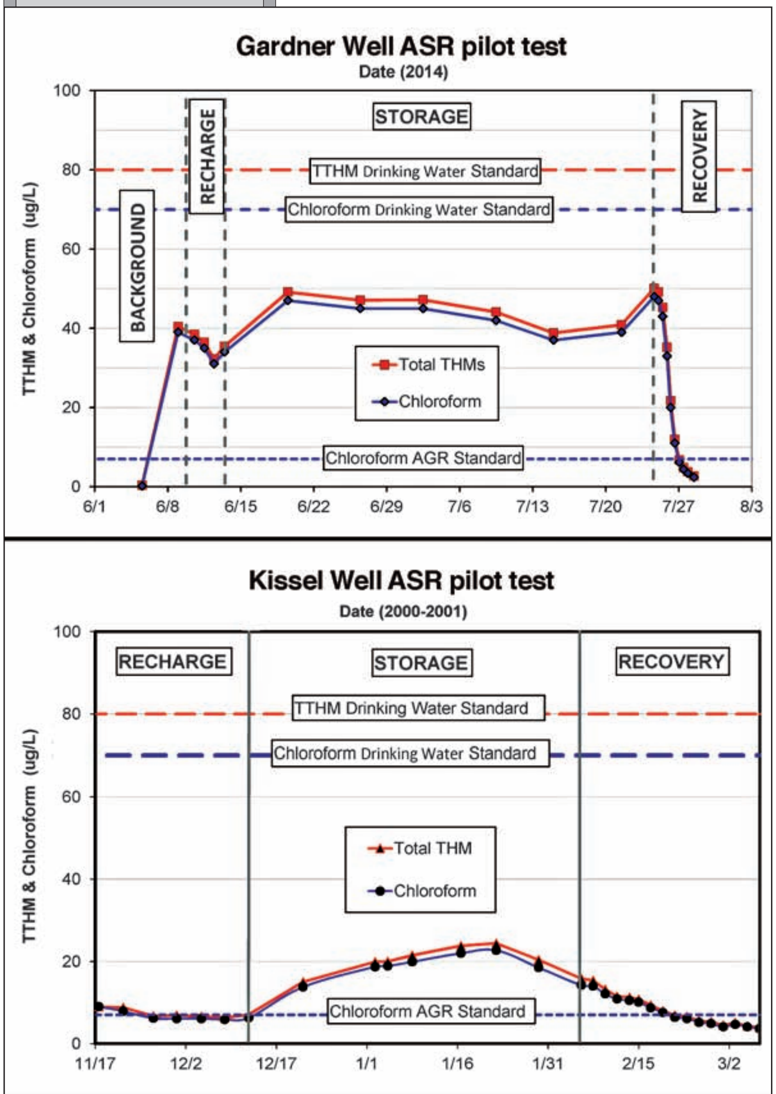

Figure 1

THM and chloroform formation as measured during City of Yakima ASR cycles. The dynamics of chlorination DBP formation during ASR cycles are well-known from drinking water disinfection science. The rate of TTHM/chloroform formation and maximum resulting concentrations are determined by temperature, the amount and type of organic carbon in the source recharge water and aquifer, contact time, and the residual chlorine concentration. Chloroform concentrations can also increase from the decomposition of HAAs to chloroform. These process can occur in the distribution system before recharge or in the ground after recharge.

Similar to California's IPR, Australia recognizes a mode of ASR called Aquifer Storage Transfer and Recovery (ASTR). The term ASTR involves recharge at one location and recovery (transfer) at another location. The term was originally applied to the recharge of stormwater treated by being passed through a reed bed or wetland, into an aquifer. Here, the recovery of the same molecule of recharged water is not feasible because the quality of the recharged water doesn't immediately match its intended end use as drinking water or where negative public perception of recovering and using the same water is an issue. Recovery at a point different than the recharge point appropriately separates the water quality and water quantity components of water resource management and managed aquifer recharge in the context of western water law, water balance, and ASR permitting.

Where ASR is permitted based on water balance considerations, recovery of the "same molecule" of recharged water is not relevant, as long as recovery is of the surplus balance created by the recharged water. This is exemplified in ASTR or IPR programs which may or may not recover the same molecule of recharged water. The application of ASTR is particularly important to permitting additional points of withdrawal and/or increased instantaneous withdrawal rates.

ASR

Limitations & Reliability

Recharge at wells is commonly limited by available system/recharge pressure, gravity, and periods of recharge water availability. The withdrawal capacity of a well on an annual basis can easily exceed the practical annual recharge capacity. Therefore, for systems with seasonal demand (e.g., for irrigation or municipal demand) recharge at multiple wells may be needed to sustain the capacity available or peak demand-driven supply needed from one new well. Additionally, in the operation of a wellfield, specific wells used at various times for recharge may be temporarily out of commission for maintenance or system upgrades. Maintaining access to recharged water for recovery through other than recharge wells is reasonable to maintain supply reliability.

GROUNDWATER QUALITY REGULATION

Contamination Issues

Washington State has an Antidegradation of Groundwater Rule (AGR) to protect the groundwater from contamination. The rule establishes maximum concentrations for a broad suite of constituents that may be introduced to groundwater. Background water quality is the reference standard for all constituents for which criteria have not been established. The AGR states that the purpose of these criteria is "for the protection of a variety of beneficial uses of Washington's groundwater" and that, "Drinking water is the beneficial use generally requiring the highest quality of groundwater." (WAC 173-200-040(1)(a)). The AGR sets a high bar for ASR projects in Washington State that is often not met *prima facie* (at first sight) due to the common presence of some organic compounds in chlorinated drinking water.

Disinfection By-Products

Chlorination Effects

Municipal ASR programs typically recharge water from their drinking water system, which meets federal Safe Drinking Water Act (SDWA) standards. Chlorination is the most common disinfection process to produce potable water for injection. Recharge source water is commonly treated to drinking water quality standards and delivered through drinking water distribution systems to recharge wells. A *minimum* residual chlorine disinfection level of 0.2 mg/L is required by the SDWA at the drinking water treatment plant, and a measurable residual is required throughout the distribution system. An advantage of using chlorine disinfection for ASR projects is that this residual disinfection helps control biofouling (accumulation of organisms on wetted surfaces) in recharge wells. A disadvantage is the creation of chlorination **d**isinfection **b**i-**p**roducts (DBPs) in concentrations above AGR standards (Table 1).

Regulated By-Products

Regulated DBPs include **t**ri**h**alo**m**ethanes (THMs) and **h**alo**a**cetic **a**cids (HAAs). HAAs typically degrade to below detection limits within a few weeks after recharge while in groundwater storage. THMs are persistent in groundwater. The concentrations of THMs can initially increase as a result of continued reaction between residual chlorine and organic matter, as well as decomposition of HAAs (specifically trichloroacetic acid), and thereafter decrease by dilution (Figure 1).

Table 1: Chlorination Disinfection Byproducts and Regulatory Criteria in Washington State
All concentrations are in micrograms per liter (µg/L).

Parameter	Drinking Water Standard (a)	Range of Distribution System Concentrations Representative of Recharge Water (b)	Groundwater Criteria (c)
TTHMs (d)	80 (total)	0-79 (average = 21)	Not applicable
Bromodichloromethane		0-4 (average = 1)	0.3
Chloroform		0-77 (average = 20)	7
Dibromochloromethane		Not reported	0.5
HAA5 (e)	60 (Total)	0-42 (average = 6)	Not applicable
Dibromoacetic Acid		Not reported	0 (f)
Dichloroacetic Acid			
Monobromoacetic Acid			
Monochloroacetic Acid			
Trichloroacetic Acid			

(a) WAC 246-290
(b) Representative of the cities of Kennewick, Walla Walla, White Salmon and Yakima reported in recent water system consumer confidence reports.
(c) WAC 173-200
(d) TTHM = Total trihalomethanes, including chloroform, bromodichloromethane and dibromochloromethane
(e) HAA(5) = the five haloacetic acids regulated for drinking water
(f) No numeric criteria are established for these parameters. Therefore the compliance criteria is background, which is zero, without a determination of OCPI.

ASR

"OCPI"

AKART Analysis

Natural Attenuation

OCPI & Water Rights

OCPI & Water Quality

Use of Drinking Water Standards

Federal Standards

Washington's Anti-Degradation Rule (AGR)

In Washington, recharge water concentrations of constituents that do not have numeric standards under AGR may exceed background groundwater concentrations if Ecology determines there is an **o**verriding **c**onsideration of **p**ublic **i**nterest that will be served ("OCPI"; WAC 173-200-030(2)(c)). For constituents for which numeric standards have been established, Ecology may issue a five-year variance to the AGR on the basis of OCPI. A reconsideration of the OCPI decision is required every five years. Variances can be obtained by conducting an All Known Available and Reasonable Technology (AKART) analysis, and presenting arguments supporting a determination of OCPI.

Our observation on AKART as applied to ASR projects is that the analyses are remarkably similar in their methods, findings, and recommendations for municipal ASR programs. DBPs are an issue with all water systems that use chlorination disinfection and the minimization of DBP formation at the treatment plant is an increasing priority. Technologies typically considered in the AKART analysis to reduce DBP formation include **r**everse **o**smosis (RO), **g**ranular **a**ctivated **c**arbon (GAC), and natural attenuation. However, RO and GAC are expensive and both technologies develop waste streams of their own. Treatment after DBPs are formed can involve multiple technologies, many of them associated with filtration. Not surprisingly, the typical recommendation of AKART analyses for ASR projects is natural attenuation, since movement of recharge water through an aquifer can be an effective form of filtration.

Potential conflict between ASR and anti-degradation rules was recognized when the ASR rule was under development in the mid-1990's. The rule directs Ecology to "give strong consideration to the overriding public interest in its evaluation of compliance with groundwater quality protection standards." (WAC 173-157-200(2)). However, two recent court decisions have given regulators pause in exercising that discretion.

This concept of **o**verriding **c**onsideration of **p**ublic **i**nterest (OCPI), is also present in water rights regulations. In October 2013, the Washington State Supreme Court (Court) ruled against Ecology where it had used an OCPI determination in 2006 to revise a 2001 instream flow rule (WAC 173-504) (*see* Pors, *TWR* #124 — regarding decision known as the "*Swinomish*" case). The Court held that Ecology exceeded its authority to use the "overriding considerations of public interest" exception to grant reservations for future water rights in the Skagit River basin where instream flow rights would be impacted. The ruling also found that the use of OCPI that impairs an existing instream flow was in conflict with the water rights doctrine of prior appropriation. Finally, the Court rejected the simple economic balancing test used by Ecology and found that the OCPI exception "is a *narrow* exception, not a device for wide-ranging reweighing or reallocation of water through water reservations for numerous future beneficial uses." *Swinomish Indian Tribal Community v. Ecology*, 178 Wn2d 571, 585 (2013) (emphasis in decision). The courts also ruled against the use of OCPI in the "*Foster*" case, *Foster v. Ecology, et al.*, Case No. 90386-7 (Oct. 8, 2015), in which *de minimus* impacts on instream flows from a new water right for the City of Yelm were involved. The Court in *Foster* definitively ruled that instream flows (minimum flows) are fully protected water rights, and senior existing water rights cannot be impaired — to even a *de minimus* degree — by a new permit, despite mitigation plans that may provide ecological benefits *See* Moon, *TWR* #141.

The application of OCPI to an instream flow rule is different than the application of OCPI under the AGR. In *Swinomish* and *Foster*, the application of OCPI was evaluated relative to the western water law doctrine of prior appropriation, and resulted in permanent water right allocations. An application of OCPI under the AGR relates to water quality regulations and such decisions must be reviewed every five years.

A legislative bill was introduced in 2015 by State Senators Jim Honeyford (Yakima Valley) and Doug Eriksen (Nooksack) that included a provision to allow recharge water to contain constituents of up to 50% of drinking water quality criteria, as allowed in Oregon. The bill was introduced late in the session and failed under opposition by some environmental groups and Indian Tribes.

Recharge Water Quality Regulation in Other States

Washington State is unique from many other jurisdictions in having an Antidegradation of Groundwater Rule. While the rule was enacted with the best of intentions when it was passed in 1990, it creates a compliance challenge for ASR projects in Washington State many other jurisdictions do not have to consider. These other jurisdictions typically consider drinking water standards as the compliance standard when establishing compliance criteria for ASR projects. AGR criteria for DBPs are typically an order of magnitude stricter than drinking water standards (Table 1, Figure 1).

The federal law allows the recharge of water if that recharge does not cause endangerment (i.e., an exceedance) of primary federal drinking water standards (Section (§) 1421(d)(2) of the SDWA and 40 CFR Part 142). Federal regulations require the registration of injection wells under the Underground Injection Code. While there has been no endangerment of drinking water supplies in recharged water, there have been some instances of endangerment issues after recharge and during storage such as dissolution of metals (including arsenic) reported on the East Coast and in the Midwest, and potential issues regarding radionuclides and disinfection by-products.

ASR

Oregon Standards

Oregon allows ASR projects to recharge water containing up to 50% of the primary **m**aximum **c**ontaminant **l**evels (MCLs) of drinking water parameters, which are of human health concern, and up to 100% of the secondary MCLs of parameters, which are of aesthetic and potentially operational concern. Recharge must stop immediately upon the detection of concentrations above specified levels (e.g., 50% of primary MCL) until concentrations decline below allowed levels. Recharge of water with concentrations above 50% of MCLs is allowed under certain conditions. Oregon has approximately 25 permitted and operational ASR projects.

RESOLVING PERMITTING DIFFICULTIES

Permitting Uncertainty

Increasing pressure on water supplies, combined with a general application of "precautionary principles" in the regulatory environment has created frustration and uncertainty for both water managers and regulators. The concept of ASR has remained valid since its endorsement by Ecology in the 1990s. If anything, the implementation of this water resource management tool has become ever more indispensable in the face of climate change. "Water balance neutral" is a tenet of water supply that most people can agree with and that the courts have left for Ecology's use in making water right decisions. With these points in mind, we should be looking for means of simplifying and enabling the permitting and implementation of ASR programs in Washington State, both for project proponents and regulators.

Recoverable Quantity

Recoverable Quantity ≠ Recovery Efficiency

Recovery Efficiency

"Recoverable quantity" and "recovery efficiency" sound similar but are very different concepts and confusion about their meaning and appropriate use can arise. Recovery efficiency (as defined by Pyne (1994)) is the amount of high quality water recharged into an aquifer of poor water quality (e.g., a saline or non-potable aquifer) that can be recovered and still be of acceptable quality. This is generally shown as a percentage of the recharged volume. Recovery efficiency can change with subsequent recharge cycles. The aquifer can be conditioned, or a buffer zone established. Recharge cycles conducted within a "bubble" thus created can achieve 100% recovery efficiency. This definition was primarily developed in the context of recharge into deep brackish non-potable Floridian aquifers and is defined by water quality criteria. Thus, recovery efficiency, as defined by Pyne, has no relation to water quantity. Likewise, it bears no relation to: recoverable quantity as defined earlier in this article in the context of western water law; associated ASR regulations; or, the amount of water that should be allowed to be recovered under an ASR permit.

Recoverable Quantity is Fungible

Fungible Asset

Too much focus has been placed in past technical analyses of ASR projects on the water quality variables as an indicator of recoverable quantity. Technical consultants have conducted mass balance analysis as "recovery efficiency" or present modeled recharged ASR groundwater plumes similar to wellhead protection exercises that show molecules of water not being recovered and "getting away."

Similarly, regulators have applied these water quality exercises in some cases to determinations of recoverable quantity in permits. Water, in the context of a water right / water balance / western water law variable under the ASR rule WAC 173-157, is fungible (i.e., able to replace or be replaced by another identical item; money is fungible — any dollar bill withdrawn from a bank can represent any deposit, not just the one transaction through which it was deposited — just as any molecule of recovered water should represent recharged water that remains in the aquifer bank from ASR recharge and has not leaked away).

Models and Modeling

The best means of estimating recoverable quantity is with a well-developed conceptual model, a quantitative groundwater flow simulation model, and water level monitoring.

Alternative Recovery Points

Recovery Points & Capacity

If there is a valid water right to recharge an aquifer, one should generally be able to recover it anywhere within the same body of groundwater, subject to an assessment of impairment. This is consistent with western water law.

In the example cited above for the City of Yakima, the City's need for additional groundwater withdrawal capacity can best be realized with permitting of a new water well within an ASR/ASTR program. Existing wells are already permitted to their installed capacity. Therefore, recharging through existing wells provides no additional permitted capacity if recovery is limited to those wells. Because the operational withdrawal capacity of a well exceeds its recharge capacity, limiting recovery of a new well to water that is recharged through it limits the use of that well to possibly only 30-50% of its actual capacity. Otherwise, construction of additional dual purpose recharge/recovery wells adds considerable expense to a program when each well costs on the order of several million dollars, or seriously constrains needed redundancy and backup capacity. Allowing recharge though multiple wells when they are not being used for production in the winter and recovery through a new well under ASTR optimizes the use of infrastructure and lowers costs.

Infrastructure Costs

ASR

Management Options

Quality Evaluation

Reconciling Rules

Analysis Efficiencies

Historical Records

Up-Front Monitoring

Adaptation Petition

Adaptive Management

Ecology has incorporated adaptive management options in its most recent permits in which project proponents can petition for amendments of the permit parameters with supportive information (e.g., reduction of monitoring burden or increase of recoverable quantity). Such options allow the regulator to issue a permit with conservative parameters that can be eased over time with confidence.

Water Quality and the Anti-Degradation of Groundwater Rule

PROCESS IMPROVEMENT CONSIDERATIONS

Monitoring of water quality during recharge/recovery cycles of recharged water in the evaluation of ASR projects is necessary to:

- Foresee potential operational problems (e.g., biofouling).
- Ensure water quality is appropriate for its intended end use; (e.g., compliance with the SDWA).
- Comply with regulatory requirements.

The majority of the issues are characterized through the early ASR development phases of AKART analysis and pilot testing. The following options are recognized for possible improvements when dealing with the AGR in ASR projects:

Statutory Fix

A statutory fix processed through the State legislature to reconcile the AGR and ASR rules could be modeled on Oregon's regulations. It would be appropriate for Ecology to coordinate this effort because it manages both the ASR and AGR rules. Legislation would have to be drafted and facilitation and outreach to stakeholder groups such as other State departments, tribal and environmental interests would be required. However, the record of passing any legislation in the current partisan environment is not encouraging. Therefore, the other options should be concurrently developed.

Programmatic AKART

Ecology has invested significant resources — both staff and financial — for the support and development of ASR programs in Washington State. Many components of AKART analyses are repetitive. Additionally, the level of rigor required by Ecology in the execution of the analysis varies. Significant efficiencies may be realized by conducting a programmatic AKART analysis that would be applicable to projects that fall within certain parameter ranges (e.g., all regulated constituents are less than 50% of federal Safe Drinking Water Act (SDWA) drinking water levels).

AKART Analysis Template

The requirements for AKART analysis involve examining the historical water quality record of a drinking water system considering ASR, typically that submitted to the Washington State Department of Health (DOH) as part of the SDWA monitoring requirements, such as required by Class A public drinking water systems. The data record can be significant, going back 20 years or so, involving a broad suite of analytes including benign general chemistry and usually an extensive record of DBPs. The more recent record may be readily available in electronic format by downloading it from DOH or in project proponent files. Some of the record may be more difficult to obtain. Also, it is common that treatment systems have been modified over time and the older record does not reflect current conditions. It is recommended that the examination of the historical record be limited to a recent period, for example the last five years, or since a treatment system was last modified — whichever is less.

Monitoring

Careful and deliberate analysis and monitoring during feasibility assessment and pilot testing are advisable. Water quality in every ASR project in the Pacific Northwest has been excellent and has always met drinking water standards. This experience should be considered and less rigorous monitoring may be reasonable during the operational phase where new projects are developed in similar settings (e.g., Puget Sound Lowland sand and gravel aquifers, and Columbia River Basalt aquifers). Where new settings are being tested, more rigorous monitoring should be considered in previously untested aquifer systems (e.g., the western slope of the Cascades where naturally high arsenic concentrations exist).

Adaptive Management

Significant water quality monitoring requirements are included in the permits including whole water chemistry and DBPs. These requirements are generally greater than necessary, and are likely included out of an abundance of caution. The project proponents may petition Ecology for relaxed schedule after an initial period of operations (e.g., two years). This is reasonable if no concerns are identified; if the project proponents control DBPs to the best of their ability; and if the data are sufficient to impart confidence to the regulators that future conditions are predictable.

ASR

Clear Communication

Close and Collaborative Coordination Between Applicant and Ecology

The applicant and Ecology usually have common interests in permitting an ASR project: responsible resource management; including protection of groundwater quality; the provision of water for public and economic development; and controlling costs. The permitting process could be much improved by closer and clearer communication between the applicant and Ecology on the specifics of each step of the process, starting with the conceptual model, groundwater flow simulation modeling, pilot testing, and AKART analysis. Developing a general programmatic framework early in the process, as was done for the Yakima ASR program, can lay down principles and anticipated outcomes to more smoothly move understanding and the project permitting process forward.

Costs

Developing an ASR project can be a long-term project involving significant costs. This leaves ASR to be primarily developed by public agencies such as cities and water districts. Therefore it is necessary within the structure of an applicant's organization to have the foresight and leadership to champion a project. It is in the best interests of all involved to minimize hurdles to developing ASR projects, including financial and management burdens.

Project Encouragement

Ecology must take a conservative approach in making water right decisions, particularly in light of recent court decisions. It is easier to start with stricter provisions and then ease up, rather than over-promise or raise an applicant's hopes and then reverse decisions. However, in order to allow good projects to move forward, Ecology must not be so overly precautionary so as to discourage project development. Monitoring and adaptive management can provide a comfort zone to regulators in making decisions.

STATUS OF ASR PROJECTS IN WASHINGTON STATE

Two ASRs Operational

Ecology's ASR webpage shows multiple ASR projects, though only two are operational (Figure 2). The City of Yakima received an ASR permit in 2016 for the storage of 14,400 acre-feet. The City of Walla Walla has been operational since 1999 and received its permit in 2015 to store a maximum of 11,750 acre-feet of water. A brief summary on each project is provided below.

Yakima

Surface Water Backup

The City of Yakima ASR project conducted two ASR pilot tests (2001 and 2014) that proved the feasibility of ASR. The Ellensburg Formation sandstone aquifer system underlying the Yakima River and overlying the Columbia River Basalts is slightly leaky. The recoverable quantity is estimated with a computer groundwater storage and flow simulation model to be over 90% after one year of recharge and less in subsequent years. The City needs ASR to permit additional groundwater supply as a backup for when their surface water source is curtailed for whatever reason (e.g., drought, water rights curtailment, incapacitation of their surface water treatment by surface water conditions, etc.). The City's ASR system is operational.

Conjunctive Management

Ecology's Central Regional Office issued a permit in 2016 allowing 85% recovery in the same year as recharge, a decrease of 5% in the first year following recharge, and an annual decrease of 10% in subsequent years. This is reasonably close to predicted technical analysis, and a petition may be made to amend the quantities and expand the program after two years of operation.

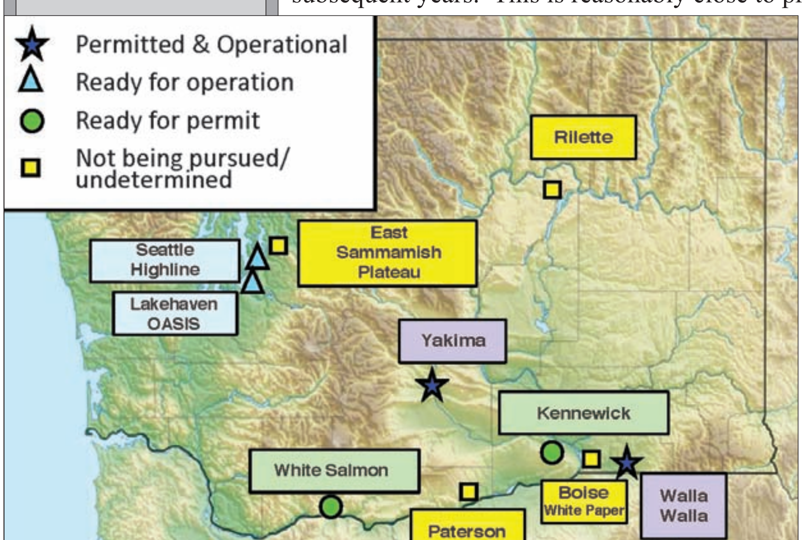

Figure 2: Washington ASR Project Locations
Adapted from Ecology's website: www.ecy.wa.gov/programs/wr/asr/asr-home.html
02/02/2017 (Rilette and Paterson added)

One reason that the permit was issued within two years of a concerted effort to process the application was because the Yakima Basin Integrated Plan recognized the multiple benefits the project would impart, not only for improving the reliability of the City's water supply, but also the leakage of recharged water back to creeks and the Yakima River thereby creating thermal refugia (i.e., areas of cooler to support fish runs). With a fully permitted ASR system, the City can now conjunctively manage surface water supplies, including making water available to others in the Yakima Basin in drought periods, which have been occurring more frequently and are predicted to increase in frequency due to climate change.

Walla Walla

The City of Walla Walla's ASR system is fully constructed and has been operating since 1999 with plans for expansion. The City's principal drinking water supply source is surface water from a protected watershed

ASR

Adaptable Permit

Regional Supply

straddling the Washington/Oregon border. The principal motivation for the City to implement ASR was the declining water table and to ensure adequate groundwater supply from the Columbia River Basalt system if their surface water treatment plant were incapacitated by a forest fire in the watershed — which almost occurred in the Blue Creek Fire in the 2015 forest fire season. The availability of groundwater supply for the City is dependent on both the actual supply in the aquifer (susceptible to depletion) and permitting issues. ASR operations are restoring the aquifer storage.

The City worked through details of a permit with Ecology since 2009 and received a permit in June 2015, issued by Ecology's Eastern Regional Office. The Walla Walla permit, allows a maximum recovery of 60% in the first year of storage, and an annual reduction of 10% of unrecovered water in subsequent years. The permit cites a "water quality mass balance" as the basis for the 60% recoverable quantity in the first year. This is despite numeric modeling that a water balance supported upwards of 90% recoverable quantity. The geological setting (block-faulted basalts) is similar to projects in Oregon in which initial recoverable quantities of 90% are routinely granted and amendments of up to 95% recoverable quantity have been allowed. The permit allows the City of Walla Walla to request an amendment to these volumes when sufficient data has been collected and to expand the program.

Lakehaven OASIS

Lakehaven's OASIS ASR project was among the first in the state to receive an ASR permit, issued by Ecology's Northwest Regional Office in 2006, upon passage of the ASR rule in 2000. The project is located immediately northeast of Tacoma, hosted in a well-bounded aquifer within the glacial sand and gravel aquifer system. The planned source of recharge water is from the Green River flowing off of the Cascade Mountains through a regional water supply pipeline under construction by Tacoma. The project is constructed and has been thoroughly tested. The permit allows for 80% recoverable quantity, with allowance for up to 100% based on monitoring data.

Operations will start once a regional water supply pipeline begins delivering surface water for recharge.

Table 2: Status of Washington State ASR Projects

Project	Nominal Storage Volume (acre feet)	Operational Status	Permit Status
Yakima	50,000	Operational	Permitted 2016.
Walla Walla	11,750	Operational since 1999	Permit received in 2015.
Oasis (Lakehaven)	3,977 (Phase 1; 29,000 at full buildout)	Partly constructed – awaiting construction of regional pipeline from surface water source.	Permitted since 2000.
Boise White Paper	2,577	Tested and not considered feasible.	Not being pursued.
Seattle Highline Wellfield	1,500	On standby until needed during drought.	Able to operate under an indefinite temporary permit pending processing of application.
Kennewick	714	Constructed, awaiting permit.	Application pending since 2003. On hold until better clarity on Qr is obtained.
White Salmon	600	Constructed, awaiting permit.	Application pending since 2013.
East Sammamish Plateau	200	Operations suspended due to economic feasibility and permitting uncertainty.	Permits issued for testing purposes only. Application not being pursued due to unlikelihood of obtaining an acceptable Qr.

ASR

Cooling Purposes

Supply Reliability

Leaky Aquifer

Winter Surface Recharge

Multiple Uses

Proof of Concept

River to Plateau

Supply Tool

Boise White Paper

The Boise White Paper ASR project in Eastern Washington near Walla Walla was to use existing Columbia River surface water rights for a finished paper mill. With a productive candidate ASR basalt aquifer on site, the ASR concept was to recharge cool winter river water to recover during the hot summer for cooling purposes and possibly industrial processing. Washington State provided $2.3 million in grants in support of the project to build a water treatment plant to reduce suspended solids to avoid well clogging, and the installation of a recharge well and an observation well. However, the recovered water was too warm for use in cooling, and contained unacceptable concentrations of silica from dissolution of volcanic glass in the basalt during storage for use in industrial processes. The project is no longer being pursued.

Seattle Highline Wellfield

The City of Seattle's Highline Wellfield ASR project (now called the Boulevard Park and Riverside Heights Wellfields), was stimulated by the 1992-1994 drought. The purpose of the project was to diversify supply and increase reliability. It is located in the glacial sand and gravel upland area between Seattle and Tacoma and uses surface water from the Chester Morse Reservoir on the Cedar River. It was an early project in the ASR history of Washington and was pilot-tested through the 1990s with funding support from the US Bureau of Reclamation. However, the aquifer is only able to hold water for a few months. Therefore, ASR operations are only started if an imminent need is recognized. The City has an indefinite temporary permit to operate while the application is pending, and maintains the option to reactivate the system in critical years — which almost happened in 2015.

Kennewick

The cities of Kennewick, Richland, West Richland, and Pasco received a surface water right in 2000 to divert water in the winter from the Columbia River. ASR was conceived in order to store water diverted in the winter for withdrawal when there is a demand in the summer. The basalt aquifer system is similar to Walla Walla's in that it is compartmentalized into fault-bounded blocks that hold water very well and should yield a high value of recoverable quantity. Ecology provided grant funding ($2.5 million) to develop the project with which a recharge/recovery well and monitoring well were installed and tested. Although the City's ASR system is constructed and ready to operate, the City is waiting for more clarity on how recoverable quantity will be defined before signing onto a permit.

White Salmon

The White Salmon ASR project is hosted in a basalt aquifer system and is intended to restore depleted aquifer water levels, increase community water supply, and augment streamflows. The system is constructed to recharge water under gravity and is awaiting a permit. The recharge capacity of the system could be increased in the future with modifications to the system to recharge under pressure.

East Sammamish Plateau

The East Sammamish Plateau ASR project received two permits to conduct testing during 2005-2015 in a sand and gravel aquifer system. The permits allowed for recharge of water pulled from one aquifer and recharged into another aquifer. The permits were intended to provide for proof of concept testing and did not provide for additional water supply. If supported, full scale ASR would occur using a blend of groundwater and piped in regional surface water source (e.g., the Cascade Water Alliance). The ten-year testing period was suspended in 2012 based on the inability to obtain a permitted recoverable quantity that would make the project feasible.

Paterson & Rilette Projects

Two ASR projects added to those in Figure 2 from Ecology include evaluation of pumping water from the Columbia River to recharge sites on the basalt plateau approximately 1,000 to 1,500 above the river in the Paterson and Rilette areas. The intent of the Paterson project was to restore the depleted basalt aquifer to maintain and expand agricultural irrigation activities on Washington Department of Natural Resources lands that are leased out. The project was deemed economically infeasible and has been put on hold.

The objective of the Rilette evaluation is to determine whether ASR is hydrogeologically feasible, results of which are anticipated to be available soon. If found to be hydrogeologically feasible, potential markets for the stored water and economic feasibility will be evaluated.

CONCLUSION

ASR is a water resource management tool that can increase water supply and provide environmental benefits without the impact and cost of conventional above ground storage reservoirs. Environmental benefits can be realized by leakage of cold recharged water from storage to streams that improve aquatic habitat conditions. It can also be used to forego summer diversions during times of greatest water need by all (e.g., farms and fish) and leave that water in the stream. Hopefully, the experience gained in Washington State over the past 20 years and the two significant ASR permits issued in the past two years will pave the way to a smoother permitting process and more ASR projects.

ASR

Appropriate Aquifer

Money in the Bank

Programmatic Solutions

Instream Benefits

ASR, however, is not a panacea and requires a minimum set of conditions to be feasible, such as an appropriate aquifer. The spectrum of candidate ASR projects currently being considered range from the speculative to the apparently feasible. Project proponents and grant administrators should conduct "fatal flaw" analyses before committing significant funds.

Determining recoverable quantity for permit purposes may be simply achieved with water level monitoring in selected cases, such as fault-bounded blocks in basalt aquifers. Computer simulation modeling of groundwater storage is a valid tool that is applicable to most projects and should be given due consideration.

Water placed in aquifer storage is similar to money placed in the bank — it is a fungible asset, for which the same molecule (or dollar) does not have to be recovered. Hence, ASTR — where water is recharged at one point and recovered at another — should be allowed within the same body of groundwater, consistent with RCW 90.44.100(3)(a) and as allowed in the city of Yakima permit issued last year.

Regarding consistency with the antidegradation rule, Ecology should press forward to facilitate the implementation of ASR projects by either introducing legislation, exercising its discretion to make OCPI determinations, or providing other programmatic solutions. It is suggested that a statutory amendment be modeled after Oregon's regulations that allow water quality that is better than 50% of the Safe Drinking Water Act standards to be recharged. Establishing a programmatic AKART analysis for ASR programs across the state would be more efficient than requiring the same work to be conducted repeatedly for each project. A simple checklist could then be prepared for each project that references the programmatic AKART.

Ecology staff are already juggling an overly heavy workload and require more support. While some of the suggestions may require some upfront work, it is expected to reduce effort in the long run while encouraging more ASR projects to come on line.

The broader water resources community, meanwhile, is anticipated to be supportive of ASR projects. ASR is a good water resource management tool that can provide environmental benefits. Opposition to ASR projects sometimes comes late in the game, without a full understanding of the benefits. It is incumbent upon project proponents to engage with stakeholders early on to solicit their support.

Once the path to permitting ASR projects is made clearer, we can expect additional ASR projects to come on line in short order, and additional ones identified for development. This will result in less cost, greater water supply availability, and instream flow benefits as well.

Acknowledgements

The author would like to acknowledge Bob Anderson, Principal Hydrogeologist from Geosyntec Consultants for his thoughtful review; Dave Brown from the City of Yakima for his leadership and support of the Yakima ASR project; and Derek Sandison and Tom Tebb as former and current managers, respectively, of the Office of Columbia River of Ecology for their strong support of Managed Aquifer Recharge (MAR) of all stripes. The Office of Columbia River and the US Bureau of Reclamation have also provided significant support of MAR as part of the Yakima Basin Integrated Plan.

For Additional Information:
Chris Pitre, Coho Water Resources, 206/ 406-9596 or chris@cohowr.com

Chris Pitre is a principal owner of Coho Water Resources based in Seattle. Washington (www.cohowr.com). He is a licensed geologist and hydrogeologist, and a certified water rights examiner (Washington State) with degrees in geology, chemistry (Carleton University) and hydrogeology (University of Waterloo). He has practiced hydrogeology and integrated water resources management in the Pacific Northwest since 1992, participated in the Washington ASR rulemaking in 2001, and is currently participating in Washington State's reclaimed water rulemaking effort. Chris was the project manager for the City of Yakima ASR project since its inception in 1999. He also managed portions of the City of Kennewick ASR project, provided ASR permitting support to the City of Walla Walla and conducted numerous ASR feasibility assessments. He was an invited presenter to the National Academy of Sciences on water quality issues of ASR in 2008, and spent 2011-2012 in Australia implementing ASR projects in a nascent regulatory environment. His practice areas include: water rights; groundwater supply wells; watershed planning; wastewater management; and reclaimed water. He frequently lectures at the University of Washington and Central Washington University, and chairs, moderates and presents at conferences for both lay and technical audiences.