JOURNAL OF THE

NEW HAMPSHIRE WATER WORKS ASSOCIATION

Site of Manchester Water Works' new 3MG tank in Londonderry.

VOLUME II 2018


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Front Cover Photo: One of the stops on the 2018 Construction Field Day was at the site of Manchester Water Works' new 3MG Tank in Londonderry, NH

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Andover	Andover Water Works	Todd Cartier
Antrim	Antrim Water Works	Matthew Miller
Ashland	Ashland Water Works	Russell Cross
Bartlett	Bartlett Village Precinct	Scott Hayes
Bartlett	Lower Bartlett Precinct	Gary Chandler
Bath	Bath Village Water Works	Timothy Bemis
Belmont	Belmont Water Works	Craig Clairmont
Bennington	Bennington Water Department	Matthew Miller
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Bow	Bow Municipal Water System	Eric Burkett
Brentwood	Rockingham County Home	Tom Schulte
Bristol	Bristol Water Works	Jeffrey Chartier
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Campton	Waterville Estates Village District	Corey Smith
Canaan	Canaan Water Department	John Coffey
Carroll	Carroll Water Works	Scott Sonia
Carroll	Rosebrook Water System	Brian McCall
Charlestown	Charlestown Water Works	Dave Duquette
Claremont	Claremont Water Works	Robert Lauricella
Colebrook	Colebrook Water Works	Brian Sullivan
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Contoocook	Contoocook Water Precinct	Charles Damour
Conway	Conway Village Fire Precinct	Gregg Quint
Conway	N. Conway Water District	Jason Gagnon
Derry	Derry Water Works	Thomas Carrier
Dover	Dover Water Works	John Storer
Durham	UNH/Durham Water Works	Wesley East
Enfield	Enfield Village Fire Precinct	James Taylor
Epping	Epping Water Works	Daniel Mattus
Epsom	Epsom Village District	Joseph Damour

Town	System	Name
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Fitzwilliam	Fitzwilliam Village Water District	Joseph Damour
Francestown	Francestown Village Water	Dennis Orsi
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Haverhill	N. Haverhill Water & Light	Robert Fagnant
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Northumberland	Groveton Water System	Reginald Charron
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Artificial Recharge – Another Water Supply Option for New Hampshire

Case Study: Spruce Hole Groundwater Supply & Artificial Recharge Facility

UNH/Durham Water System (UDWS)

Durham, New Hampshire

By Michael Metcalf, P.E., Underwood Engineers, Inc.

Introduction/Background

In most of the United States, Artificial Recharge (AR) is better known as Aquifer Storage and Recovery (ASR), and in this paper both terms will be used interchangeably. Regardless of what you call it, the concept is the same; during times of plentiful water, water is pumped from a river or other source and then injected or allowed to infiltrate into an aquifer and stored there. When that surface water source is unavailable due to low flow, drought, or withdrawal restrictions, the stored water can be pumped from the aquifer.

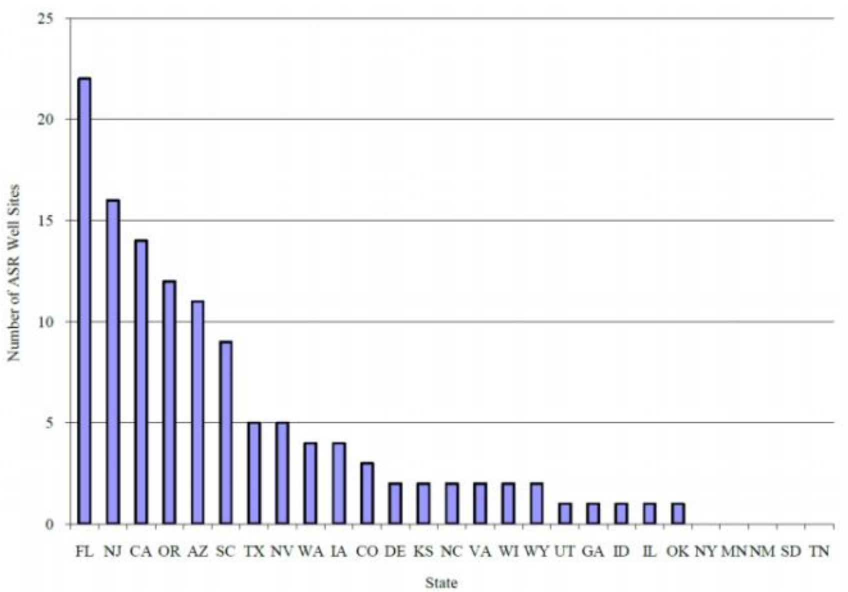
The idea behind ASR is not new. Nomads in present-day Turkmenistan practiced a rudimentary form of ASR for centuries by capturing rainfall in trenches and then funneling it toward more permeable sand dunes where it was later recovered using hand dug wells. ASR is presently being practiced in Canada, the Netherlands, England, Israel and Australia. In the U.S., well recharge studies were conducted in the 1940's and 1950's due to concerns about protecting drinking water supplies during both World War II and the Cold War. The first municipal ASR system was installed in Wildwood, New Jersey in 1968. Since then, many ASR systems have been installed throughout the US including the following examples:

- El Paso, TX
    - 10 MGD of treated wastewater is injected into aquifers 300 to 835 feet below ground.
- San Antonio, TX
    - Up to 60 MGD of water from the highly permeable limestone Edwards Aquifer is injected 400 to 600 feet below ground into the sandy, less permeable Carrizo Aquifer.

- Las Vegas, NV
  * Up to 103 MGD of treated Colorado River water from Lake Mead is injected into aquifers using 64 wells, 22 of which are for recharge and 42 are dual-purpose.
- West Palm Beach, FL
  * Up to 10 MGD treated water from Clear Lake is injected into the aquifer underlying the site.

In a 2017 presentation on ASR to the Pacific Northwest Section of AWWA, EA Engineering, Science and Technology noted the number of ASR sites by state in the US (see **Figure 1**).

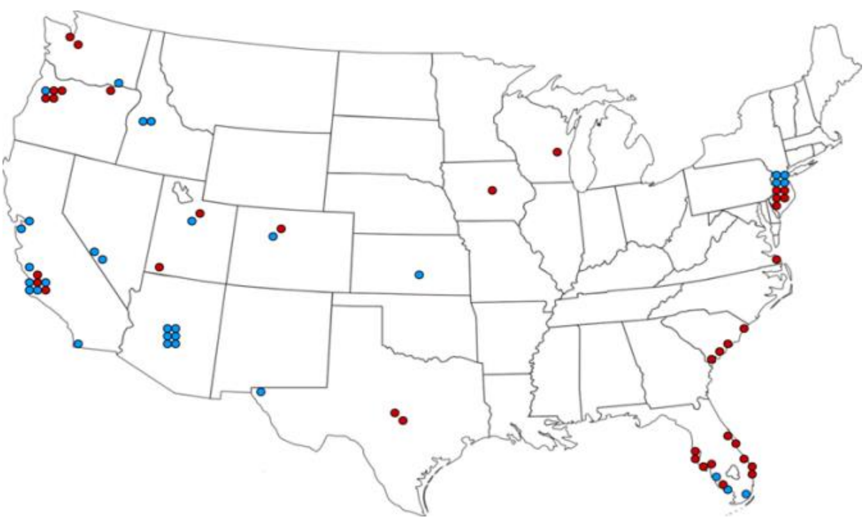
Figure 1 – ASR Well Sites in the US



The distribution of ASR sites in the U.S. was shown geographically in a slide prepared by the South Florida Water Management District (**Figure 2**). This was developed in 2010, so not all the sites indicated in Figure 1 are shown in Figure 2. The point, however, is that many of the ASR sites are located in dry states where "banking" of water in aquifers allows use during dry periods. It can also be seen that many systems such as those in Florida, California, South Carolina, and New Jersey are located close to the ocean and serve not only to bank fresh water, but also to prevent salt water intrusion into coastal aquifers.

Neither figure shows any ASR sites in New Hampshire, which is not accurate since we are aware of three ASR installations (two in Dover and the Spruce Hole Facility in Durham/Lee), but these relatively small facilities have most likely escaped national notice in comparison to some of the large facilities listed previously. Additionally, in a fairly water rich state such as New Hampshire, ASR has not normally been included in the list of alternatives for systems looking to augment their water supply capability, and with our relatively short coast line, salt water intrusion has not been a major issue. However, with increasing residential and commercial development, competing demands for water resources, and more stringent permitting and environmental requirements, it is increasingly more difficult and expensive to develop new sources of water supply. Add climate change to this with more frequent drought periods and more high intensity precipitation events, and the alternative of ASR becomes a favorable option that New Hampshire water utilities should be considering. Some of the potential benefits of AR/ASR are noted below:

Figure 2 – Distribution of ASR Sites in the U.S.



- Allows pumping of peak river flows for storage and later use during periods of low flow, unavailability due to instream flow rules, and/or drought. This improves the integrated management concept of water resources.

- With proper Well Head Protection measures in place, less chance of spill or contamination events impacting the supply source.
- Can be used to create a groundwater "mound" to prevent salt water intrusion or movement of a known contamination plume towards a groundwater supply.
- Can provide some degree of treatment for surface or storm water as water moves through sands and gravels so that treatment costs are reduced.
- Can increase the sustainable yield of a groundwater supply with a transmissive, but limited aquifer in areal extent.
- Can reduce overall costs in adding water supply capacity when compared to the cost of developing new supplies.

The remainder of this article will concentrate on the Spruce Hole Groundwater and Artificial Recharge Facility which was implemented by the Town of Durham, NH in concert with the University of New Hampshire, and which realized a number of the benefits listed above.

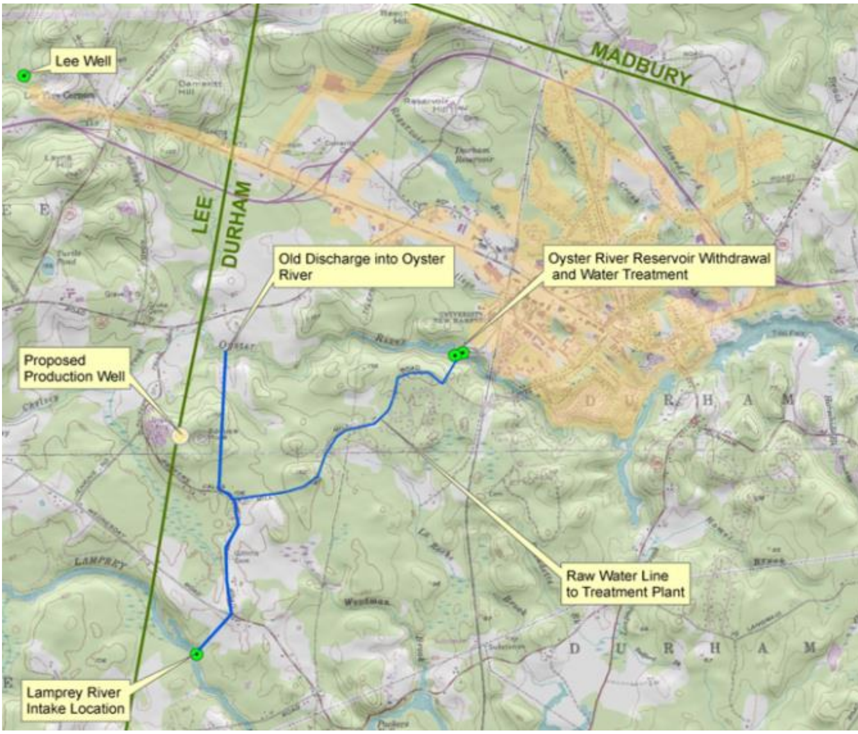
Spruce Hole Groundwater Supply and Artificial Recharge Facility

The Town of Durham, NH is home to the University of New Hampshire (UNH) which, when in session, essentially doubles the year-round population. From the 1930's to the early 1970's, the sole water supply for the Town and University was the Oyster River, which was and still is treated at the Arthur Rollins Water Treatment Plant (ARWTP) located on the UNH campus (currently being replaced with a new WTP adjacent to the existing facility). During the drought of the mid 1960's, the Oyster River, with its 16.5 mi^2 watershed, was nearly dry, prompting an evaluation of additional supply sources. In 1971, a pump station and intake were constructed on the Lamprey River, with its 183 mi^2 watershed, and a transmission main was constructed so that Lamprey River water could be pumped into the Oyster River upstream of the ARWTP when needed. The general mode of operation was to activate the Lamprey River Pump Station if water stopped flowing over the flashboards of the Oyster River Impoundment next to the WTP. Due to the impending Instream Flow Rules and possible withdrawal restrictions on the Lamprey River, in 2001 a new raw water main was connected to the main installed in 1971 and run directly to the WTP as a more efficient means of transferring this water. Valves installed at the connection point of the new main to the existing main allow the use of either one for transfer of water.

In 1986, a groundwater supply, the Lee Well, was added to the system. In 1989, a second potential groundwater supply was identified for future use in the Spruce Hole Aquifer which is situated between the Lamprey and Oyster Rivers. The Town obtained the necessary land, and commissioned work led by UNH professors who confirmed the supply potential in this sand and gravel aquifer. Additionally, they identified the possibility of applying surface water to "artificially recharge" the aquifer since it is relatively small and only recharged by precipitation. In a 1996 Summary Report, it was indicated that initial computer modeling of the aquifer showed that after three months 90% of the water applied to the aquifer would still be in the formation and anywhere from 30 to 75% could be recovered depending on the final well(s) location(s) and pumping rate(s). After submission of this report, Hurricane Bob came through the Durham area and dumped 11 inches of rain in about 16 hours. All UNH monitoring wells were still in place and the research team recorded daily water levels before, during, and for two weeks after the event. While this was natural recharge, it simulated an artificial recharge experiment in which a great deal of water was applied to the aquifer in a short period of time. Based on the data collected and 3-dimensional computer modeling, the researchers found that 99% of the water applied to the aquifer in late May or early June would still be in the aquifer in August or September, and a model pumping well was able to recover 90% of this amount. These results validated AR as a viable concept for the Spruce Hole Aquifer.

Figure 3 shows the location of the UDWS supply sources as well as the raw water mains installed in 1971 and 2001. This figure was created before installation of the Spruce Hole Well which is labelled as "Proposed Production Well". It can be seen that the original transmission main passes relatively close to the Spruce Hole Well site, and in fact right through part of the Spruce Hole Aquifer. The concept for AR was therefore to utilize the existing Lamprey River Pump Station to pump water from the Lamprey River during periods of high flow, install a spur off the existing transmission main, and apply the water to infiltration basins excavated in the sand and gravel near the well. This approach maximized use of existing infrastructure and eliminated the potential lengthy process of permitting and installing a new intake, pump station and transmission main.

Figure 3 – UNH/Durham Water System Supply Sources & Raw Water Mains



The Town and University deliberated for several years on the need, expense, and various options for adding the new well and recharge facility. In 2007, due to ongoing and increasing water supply demands, the decision was made to proceed with the process of adding this new supply source. The team of Underwood Engineers (UE) and their hydrogeologic subconsultant, Emery & Garrett Groundwater Investigations (EGGI) were retained to plan, design, implement and oversee construction of a new groundwater supply and artificial recharge facility in the Spruce Hole Aquifer. Between 2007 and 2016, when the facility went on line, a number of tasks were completed which were all important in determining the final configuration of the well, recharge facilities, and associated infrastructure. These are briefly described in the following paragraphs.

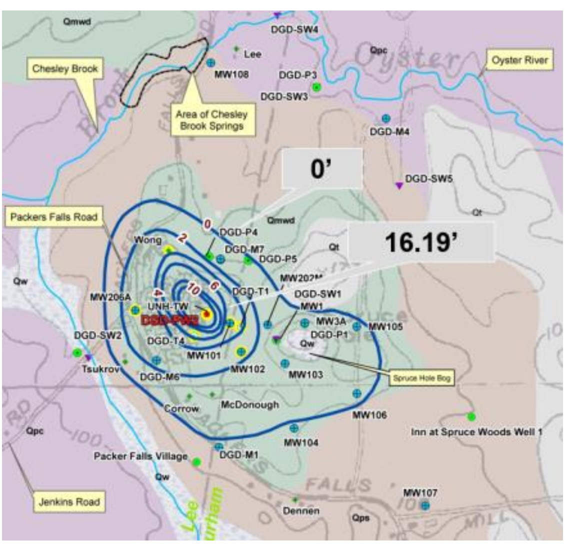
Installation, Pump Testing, and Permitting of the Spruce Hole Well

EGGI completed the Preliminary Hydrogeological Evaluation and Report which led to installation of a 130-foot-deep, 12" x 18" gravel-packed well with 35 feet of screen (**Figure 4**). An 8-day pump test (**Figure 5**) at a pumping rate of 725 gpm was conducted and a final hydrogeological report was completed with the following recommendations:

- The Well can withdraw up to 63 million gallons per year.
- A sustainable year-round withdrawal rate of 120 gpm or 172,800 gpd can be achieved.
- The Well is capable of producing 725 gpm or 1.04 MGD for up to 60 days per year.

Figure 4 – Spruce Hole Well Screen

Figure 5 – Pump Test Drawdown*



*Data collected and analyzed by EGGI

It is noted that the annual withdrawal of 63 million gallons per year is without artificial recharge. Due to the high transmissivity of the aquifer, the well can be pumped at 725 gpm far above the sustainable rate of 120 gpm, but only for 60 days before reaching the annual withdrawal limit. However, with artificial recharge, this higher rate can be sustained for longer periods.

Column Testing/Obtaining a Permit for Artificial Recharge

Of primary concern was the water quality of the recharge water reaching the well given that this is surface water requiring treatment at the WTP. To determine the degree of treatment provided by the aquifer, a test was set up using two 10-foot-long 16-inch diameter columns (**Figure 6**) packed with sand and gravel taken from the aquifer. Water pumped from the Lamprey River was then applied to the columns as shown in Figure 6. The first column represented the unsaturated portion of the aquifer with downward flow, and the second column represented the saturated portion with upward flow. Water samples were taken at the noted sample sites shown in Figure 6 and analyzed for a number of parameters to determine what treatment was occurring as water passes through the aquifer. **Figure 7** shows the results for True Color which was shown to be reasonably representative of Dissolved Organic Carbon (DOC).

Figure 6 – Column Test Schematic

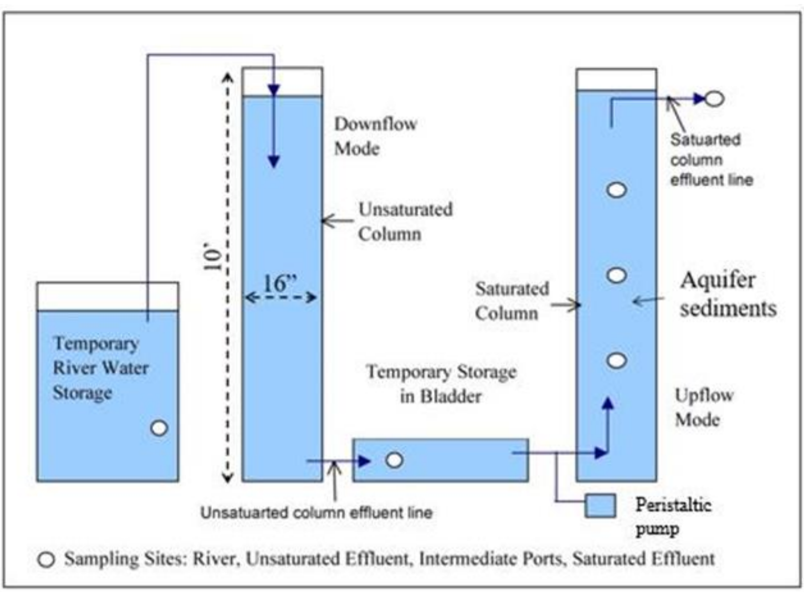
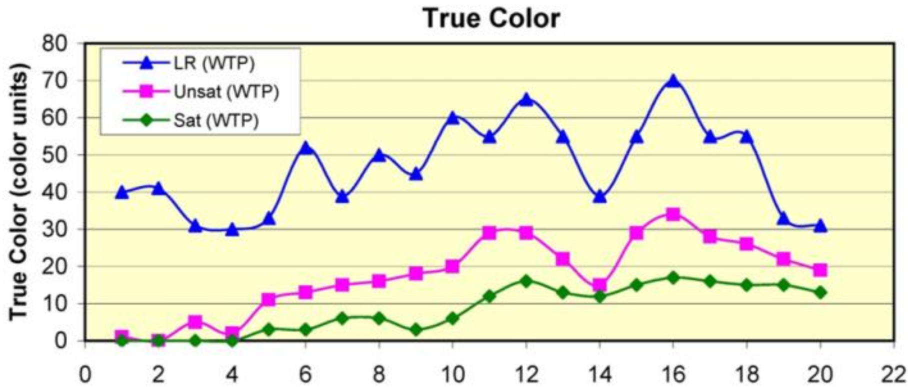


Figure 7 – True Color Column Test Results*



*Data collected and analyzed by EGGI

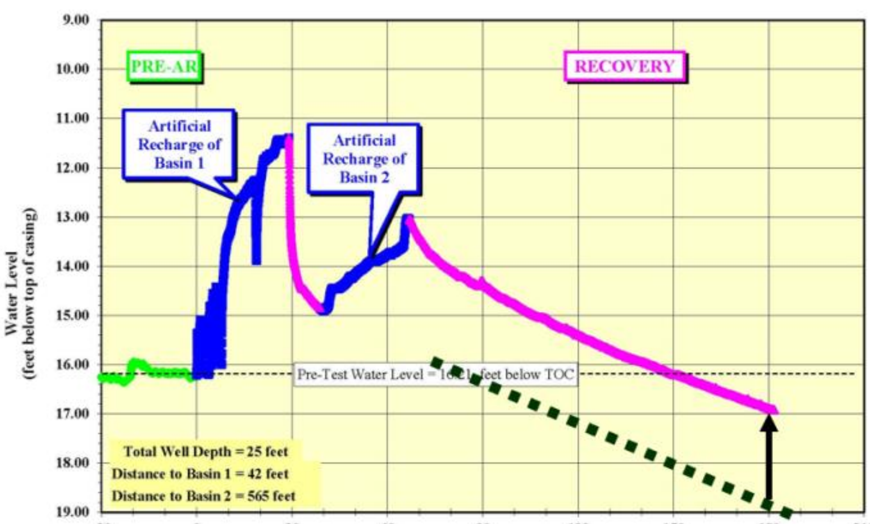
As shown, True Color, and therefore organic material was considerably reduced by the time the water exited the saturated column. A spike of bacterial organisms demonstrated 4-log removal through the columns. Based on these and similar results for other parameters, NHDES issued a Groundwater Discharge Permit to add up to 1,000 gpm of AR to the Spruce Hole Aquifer.

Aquifer Recharge Pilot Test

Two test recharge basins, one upgradient and one downgradient of the new well were installed and a hose was run from a hydrant on the raw water line so that Lamprey River water could be applied to the basins (**Figure 8**). This test was run for several months, first on Basin No. 1 and then Basin No. 2, while monitoring aquifer level (**Figure 9**) and water quality. The results showed that the aquifer level was raised about 2 feet during the pilot test and that aquifer materials adequately treated the surface water as represented by UV 254 absorbance, a surrogate for DOC in **Figure 10**.

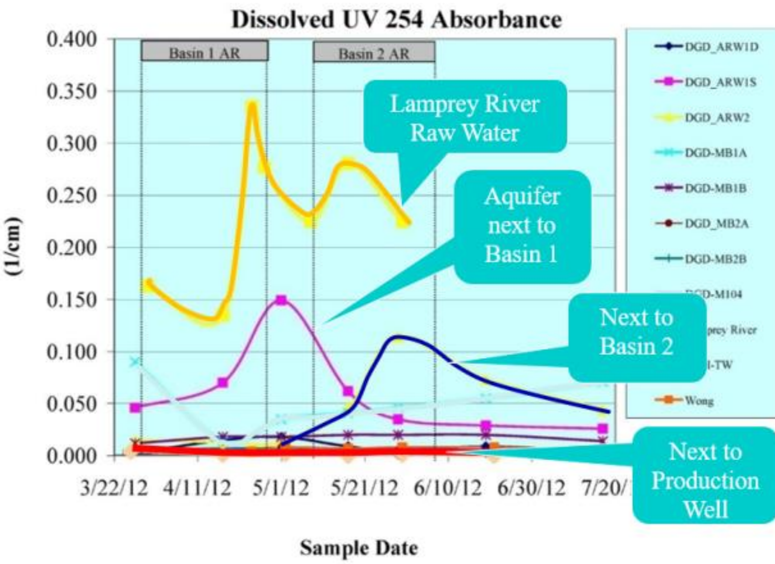
Figure 8 – Pilot Test, AR Basin No. 1

Figure 9 – GW Level Change-Basin No. 1



*Data collected and analyzed by EGGI

Figure 10 – Pilot Test Water Quality Results – UV 254 Absorbance



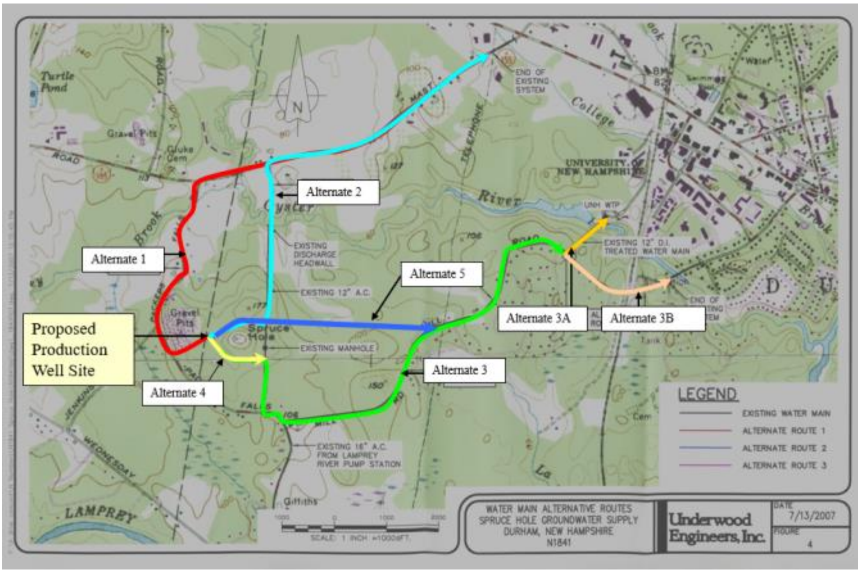
*Data collected and analyzed by EGGI

Infrastructure Evaluation, Design and Construction

Many options were evaluated to determine the most advantageous route to connect the new well to the system considering cost, environmental impact, system looping, and ability to serve new users (**Figure 11**). Ultimately, given the expense of a lengthy new treated water main, a decision was made to direct the well discharge into the existing raw water main and run the well water through the WTP. The Chief Operator of the WTP preferred this option as it allows him better control over the water quality of the water entering the system, rather than having groundwater mix with surface water within the distribution system. Another design decision to reduce the project cost was a single main between the raw water main and the well and recharge basins. This means that recharge and well pumping operations cannot be conducted simultaneously. Based on the evaluation and preliminary design, the final design included the following components:

- Spruce Hole Well
    - Submersible pump and motor, 725 gpm
    - Pitless Adaptor

Figure 11 – Spruce Hole Well Water Main Evaluation



- Connecting Water Main
  - ∗ Single 12-inch main from existing 1971 raw water main to control station
  - ∗ 8-inch mains from control station to AR basins
- Three Phase Power
  - ∗ Overhead 3-phase primary service extended to start of new water main
  - ∗ Buried primary service run parallel to water main
  - ∗ Step down transformer at control station site
- Control Station (**Figure 12 & 13**)
  - ∗ Modulating control valve to either allow recharge to flow to basins or well water to flow to the raw water main.
  - ∗ Two-way magnetic meter to measure both recharge and well water flows
  - ∗ Valving to allow use of either or both basins and a check valve to prevent siphoning between basins which are at different elevations
  - ∗ Electrical equipment

Figure 12 – Control Station & Transformer

Figure 13 – Control Station Process Piping

- SCADA panel with controls to:
    - ◊ Activate well or recharge operations remotely
    - ◊ Set recharge flow to basin(s)
    - ◊ Allow Lamprey River Pump Station to simultaneously supply both the recharge basins and the WTP
- Artificial Recharge Basins
    - ∗ Size based on pilot tests and actual field conditions. Basin #1 is on floor of gravel pit which allowed it to be made larger. Basin #2 is on bench above well and was made smaller to avoid possible slope breakout issues.
    - ∗ Basin #1 (**Figure 14)** downgradient of well and Basin #2 (**Figure 15**) upgradient of well.
    - ∗ Provisions included to allow access for cleaning of basins if sediment builds up.
    - ∗ Inlet structures to keep mains below frost line and dissipate energy of recharge water (**Figure 16, 17 & 18**).
    - ∗ Level controls to stop recharging if high level reached.

Figure 14 – AR Basin #1

Figure 15 – AR Basin #2

Figure 16 – Basin Inlet Structure Detail

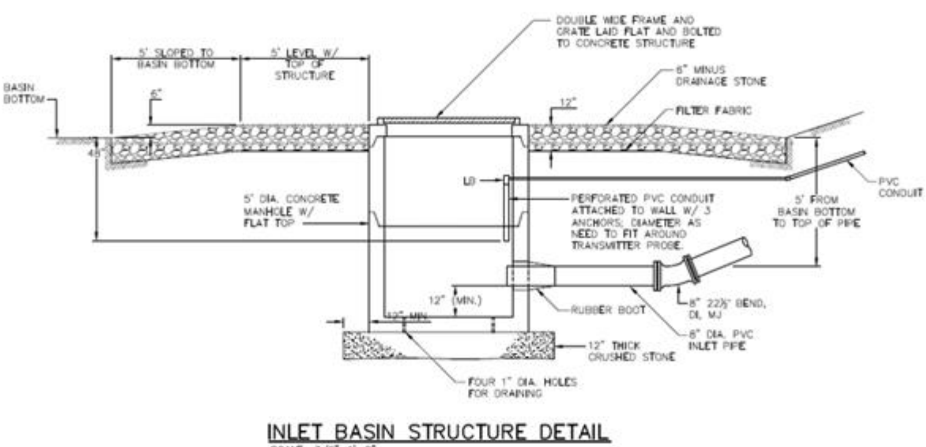


Figure 17 – AR Basin #2 Inlet Structure

Figure 18 – AR Basin #1 During Recharge

Use of Spruce Hole Well and Artificial Recharge in 2016

The facility went on line in May of 2016 in the midst of an on-going drought. Per the instream flow rules, withdrawals from the Lamprey River must cease when the flow drops to 16 cfs as measured at the USGS gauge at Packers Falls in Newmarket. **Figure 19** is a plot of the flow measured at this gauge from January 1 through October of 2016. It can be seen that the 16 cfs threshold was passed near the end of June. As soon as the system was operational, recharge operations were initiated and continued until flow dropped to 16 cfs, at which point, recharge stopped and the well was pumped at 725 gpm. **Figure 20** shows the water level response of the aquifer to both recharge and pumping. As flow in the Lamprey River dropped, so did flow in the Oyster River such that neither surface supply was available for use. Without the Spruce Hole Well, as recharged before the end of June, it is questionable whether the Lee Well alone would have been able to meet system demand. However, with the Spruce Hole well in place and the enhanced recharge system, the Town of Durham was one of the few towns in southeastern NH that did not have to enact water use restrictions in 2016. Heavy rain near the end of October raised the Lamprey River flow above 16 cfs so that recharge was once again initiated. Between both natural and artificial recharge, by May of 2017, the aquifer level was higher than when recharge was initiated in 2016 and ready for use as necessary in the summer of 2017.

Figure 19 – Lamprey River Flow at Packers Falls – 2016

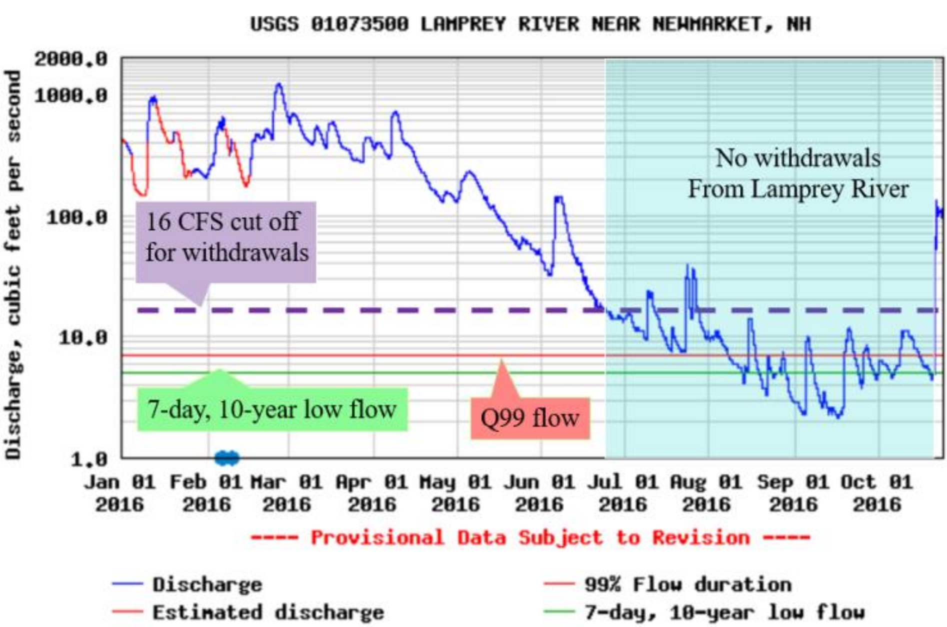
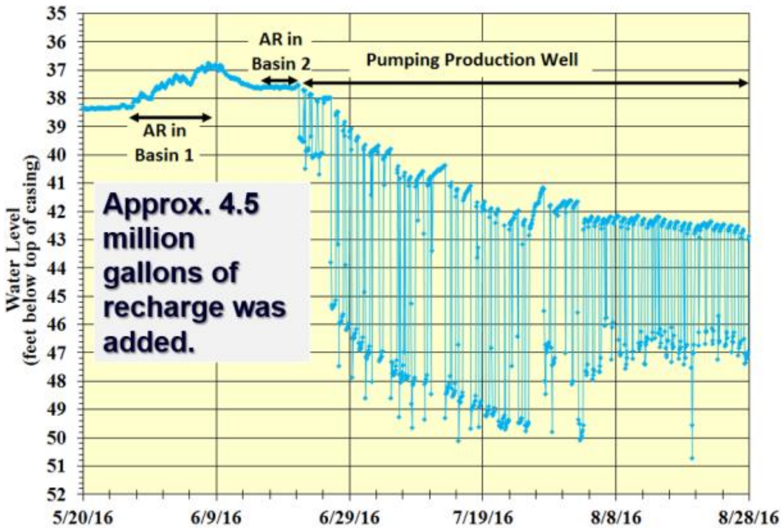


Figure 20 – Water Level Response to AR & Pumping – 2016*



*Data collected and analyzed by EGGI

Conclusions

Artificial recharge, or Aquifer Storage and Recovery, has been practiced for many years in dryer and coastal states to both provide supply when other sources are not available and to help prevent salt water intrusion into coastal aquifers. It has been used less frequently in New Hampshire, but as demonstrated by the Spruce Hole facility in 2016, it has the potential to play a critical role in diversifying a community's water supply picture. As previously noted, there are also potential roles in preventing contaminant migration, increasing the sustainable yield of a groundwater supply, and reducing treatment costs. As the demand and competition for water resources increases, artificial recharge where appropriate should be included in evaluation of a water utilities water supply options.

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Construction Field Day—August 7, 2019
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Please note that billing for advertising will be done once per year. Sponsorships are solicited prior to each event.

20th Annual Construction Field Day
August 1, 2018

Above: The 2018 Construction Field Day started at the Pike Quarry in Hooksett to view the future site of Hooksett Village Water Precinct's 1MG glass-fused steel storage tank. The tank will address storage capacity for rapidly growing domestic water use needs as well as fire protection. Below: Kent Brown, P.E. of Brown Engineering discusses the project which will also include updated transmission main. The project will provide for significant improvements in public health protection and SDWA compliance.

Left: Chris Hodgson of DN Tanks and Dave Miller of Manchester Water Works shared the scope of a project which will result in a new 3 MG Manchester Water Works storage tank in Londonderry. The new tank will be located near an existing 2MG tank built in 1982. The site was chosen due to cost savings for land purchase, site development, and pipe extension considerations.
The new tank, increased from a planned 2.5 MG tank, will address a request made by the State of NH to provide water to the southeast region of New Hampshire.

Construction Day also included a stop in Merrimack to see Pennichuck Water Works' river crossing project. This project will help Pennichuck meet growing demand east of the Merrimack River, which has increased due to land development and the response to PFOA contamination in private wells. The day concluded with a tour of Pennichuck' s 55,000 sf distribution facility in Merrimack.

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