The State of New Hampshire
DEPARTMENT OF ENVIRONMENTAL SERVICES

Robert R. Scott, Commissioner

August 22, 2017

John Boisvert, Chief Engineer
Pennichuck Water Works
25 Manchester Street
Merrimack, NH 03054

Subject: Drinking Water State Revolving Loan Fund (DWSRF) Pre-Applications
FY 2017 Project Priority List

Dear Mr. Boisvert:

The purpose of this letter is to inform you that the FY 2017 DWSRF Project Priority List has been finalized and that DWSRF funding is available for the following project:

Public Water System	Project Description	Project Amount
PEU-Locke Lake	Locke Lake New Groundwater Source	$4,240,000

The Pennichuck Water Works-Nashua (PWS #1621010) Pennichuck Core Water Main Replacement Project ($3,375,000) project was not selected for funding.

The next step to move forward with the Locke Lake New Groundwater Source project funding is to submit a final application. The documents are listed on the enclosed checklist and available on line at http://des.nh.gov/organization/divisions/water/dwgb/capacity/dwsrf.htm

Funding for the Locke Lake New Groundwater Source project is available until June 30, 2018. However, we encourage you to move forward at this time to seek the authority to borrow. The current charge rates have been enclosed. Please be advised that these rates are subject to change. From this point forward any non-construction work completed after the date of the public hearing (8/3/17) is eligible for reimbursement.

Save the date: On Monday November 20, 2017, the DWSRF will be hosting a State Revolving Fund workshop. Please see the attached flyer for additional information.

We ask that you keep us informed of progress made toward seeking the authority to borrow. Should your project not move forward, please contact us as soon as possible. If you have any questions, please contact me at 271-7017 or at johnna.mckenna@des.nh.gov.

Sincerely,

Johnna McKenna
Drinking Water and Groundwater Bureau

cc: Donald Ware, PEU

Attachments: Final Application Checklist, SRF Workshop-Save the Date and Charge Rates

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

CHARGE RATES For Drinking Water State Revolving Fund (DWSRF) Loans

Term of Loan	*Charge Rate* *Effective 8/2/2018*
5 Years	0.845%
10 Years	1.69%
15 Years	2.535%
20 Years	2.7040%
30 Years*	2.7040%

11-Bond GO Index for July 26, 2018 is 3.38

*Available to disadvantaged communities only

Source: NH Department of Environmental Services, July 2018
Per Env-Dw 1106.03(b)

The State of New Hampshire
Department of Environmental Services

NHDES

Clark B. Freise, Acting Commissioner

January 9, 2017

DONALD WARE
PENNICHUCK WATER WORKS
PO BOX 1947
MERRIMACK NH 03054-1947

SUBJECT: BARNSTEAD, PEU LOCKE LAKE WATER SYSTEM
EPA # 0142010
SANITARY SURVEY 2016

Dear Mr. Ware:

On November 15, 2016, a staff member from the Department of Environmental Services (DES) conducted a sanitary survey of the PEU Locke Lake Water System in Barnstead. The purpose of the survey was to review the capacity of the water system's sources, treatment, distribution, and management to continually produce safe drinking water. We would like to thank Chris Countie, Water Supply Manager, for his assistance in conducting this survey.

The PEU Locke Lake Water System is currently in compliance with Safe Drinking Water Act water quality standards. The operator is very knowledgeable of the components of the water system. Also, the managers continue to invest in water main replacement which continually reduces water losses.

However, this past year the water system has had over 1,500,000 gallons of bulk water delivered since June 2016 with the latest delivery occurring the week of January 4, 2017. The existing water supply capacity cannot meet the current demand of the public water system. This is a significant deficiency and the managers need to develop a water supply which will meet the current demand and accommodate any potential growth.

Typically, significant deficiencies are required to be addressed within 30 days of notification in writing by DES. However, we recognize that this significant deficiency identified may not be able to be addressed within the 30 day time frame. Therefore DES requires that the managers develop a comprehensive action plan (CAP) which would outline the steps the managers will take to address this deficiency. This CAP must be submitted within 30 days of receipt of this sanitary survey letter.

DES recognizes that the managers have an aggressive water main replacement project which included replacement of over 18,000 feet of water main this past year. We commend the managers for undertaking this effort.

FACILITIES DESCRIPTION

The PEU Locke Lake water system provides domestic water to approximately 858 residential services for a total population served of 2,145 people. The reported average daily usage for 2015 was approximately 125,000 gallons per day (GPD). This appears down from average flow in 2013 of 156,000 and substantially lower than 2010 reported usage of 174,000 GPD.

In general, the water system is comprised of seven bedrock wells, associated pump houses, one storage tank having a capacity of 250,000 gallons, and two 18,000 gallon buried steel tanks. The water system serves the Locke Lake residential development from Peacham Road along the south to North Barnstead Road and extending to the Alton town line.

The system draws water from a dispersed group of bedrock wells which are now treated in two treatment systems as follows:

Well EPA ID#	Name	Well pump rate (gpm)	Depth	Treatment Facility
003	BRW 3 Golf Course	2	500	Peacham Road
009	BRW 9 Golf Course	5 (15 current yield)	800	Peacham Road
010	BRW 10 Air Strip	32	563	Air Strip
011	BRW 11 Golf Course	40 (14 current yield)	425	Peacham Road
017	BRW 14 300 S PH	45 (current yield 21)	704	Peacham Road
018	BRW 15 563 S PH	39	662	Peacham Road
116	BRW 13 120 E PS	39	700	Peacham Road

We note that the yield of the existing wells has dropped significantly due to the ongoing drought in 2016. As a result, the managers need to haul in bulk water to meet the demand during peak times. The three Peacham Road wells are adequately protected on 50 acres of property owned by PEU Locke Lake, including a gated entrance and fenced/gated protection around each well. Water from these wells is pumped directly to the Peacham Road treatment facility.

The Golf Course wells are located on the fairways, where there is no evidence of fertilizer or pesticide use. All of these wells are manifolded in a below ground vault with a dedicated raw water transmission main to the Peacham Road treatment facility

The Peacham Road treatment facility is a single story block building housing chemical treatment systems for iron and manganese, arsenic, and disinfection. The specific treatments include injection of sodium hypochlorite (disinfection and pre-oxidation of iron and manganese), ferric chloride (for co-precipitation of arsenic) and carbonic acid (generated on-site for pH depression). Filtration and adsorption takes place in dual

LayneOx pressure filters in series. Periodic backwash (from treated water storage) of the filters flows to a 20,000 gallon backwash holding tank from which decant is recycled into the treatment process prior to the point of raw water chemical injection. Treated water flows to a 250,000 gallon Natgun storage tank adjacent to the treatment facility. Five finished water pumps equipped with variable speed drives draw water from the storage tank and maintain constant pressure to the distribution system. The facility is equipped with backup power which is exercised weekly.

The Airstrip well is located at the edge of the woods along a grassy area beyond the airstrip runway. The Airstrip pumphouse/treatment station is a two story concrete building with the arsenic treatment on the first floor and the pipe gallery and storage tank access in the lower level. The arsenic treatment consists of adsorption vessels containing Arsenex media. Equipment in the lower level includes the two 18,000 gallon steel storage tanks, booster pumps, well pump controls, and flow monitoring equipment. The Airstrip section and 'Section S' section of the distribution system are looped with the Peacham Road distribution system. In the event of a power outage, a pressure loss would trigger the water supply to flow from the Peacham Road system to the Airstrip and Section S systems.

Alarms for the Peacham Road and Airstrip treatment stations communicate with the PEU headquarters in Pittsfield, which in turn communicates with the Pennichuck Water Works headquarters in Nashua and is accessed by the duty operator in Pittsfield.

The distribution system consists of 18 miles of piping which is primarily small diameter plastic mains ranging in size from 2 – 6 inch diameter. Since taking over ownership PEU has been replacing and upgrading the distribution system which will reduce leaks and improve the reliability of the distribution system. PEU has implemented a capital improvement program to replace water mains each year. Each service is metered with either radio-read or touch pad reading capabilities. Pennichuck has installed check valves on all houses with expansion tanks. According to the operator, overnight flow is reported at approximately 20 GPM.

The finish water storage consists of a 250,000 gallon pre-stressed concrete tank at the Peacham Road treatment facility and two 18,000 gallon below ground steel tanks at the airstrip pump house. We note that these steel tanks have been cleaned, sealed, and recoated in 2012. The entire distribution system is flushed every other year. Valve exercising occurs at a rate of approximately 50% each year with an intended goal this year of 100% being exercised. We note that typically storage tanks should be inspected every five years.

CERTIFIED OPERATOR VERIFICATION

The PEU Locke Lake water system is required to retain an operator certified at the Grade I Treatment and the Grade II Distribution level. The following operators are listed as certified operators for this system:

Operator	Cert. No.	Treatment Grade	Distribution Grade
Chad Call	2848	I	II
Dave Hall	1916	II	II
Chris Countie	1426	IV	IV

The current operators are qualified for operation of this water system.

ISSUES AND RECOMMENDATIONS

Currently, reported daily water usage for Locke Lake is approximately 125,000 gallons per day. Large water systems are required to have adequate source capacity to meet average day demand and to meet maximum day demand with the largest well out of service. According to the operator, some of existing wells are decreasing in capacity due to the extreme drought condition this past year. The water system has received over 1,500,000 gallons of bulk water deliveries within the past eight months. DES considers this a significant deficiency which must be addressed. Even if the customer base does not expand due to residential growth, the system now needs to consider additional source capacity not only to meet future demand but to address any potential shortfall that may occur because of depletion of existing supply capacity.

If you have any questions regarding this survey letter please contact me at 271-2948 or Richard.skarinka@des.nh.gov.

Sincerely,

Richard Skarinka, P.E.
Drinking Water and Groundwater Bureau

ec: Chris Countie, PWW

PENNICHUCK EAST UTILITY, INC.
LOCKE LAKE COMMUNITY WATER SYSTEM
EPA #0142010
COMPREHENSIVE ACTION PLAN UPDATE
For
Locke Lake Colony Association Board of Directors Meeting
July 6, 2018

A Comprehensive Action Plan (CAP) was provided by Pennichuck East Utility, Inc. (PEU) on March 3, 2017 in response to a New Hampshire Department of Environmental Services ("NHDES") Sanitary Survey letter issued on January 9, 2017 in regards to the Locke Lake Community Water System ("LLCWS" or the "System"). The NHDES letter required PEU, as owner of the LLCWS, to outline the steps that PEU will take to address a significant deficiency in source of supply for the LLCWS. That shortage in supply resulted in PEU having to haul over 1.5 million gallons water into the LLCWS over the last six months of 2016 to supplement the existing well supply. The CAP provided:

1. A short history of the LLCWS system, including actions taken by PEU through the end of 2016 toward correcting the many deficiencies that existed at the LLCWS when PEU acquired the System in May 2006.
2. A desktop analysis of the long term source of supply needs of the LLCWS, and
3. An outline of the steps that PEU will take to move forward with a plan to correct the short term supply shortage of the LLCWS and to map out a path to the development of a supply that will meet the future needs of a fully developed LLCWS.

The following is meant to provide an update to the previously provided CAP.

I. LLCWS History Update

The following system improvements have been made to the LLCWS since March 3, 2017;

1. None

II. LLCWS Supply Analysis Update

PEU reviewed water supply and demand data from January 2013 to present and developed the summary figures, attached. Below are takeaways from the figures;

System Flows Figure

- The combined well production decreased significantly in January 2015. The decrease in January 2015 was likely due to the replacement of a pump in well BRW 13 with a smaller pump at that time, which is supported by the data presented in the Well Production figure. The pump in BRW

13 was replaced with a larger pump and the well was reconditioned at the end of June 2018, which should recover some of the lost well production.

- The combined well production has continued to decrease over time. This is supported by data presented in the Well Production figure, specifically for wells BRW 13, 14 and 15. Wells BRW 14 and 15 will be evaluated for reconditioning and pump replacement following the work that was just performed on well BRW 13.
- The combined well production was significantly higher than the combined station finished flows from 2013 to 2015. This was likely due to the fact that there was only a 6-inch meter at the Peacham Road facility, which did not capture low flows. The meter was replaced with a compound meter (4-inch and ¾-inch) in May 2015. After this point, combined well production and station flows were much closer.
- The combined station finished flows exceeded the combined well production several times, most noticeably in the summer of 2016. These occurrences are indicative of times where water was trucked in due to the fact that the wells could not keep up with the system demand.
- The combined well production and combined station finished flows were significantly higher than the total metered consumption from 2013 to the end of 2014. This is indicative of unaccounted for water, which is supported by the data in the Unaccounted for Water figure. It is evident that unaccounted for water was reduced significantly in the end of 2014 and beginning of 2015 and has been relatively low since then. This can be attributed to the significant replacement of water mains and water services in that timeframe.

Well Production Figure

- As previously noted, production in well BRW 13 dropped significantly in January 2015 when the existing pump was replaced with a smaller pump. The pump in BRW 13 was replaced with a larger pump and the well was reconditioned at the end of June 2018, which should recover some of the lost well production.
- Also, as previously noted, the production in wells BRW 13, 14 and 15 has slowly decreased over time, particularly since early 2015 or so. Wells BRW 14 and 15 will be evaluated for reconditioning and pump replacement following the work that was just performed on well BRW 13.

Unaccounted for Water Figure

- As previously noted, unaccounted for water was reduced significantly in the end of 2014 and beginning of 2015 and has been relatively low since then. This can be attributed to the significant replacement of water mains and water services in that timeframe.

Water Consumption Figure

- Water consumption (gpd per customer) increased in late 2014 into early 2015 and has remained relatively constant since then at approximately 120 gpd per customer.

- The number of customers has increased from about 857 to 893 customers from January 2013 to May 2018.

These figures reinforce the need for additional supply to meet current (120,000 gpd), and more importantly future (260,000 gpd) demands. As discussed in the original CAP, a future demand of 260,000 gpd is based on the following;

1. A full build out of the LLCWS system to 1100 customers.
2. The LLCWS consisting of 100% year round customers.
3. The average daily use per customer of 146 gpd (the average usage for a PEU customer during the non-irrigation season in 2016).
4. An allowance of 15% for system leakage.
5. An irrigation load based of about 75,000 gpd based on 20% of the homes using outside irrigation (the approximate percentage of homes currently using outside irrigation).

III. LLCWS Comprehensive Action Plan Update

Phase I of the CAP was to locate and develop an initial additional supply of 39.9 gpm (quickest permitting time) while looking for a location that would be large enough and productive enough to support the siting and permitting of additional wells capable of producing a combined well yield of 100 gpm. PEU was unable to locate and develop an initial additional supply of 39.9 gpm, as we were unable to find a landowner that was located in the target areas from the HydroSource Associates, Inc. (HSA) report who was willing to sell their land. PEU also had HSA perform a well-siting geophysical survey on a Locke Lake farm property in March 2018 that was believed to be a possible target area. The results of the survey, attached, indicated that major fracture networks are unlikely to exist in the local bedrock. Therefore, the likelihood was low of developing a sufficiently productive new well source that would justify the cost of developing that source.

Unable to accomplish Phase I, PEU has moved to Phase II, which includes the following;

1. New Groundwater Supply – PEU will no longer actively pursue a new groundwater source based on the results of Phase I. If PEU is notified of or presented with a possible new groundwater source, we will evaluate it fully.
2. Existing Groundwater Supply - PEU installed groundwater level transducers in all existing wells and reviewed historic flow data to determine if the existing wells can provide additional supply. Transducers were installed in the wells in October 2017. Water level and flow data was collected and analyzed and it appears the wells may have some additional available capacity. The pump in well BRW 13 was replaced with a larger pump and the well was reconditioned at the end of June 2018 in an effort to increase production by approximately 10 gpm to return its production to what was seen from the well before 2015. Groundwater transducers were reinstalled in all wells in June 2018 and levels will continue to be monitored in well BRW 13 and surrounding wells to monitor impacts that the increased withdrawal may have on groundwater levels. PEU will also

evaluate having well BRW 14 reconditioned after the work is complete on well BRW 13, and if appropriate, may increase the pump size in that well also.

3. New Surface Water Supply – PEU is evaluating utilizing Locke Lake as a new surface water supply for the LLCWS. The following steps have been taken thus far;
   a. On March 15, 2018, a meeting was held with members from PEU and the NHDES Drinking Water and Groundwater Bureau to discuss the possibility of utilizing Locke Lake as a new surface water supply. NHDES was amenable to the idea and requested that PEU develop a strategic plan moving forward. The strategic plan is outlined in Section IV, below.
   b. On June 14, 2018, a meeting was held at Locke Lake with members from the LLCA, PEU, and NHDES to discuss the water supply situation and the strategy moving forward. The possibility of utilizing Locke Lake as a new surface water supply was discussed. PEU will continue to communicate and work with the LLCA as the plan progresses.

IV. Locke Lake Surface Water Supply - Strategic Plan

A strategic plan for developing Locke Lake as a new surface water supply for the LLCWS is outlined below. The overall goal would be to utilize Locke Lake as a seasonal water supply, withdrawing 100 to 200 gpm of water from an intake near the dam, to be treated, stored, and pumped into the distribution system from the Peacham Road station. The Locke Lake source would likely be utilized during the fall, winter, and spring seasons, allowing the existing wells to rest and recover during that period. An overall schedule is outlined in Table 1, below.

Table 1 Schedule for Development of Locke Lake Surface Water Source

No.	Name	Description	Dates
1	Initial Investigation and Planning	Meetings with LLCA and NHDES. Strategic plan. Jar testing.	Jun-18 to Jul-18
2	Water Quality Sampling	Quarterly and biweekly sampling	Mar-18 to Mar-19
3	Warm Water Piloting	Pilot testing various treatment technologies.	Aug-18
4	30% Preliminary Design	Basis of design and preliminary plans	Sep-18 to Dec-18
5	Permitting	LLCA, Barnstead, and NHDES permits.	Oct-18 to Feb-19
6	Cold Water Piloting	Evaluate seasonal impacts on treatment technologies.	Feb-19
7	60% Intermediate Design	60% drawings and specifications	Jan-19 to Jun-19
8	100% Final Design	Final drawings and specifications	Jun-19 to Sep-19
9	Bidding and Award	Public bid and award period.	Oct-19 to Dec-19
10	Notice to Proceed		Jan-20
11	Construction		Jan-20 to Nov-20
12	Startup and Testing		Nov-20 to Dec-20
13	Project Complete	New system online.	Dec-20

Below is a summary of items completed or currently underway.

1. Hydrological Assessment – Streamworks, PLLC performed a benchtop study to evaluate flows through Locke Lake and developed a report titled "Flow Duration Curves and Low Flows for Locke Lake", dated August 23, 2017. The report is attached. The report determined that the drainage area or watershed for Locke Lake at the outlet is 6.17 square miles, and based on two different methods, concluded that the 7Q10 flows for Locke Lake range seasonally from a low of 0.19 cfs in the summer to a high of 3.69 cfs in the spring. A map of the watershed is in Figure 1, below.

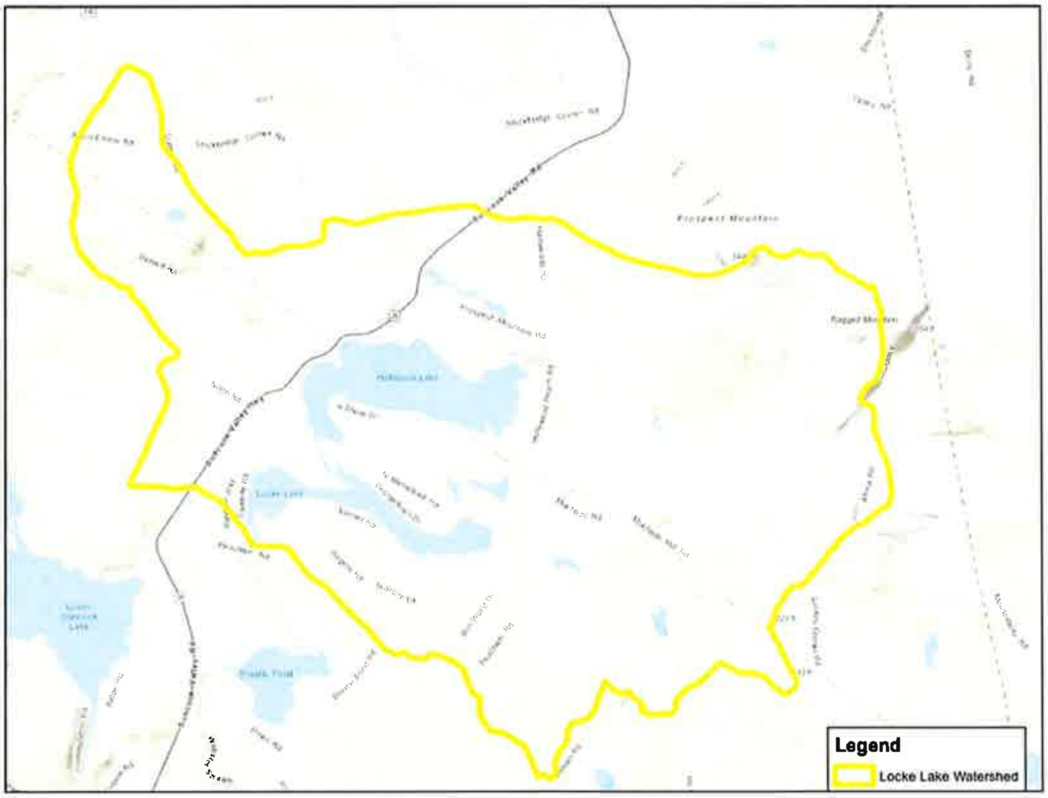


Figure 1 Locke Lake Watershed

The 7Q10 flows and the De Minimis withdrawals are shown Table 2. The permitting process with NHDES will dictate withdrawal limits and streamflow monitoring requirements, but PEU does not intend to impact the levels within Locke Lake. Water would only be withdrawn from the lake when sufficient flow is passing over the dam. PEU does not anticipate that a withdrawal from Locke Lake would impact the LLCA's current use of the lake as a recreational resource.

Table 2 Low Flows and De Minimis Withdrawals for Locke Lake

Description	Winter	Spring	Summer	Fall
Locke Lake 7Q10 Flows (gpm)	1,014	1,580	85	507
De Minimis Withdrawals (gpm)	50.7	79.0	4.3	25.4

2. Sampling plan – A sampling plan has been developed which involves quarterly sampling for a large suite of parameters as well as biweekly sampling for a smaller suite of parameters. The first quarterly sampling event was March 27, 2018 and biweekly sampling began on May 1, 2018. Results from the first quarterly sampling event are attached. Average, minimum, and maximum results from the biweekly sampling thus far are shown in the Table 3, below.

Table 3 Biweekly Sampling Results for Locke Lake

Parameter	Average	Minimum	Maximum
Turb, Field (NTU)	1.4	0.3	2.1
pH	6.55	5.99	7.09
Spec Cond (µS/cm)	109	88	161
Temp (°C)	17.77	5.40	23.90
DO (mg/L)	3.84	1.51	6.46
Alkalinity (mg/L as CaCO3)	7.32	5.91	8.30
Color, True (CPU)	44	27	95
Iron, Diss. (mg/L)	0.331	0.083	0.503
Iron, Total (mg/L)	0.507	0.171	0.700
Mn, Diss. (mg/L)	0.066	0.030	0.087
Mn, Total (mg/L)	0.073	0.031	0.091
UV Abs, 254nm	0.164	0.137	0.175
Total Phosphate (mg/L, as P)	0.03	0.03	0.03
Nitrate (mg/L, as N)	0.20	<0.2	0.21
Nitrite (mg/L, as N)	<0.2	<0.2	<0.2
DOC (mg/L)	3.99	3.73	4.2
TOC (mg/L)	4.5	4.3	4.67
Ammonia (mg/L, as N)	<0.2	<0.2	<0.2
TKN (mg/L)	1.09	1.01	1.16
E. Coli (MPN per 100mL)	59.7	3.1	>200
SUVA	3.92	3.67	4.17

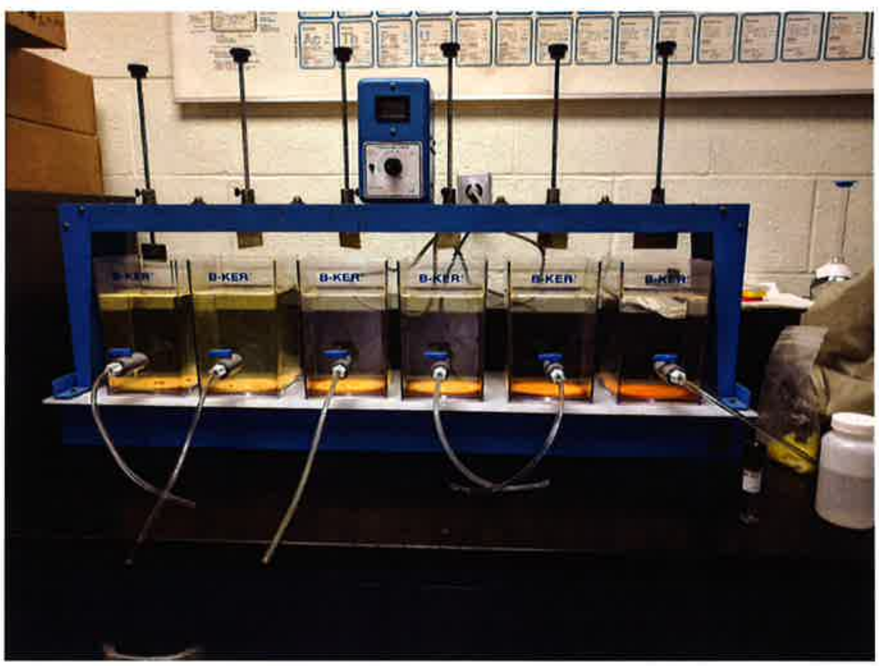
Notable results from sampling performed to date are identified and explained below.

- Slightly elevated iron and manganese above secondary standards. Iron and manganese will be addressed by the selected treatment process.
- Low levels of nutrients (phosphorous and nitrogen). We will continue to monitor for nutrients to see if they change throughout the summer with lawn care and farming practices.
- High color, which will be addressed via the selected treatment process.
- Low alkalinity. We will need to increase alkalinity in the treatment process for water stabilization in the distribution system.
- E.coli results thus far indicate a need to test for Cryptosporidium moving forward to determine treatment per the LT2ESWTR. Cryptosporidium testing will begin on July 24, 2018.

- All organics (VOCs, SVOCs, PFCs, etc) were below the detection limit, except for Perfluorobutanoic Acid (PFBA), which was detected at 3.32 ng/L. There currently is no standard for PFBA, but the detected concentration is well below the NHDES ambient groundwater quality standard and EPA health advisory limit of 70 ng/L for PFOS and PFOA combined.
- Perchlorate was detected at 0.139 µg/L, which is well below the current standards for perchlorate (Massachusetts limit is 2.0 µg/L and California is 6.0 µg/L).
- SUVA values above 2 indicate that organics will need to be removed to prevent disinfection byproduct formation in the system. Organics will be addressed by the selected treatment process.

One item that was brought up during the meeting with LLCA on June 14, 2018 was the fact that the community treats the lake for milfoil. PEU has been following up with the LLCA to understand the treatment methods such that the appropriate analyses can be performed to determine any impacts that the milfoil may have on water quality at the proposed intake location.

3. Jar Testing – PEU has collected samples and performed bench top jar testing (see figure below) to determine the effectiveness of removing turbidity and organics via coagulation and flocculation. Based on the jar testing performed thus far, coagulation and flocculation appears to be an effective treatment option using ferric chloride at a pH of between 6.5 and 8 and a dose of 35 to 45 mg/L.



PEU will continue with Phase II of the CAP and will provide an update on the status of the existing wells and the new surface water source as they progress.

Attachments

1. LLCWS Summary Figures (2013-2018)
2. HSA well-siting geophysical survey results
3. Flow Duration Curve and Low Flows for Locke Lake Report
4. Water quality sample results
5. Jar testing report

JJB 4

GROUNDWATER DEVELOPMENT PROSPECTS AROUND THE LOCKE LAKE WATER SYSTEM BARNSTEAD, NEW HAMPSHIRE

Report

October 31, 2012

Prepared by
HydroSource Associates, Inc.
50 Winter Street, P.O. Box 609
Ashland, New Hampshire 03217
(603) 968-3733

HSA

HydroSource Associates, Inc.
Post Office Box 609 • 50 Winter Street • Ashland, NH 03217
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• website: www.teamhydrosource.com

October 31, 2012

Mr. John Boisvert, P.E.
Pennichuck Water Works
P.O. Box 1947
Merrimack, New Hampshire 03054

Dear John:

Attached is HSA's Phase I Report Entitled *Groundwater Development Prospects Around the Locke Lake Water System, Barnstead, New Hampshire.* The goal of this Phase was to identify promising locations for installation of wells that can be used to supplement the supply capacity of the Locke Lake water system in Barnstead.

As discussed, we assessed the hydrogeologic setting of the area proximal to the Locke Lake system with the goal of identifying general areas reasonably near the water system (e.g., within roughly two miles) where physical conditions appear most promising for developing new high-yield well sources that are likely to meet applicable drinking water quality standards and permitting requirements of the New Hampshire Department of Environmental Services (NHDES). The results of our hydrogeologic evaluation are highly encouraging and we have identified several locations that appear capable of supplying the quantity of water the system requires.

Within this report, we have also listed specific properties within each area that we feel are key in regard to gaining access for well siting purposes. Please note that digital tax maps are not available for the Town of Barnstead. As such, we had to manually digitize property boundaries from paper maps. Hence, you should consider the property boundary locations shown on our maps as approximately located. They are more than sufficient, however, for our current purposes.

Once you have reviewed the attached report, please give me a call if you have any questions or if you wish to discuss our conclusions or recommendations.

Sincerely,

Claude A. Cormier
President

CAC:cwr
attachment

GROUNDWATER DEVELOPMENT PROSPECTS AROUND THE LOCKE LAKE WATER SYSTEM BARNSTEAD, NEW HAMPSHIRE

October 31, 2012

INTRODUCTION

The following report summarizes HydroSource Associates' (HSA) groundwater resource evaluation of the area around the Locke Lake water system in Barnstead, New Hampshire, on behalf of Pennichuck Water Works. We understand that the facility would like to supplement its existing bedrock well sources that are distributed along the shores of Locke Lake, as these have experienced declining yields over the past several years.

Per Pennichuck's request, we have focused our evaluation on an area that is roughly two-miles in radius around Locke Lake, considering the potential of developing new wells in both sand and gravel and fractured bedrock aquifers. We have not taken into consideration areas that are within the Town of Alton due to franchise restrictions. We have also limited our assessment to the Suncook River/Upper Merrimack River watershed since water withdrawals from outside this area would qualify as an Inter-basin Transfer, and be subject to a host of additional state and federal regulations and permitting requirements.

HSA's hydrogeologic evaluation was performed with the objective of identifying the most promising locations for installation of wells that will provide maximum yields, as well as applicable drinking water quality standards and permitting requirements of the New Hampshire Department of Environmental Services (NHDES). The purpose of the evaluation was to identify specific areas, or Favorable Zones, where hydrologic, geologic and other physical conditions appear most promising and advantageous for developing suitable new groundwater sources.

Tasks undertaken in this evaluation included a review of published surficial and bedrock geologic maps and reports, hydrogeologic studies, records and reports from HSA's past work in this area, photolineament and Digital Elevation Model (DEM) analysis, an inventory of contaminant threats and construction information on local wells, and a site visit/inspection. As individual tasks were undertaken, information that is fundamentally geographic in nature was added to a GIS mapping database for analysis and map-making purposes.

HSA's conclusions reached based on our hydrogeologic evaluation are highly encouraging in regard to the prospect of identifying additional new well sources that can produce the water the system requires. Based on our assessment and past experience, it is reasonable to expect that new wells tapping local sand and gravel deposits could yield from 50 to perhaps as much as 250 gallons per day (gpd) or more, whereas new wells tapping fractured bedrock aquifers in the area could reasonably be expected to yield from 50 to 100 gpm or more.

Based on the results of these efforts, a number of specific areas that possess favorable hydrogeologic characteristics for developing high-yield groundwater supplies capable of satisfying the water demands of the Locke Lake system, and that are proximal to the existing water distribution system, have been identified. The locations of some of the areas identified for possible bedrock well development are within close proximity to the existing water system, and thus should result in minimal costs to connect.

Given the local geology, and as explained within this report, Pennichuck should expect that water produced from the local bedrock aquifers will likely be comparable to the water currently produced by its existing wells. While it is likely that some wells will produce better quality water than others, and may not require treatment, common water quality flaws in local bedrock wells that could be expected include elevated iron, manganese, arsenic, and/or hydrogen sulfide. Concentrations of radiological parameters can sometimes be elevated, but situations where they exceed acceptable Maximum Concentration Levels (MCLs) are rare.

By comparison, the local sand and gravel aquifers are likely to yield water that is generally of acceptable quality, with the possibility of elevated iron or manganese depending upon the nature and chemical composition of the local sand/gravel deposits, and the physical location of the well and degree of connection with nearby surface water bodies. As is often the case, a sufficiently thick overburden deposit that offers ample filtration and a more muted connection and/or greater infiltration path/distance from nearby sources of surface water recharge would be expected to present the least chance for elevated iron and/or manganese levels, and the Favorable Zones we identify herein that overlie presumed sand and gravel aquifers each appear to have the potential to host these types of hydrogeologic environments.

HYDROGEOLOGIC SETTING OF THE LOCKE LAKE AREA

Aquifer targets available in the Locke Lake area can be divided into two categories, surficial and fractured bedrock. Surficial aquifers are generally comprised of well-sorted and highly productive sand and gravel deposits that were laid down by glacial meltwater during the final retreat of the glaciers. In this case, we are searching for areas that host thick layers of permeable sediments that are saturated (below the water table). When sufficiently permeable and below the water table, sand/gravel deposits would be expected to offer ample available drawdown, while also allowing for a good length of well screen - both critical parameters that support high-rate groundwater withdrawal.

Fractured bedrock aquifers, on the other hand, exist where the local bedrock is fissured to the extent that it provides enough open space to allow for the storage and conveyance of groundwater. Optimal scenarios include those where there is a high frequency or density of fractures and/or when the fracture zones extend great distances, such that they are able to capture ample recharge as well as provide sufficient storage.

Areas where sand/gravel directly overlie fractured bedrock is considered especially promising since the overlying sand/gravel sediment would be expected to readily allow for abundant recharge to the underlying fracture systems to support high-rate pumping.

The hydrogeologic framework for both aquifer types was gleaned from a variety of published studies within the area. This includes the "Bedrock Geology Map of New Hampshire" (Lyons, et al., 1997) at 1:250,000 scale, which provides excellent regional-scale information on bedrock geology as wells as bedrock structures. The location and extent of the local sand and gravel deposits in the area was taken from "Geohydrology and Water Quality of Stratified-Drift Aquifers in the Upper Merrimack River Basin, South-Central New Hampshire" (USGS, 1997).

Surficial Aquifers

As shown on the attached map (Figure 1), two relatively large areas within the Suncook River drainage are covered by layers of stratified drift. Stratified drift was transported, deposited, and distributed by glacial meltwater and glaciofuvial processes. In the Locke Lake study area, they occur primarily in valleys or lowlands along the Suncook River.

The deposits are typically comprised of clay, silt, sand and gravel that have been sorted, layered and stratified to varying degrees. Coarse-grained stratified drift consists of layers of well sorted mostly coarse-grained sediments (sands and gravels) deposited by glacial meltwater at the time of deglaciation. Fine-grained drift deposits, consisting of primarily sand sized sediments, are also found within the study area.

According to the USGS (1997) report, the area immediately upgradient of Upper Suncook Lake is covered primarily by coarse-grained stratified drift, with a smaller, secondary area comprised mainly of fine-grained stratified drift flanking it to the northeast. The saturated thickness of the aquifer sediments reportedly approaches 120 feet within a portion of area covered by the drift deposits.

A larger, more laterally extensive area covered with coarse-grained stratified drift occurs near the confluence of the Big River and Suncook River drainages, extending along the Big River from Center Barnstead eastward toward Strafford County. The saturated thickness of this deposit is reportedly over 40 feet in some areas. The USGS (1997) shows at least one area within this deposit to possess a comparatively much greater rate of transmissivity, indicating that the gravel deposits here are highly permeable and could very well be an excellent environment for developing high-yield wells.

Glacial till covers essentially all the remaining area under consideration. Its thickness is commonly less than 15 to several tens of feet, although it can be as much as 100 feet or more in certain areas, particularly where the underlying bedrock has been over-deepened by glacial scouring, or beneath drumlins. The till is dense, poorly sorted sediment that contains rock fragments up to boulder size embedded in a matrix of clay and silt. It generally consists of locally derived bedrock that was ground up by the action of glacial ice into a chaotic mixture of rock flour and larger fragments, and in many places the material was deposited under the weight of a great thickness of glacial ice. The dense sediment that is often described as "hardpan" typically is till.

Although till can include isolated lenses of well-sorted sand and gravel that can produce modest amounts of water, it generally is not significantly water-bearing, and is considered to have very little groundwater development potential. However, even in instances where the grain size and sorting characteristics of these deposits do not allow them to support high-yielding screened wells, thick sequences of sandy till can often provide a dependable source of recharge to wells situated in hydraulically connected gravel deposits, or those tapping underlying bedrock fracture networks.

Bedrock Aquifers

Bedrock underlying the study area consists of variably metamorphosed sedimentary and volcanic rocks of the Central Maine Trough. These rocks exist within a structural boundary that is further subdivided as the central New Hampshire anticlinorium containing metamorphic rocks of the Devonian and Silurian periods including gneiss, schist, and quartzite. These rocks were locally intruded by granite, granodiorite, syenite, and monzonite of the Devonian period.

The following rock types are mapped in the area: gray, thinly laminated metapelite (schist), rusty weathering pelitic schist, metasandstone, and ribbon banded calc silicate (southeastern portion of study area) (Figure 1). In some areas, these rocks have been intruded by the Concord Granite, a two-mica granite that can grade locally to a tonalite. Overall, the rock types exist as a layered package. They have been subjected to multiple periods of metamorphism and deformation. The rocks have been broadly folded, resulting in undulating contacts between rock types and map patterns. In some cases, differential weathering and erosion have resulted in the bedrock structure strongly influencing surface topography.

No primary porosity or permeability are expected in these rocks. Groundwater occurs in them in useful quantities only in zones of interconnected fracturing and/or faulting. Although there are no mapped bedrock faults within the study area, the area lies within the Concord tectonic zone and areas of high-density, local bedrock fracturing do occur. Such areas often constitute productive bedrock aquifer systems that can sustain high-rates of water withdrawal, especially where more than one fracture system intersect and/or when the fracture systems are in hydraulic communication and can receive recharge from overlying saturated sediments or induce infiltration from nearby surface water bodies.

Lineament Mapping/Fracture Trace Analysis

Photolineaments, sometimes referred to as "fracture traces", are linear or semi-linear features that can be seen on photographic imagery of a landscape, and which may represent the surface expression of faults and fracture zones in the underlying bedrock. Identification of such structural features is one common component of groundwater exploration and development efforts since bedrock fracture networks, where saturated and sufficiently open to allow groundwater to readily flow through them, comprise productive aquifer systems. As mentioned, because fault and fracture zones represent zones of bedrock weakness, they are also most often locations of glacial scouring and over-deepening where thick surficial sediments can be deposited, often resulting in the formation of productive overburden aquifers. Therefore, information analyzed in this effort was not only used to identify areas where bedrock aquifers may be present, but also where such over-deepened valleys may exist given the structural setting.

Lineaments can be mapped using a variety of imagery including aerial photographs (viewed stereographically), airborne radar images, topographic maps, and Digital Elevation Models (DEMs). To analyze structural trends and identify geologic features of interest in groundwater development, HSA obtained a series of aerial photographs at a scale of 1:40,000 covering the study area. The air photos were examined stereographically to search for indicators of bedrock structures that possess the necessary characteristics making them promising groundwater development settings. Similar analyses were performed of topographic maps of the region.

HSA also obtained and evaluated Digital Elevation Model (DEM) data for the study area. One such DEM view is provided as Figure 2. When displayed on a computer screen with the appropriate computer software (e.g., a Geographic Information System or GIS), DEMs can provide a nearly infinite variety of three-dimensional perspectives of topography, geomorphology and geologic structure unavailable from traditional two-dimensional topographic and geologic maps. For this project, it was possible to view the Locke Lake area from a number of different perspectives (angles of declination, azimuths, sun angles), scales and color schemes. The DEM data was processed to show specific patterns and to enhance different structural and topographic features of interest such as potential bedrock faults and fracture zones. To further analyze the structural features of the area, some of the DEM perspectives viewed and analyzed for the project were combined with various digitally-input layers of two-dimensional information, such as published geologic maps that show lithologic boundaries and mapped structural features.

Along with lineaments generated from aerial photography and DEM analyses, HSA transferred prominent lineaments from the USGS lineament map (USGS OFR 97-763) for the area to the GIS database for the project. A composite map of lineaments identified during our analysis is given in Figure 2.

A number of prominent and/or laterally extensive linear features were observed in the uplands areas that may correspond with interruptions or dislocation of the crystalline rocks. Several lineaments likely represent areas where the bedrock is more intensely fractured, resulting in the formation of bedrock aquifers. Overall, the dominant lineament orientation is northwest-trending with less frequent northeast-trending lineaments intersecting the dominant trend.

Lineaments and structural features that are of particular note include a prominent northwest-trending lineament that roughly parallels the axis of Locke Lake. It appears to extend for over eight miles and extends through an area near the local airstrip where several very high-yielding wells are present. Lineaments along the northeast and southwest shores of Upper Suncook Lake are also especially strong, and correlate well with separate clusters of several very-high yielding wells in each of these areas.

Finally, the areas underlain by stratified drift deposits nearly all correspond with at least one, and usually multiple lineaments. That is not surprising since these deposits often fill areas of over-deepening, which are also areas that have likely been preferentially scoured by glacial ice movement, with the over-deepening occurring as a result of the rock being weaker in these areas, presumably because it is more intensely fractured.

Site Inspection

As part of this first phase of our groundwater investigation, HSA made a field visit to the area. During this field trip, an inspection of surficial deposits, bedrock outcrops, geomorphology, logistical/site-conditions in regard to wetlands, and equipment access were assessed for areas considered possible candidate sites for potential new well siting and development. Observation/field-stop locations are shown on Figure 3. Particular points pertinent to the feasibility of developing new groundwater supplies for the Locke Lake system are discussed below within the description of individual Favorable Zones.

Well Data

Well information was obtained from the NHDES. Most wells drilled in the area are for domestic purposes, and although there are a few shallow dug wells and USGS borings included in the NHDES database, the vast majority of wells were completed in bedrock. As such, when evaluating well information, it is important to note that domestic well locations are commonly chosen for convenience, and not based on sophisticated means with the objective of maximizing yield potential. They are commonly located out of the main valleys where major bedrock structures typically are located.

They are also largely found in the upland areas, which are covered by till deposits, thereby necessitating the installation of bedrock wells. Even if located where sand and gravel deposits are present, most home well drillers do not install screened overburden wells simply because they either lack the capability to do so, or they use a mud-rotary installation method that precludes installation of a screened overburden well. Typically, if gravel is suspected and the well is completed to utilize the overburden aquifer, domestic well drillers will complete the well as an open-end, six-inch diameter casing without screen because it can provide sufficient production for domestic purposes. A properly designed, larger diameter well that is screened over the full thickness of the aquifer can usually produce substantially greater yield. Furthermore, even drilling into bedrock is usually terminated at a relatively shallow depth in domestic wells, usually once sufficient water is developed (typically after only a few gallons per minute are produced). Thus, such locations are not completely tested for their full yield potential.

We note that there are a high number of bedrock wells within the study area with a reported yield of at least 30 gpm. A good number of these have reported yields of 100 gpm or more, indicating that a substantially fractured bedrock aquifer is present with considerable productive capacity. Several such wells are located along the northeast shore of Upper Suncook Lake, with another grouping near the Lake's southwest end. A third cluster of relatively high-yield wells exists near the airstrip next to Halfmoon Lake. Yet another grouping occurs within the area along the Big River, just east of Center Barnstead.

It is worth noting that several exploratory wells/borings were completed by the USGS within the stratified drift deposits mapped in the area. It appears that the primary objective in these drilling efforts was to identify the nature and thickness of the stratified drift deposits. One such test well identifies a bedrock depth of 109 feet within the area just upgradient from Upper Suncook Lake. Some of the test wells that were drilled in the stratified drift deposit present along the Big River drainage were yield tested, albeit for only a brief time. One such well (WRB# 14.003), which is only 10 feet deep, has a tested pumping rate of 30 gpm. Another well in the area (WRB# 14.0107) has a reported test rate of 300 gpm, while being constructed to a total depth of only 11 feet.

Contaminant Threats Check

To preliminarily identify and exclude areas that may be unacceptably vulnerable to potential sources of contamination, HSA obtained information on potential sources of contamination sites registered with NHDES and the United States Environmental Protection Agency (USEPA). Potential threats observed during field activities were also noted. Types of potential contaminant threat facilities can include: remediation and/or environmental cleanup sites; petroleum storage; facilities registered as producing or storing regulated substances; spill sites; landfills; industrial operations; concentrated areas of septic systems, etc.

The majority of contaminant threats listed in the queried databases represent individual underground storage tank locations or relatively small fuel spills that were reported and addressed. Of particular mention is one that the USEPA environmental databases list as a potential contaminant threat at 72 South Barnstead Road near the intersection with Depot Street, at a location known as the 'Rogers Property.' This property has been designated as a 'brownfields' rehabilitation site by the USEPA. There have historically been reports of fuel and chromium releases at this property.

Another notable potential contaminant threat is located approximately 1,800 feet to the southwest at the former Timco Facility. This facility was cited for PCE and fuel contamination in the past, but has presumably been remediated and received a 'no further action' letter from the USEPA.

A 'brownfields' property cited for fuel, asbestos, and VOC contamination, known as the "Leemay Property", was identified at the listed address of 3 and 6 Sawmill Road in Gilford, but shown on the

USEPA database off Gray Road in Barnstead. We assume that the mapped location of this site is incorrect as this area along Gray Road appears to be entirely rural residential. Hence, we do not believe that this site presents a risk to groundwater sources in the present study area. This property was also reported to have been remediated in 2006.

Other potential threats depicted on the attached map are for sites that report their activities to the USEPA, due to the hazardous materials used on their properties, but have no history of reported contamination. Some of these facilities are discussed below, as warranted. Additional potential contaminant threats observed during the site visit are summarized below under the Favorable Zones section.

Recharge Assessment

Reliable well water supplies require a source of replenishment, or recharge, and successful development of groundwater resources requires locating wells in areas where sufficient recharge is available. One variable that helps determine the favorability of particular areas for groundwater development is the rate at which groundwater is naturally replenished to those areas.

Groundwater recharge estimates are used as a preliminary measure to assess the amount of water that may be safely and reliably extracted from specific areas on an indefinite basis, without creating adverse environmental impacts, or to a point where well extractions are no longer sustainable. This is performed in the early stages to ensure that areas considered for developing groundwater sources possess sufficient available water before further investment is made.

Recharge of groundwater occurs by direct infiltration of precipitation, snowmelt and surface water into unconsolidated deposits and/or through unconsolidated geologic deposits into underlying fractured bedrock. The amount of recharge available to a well depends on the specific location of the extraction point within the recharge area, the size of individual contributing drainage basins, and the extent and degree of interconnection between the aquifer and the source of recharge.

High yielding aquifers are usually directly or indirectly connected to surface water bodies from which they derive their recharge. As opposed to the open pore space which acts to store and transmit water in a sand and gravel aquifer, wells that tap high-yielding bedrock aquifers require the presence of an interval of fracturing in the well with sufficient interconnected open space to allow groundwater to flow into the well from the surrounding fractured rock at a rate at least as high as the desired pumping rate.

A qualitative assessment was performed of the recharge potential to candidate areas for groundwater development. This assessment is based on the concept that recharge potential is a function of watershed size, precipitation amount, and the permeability and expected thickness of surficial sediments, and thus anticipated available recharge. It is also predicated on the fact that in some cases groundwater can be drawn from beyond topographic drainage divides. This is especially true for bedrock wells that tap structures like faults that often extend beyond topographic boundaries.

Regardless, the relationship between watershed-specific factors and sustainable yield is proven, and the conclusion that sustainable yield generally shows a correlation with watershed size is a dependable one.

A number of extensive watersheds are present in the study area near the Locke Lake system that would be capable of providing substantial available groundwater recharge to support well extractions in the range of up to several hundred thousand gallons per day, and the Favorable Zones described below are each situated such that if a productive aquifer is present, it has a good chance of being hydraulically connected to such a dependable source of recharge. The lakes associated with the Suncook and Big River watersheds, as well as the rivers themselves should easily be able to provide at least this amount of recharge to support groundwater extractions in their respective areas. The potential recharge would be expected to be especially high to each of the areas where sand and gravel overburden is present. It should be available regardless of whether a screened well or bedrock well is ultimately developed, as the potential for inducement of recharge from these surface water bodies and watersheds to sand and gravel aquifers, and then to any underlying bedrock fracture networks in these areas is very high.

Favorable Zones

The following areas are recommended for consideration in regard to developing additional productive groundwater sources to supplement the water supply capacity of the Lock Lake system. We have ranked them in three categories according to perceived yield potential, with the "A" Zones expected to offer the greatest promise, and the "C" Zones the least. Affected property owners for each Favorable Zone are depicted in Figure 4.

"A" Zones

Note that all the "A" Zones offer the potential of developing a sand and gravel well, while some overlie areas where productive bedrock aquifers may also be present. In these cases, even if a productive sand and gravel aquifer does not occur, the overlying permeable sediments would be expected to allow comparatively higher rates of infiltration and greater amounts of recharge to underlying fracture networks, and thus more likely support higher rates of withdrawal from the bedrock in comparison to areas with lower permeability overburden (e.g., glacial till). The likelihood for well yield declines over time should also be lessened significantly in these areas as a result.

A1 - There is the possibility of developing either a sand/gravel or bedrock well in this area. First, it overlies stratified drift within the Suncook River valley, and information in the USGS Water Resources Investigations Report 95-4123 on Stratified Drift Aquifers in Upper Merrimack River Basin shows that wells located in the vicinity intersected from 30 to as much as 50 feet of predominantly well-sorted sand. A number of former sand and gravel pits are located in the surrounding area, and sand is the dominant sediment seen in most of the local excavations. However, coarse, well-sorted gravel was observed along White Oak Road immediately adjacent to this site. This deposit appears to be highly permeable, and would likely comprise a highly productive aquifer if it extends below the water table.

The USGS (1997) also shows that an over-deepened area with a saturated thickness of up to 120 feet is present beneath this location. If the sand/gravel deposits extend to even one third to one half of this depth, they could provide a substantial amount of available drawdown to support high-rate pumping. Our objective here would be to find a location where the sediments are coarsest and most permeable while also maximizing saturated thickness as a means of optimizing potential well yield.

Overall, the sand and gravel is likely to yield water that is of acceptable quality, with the possibility of elevated iron or manganese depending upon the nature and chemical composition of the local sand/gravel deposits, and the physical location of the well and degree of connection with nearby surface water bodies. A sufficiently thick overburden deposit that offers ample filtration and a more muted connection and/or greater infiltration path/distance from nearby sources of surface water recharge would be expected to present the least chance for elevated iron and/or manganese levels.

As mentioned, this area overlies an over-deepened bedrock valley which is marked by prominent lineaments, and bedrock wells reportedly yielding 25 to 100 gpm are located nearby. The rock type that underlies this area is mapped as a unit of the Rangeley Formation that varies only slightly from the lithology underlying the Lock Lake system's current wells. Hence, while it is possible that water chemistry from a bedrock aquifer here could be different than that observed from existing wells in the Peacham Road area, it is more likely to be similar in general. A 1996 report that HSA had prepared for Integrated Water Systems also describes this area, and how local bedrock well owners have reported elevated levels of iron and hydrogen sulfide in their well water.

The area is limited in size, but may be able to accommodate up to a 400-foot protective radius if the protective area were allowed to overlap onto the north side of the Suncook River. A smaller radius required for a well yielding less than 100 gpm should certainly be possible.

Recharge should also be ample to support high-rate pumping given the size of the upgradient watershed, and access for well installation equipment from White Oak Road appears reasonably good. The Town of Gilmanton's Highway Garage is located about 1,000 feet to the west. Above ground fuel storage tanks are present here, as is covered road salt storage. HSA's 1996 report explains that the Garage has a dug well on-site that had not shown signs of contamination. Pine Grove Cemetery is located along Stage Road, about 2,000 feet to the west. Otherwise, the area is sparsely developed and significant contaminant threats were not observed to be present.

Key Property: 417-008

A2 - Zone A2 is similar to Zone A1 in nearly every hydrogeologic respect as it is located directly across White Oak Road, and like Zone A1, there is the possibility of developing either a sand/gravel or bedrock well here. One difference is that well information in this area suggests the underlying sediment is mainly comprised of fine sand that is up to a maximum of 50 feet thick. This area is also fairly large in size and should allow for up to a 400-foot protective radius depending upon where a well is developed. Part of the area is occupied by wetlands which may need to be crossed, again depending upon where a well may be developed. As described in its 1996 report, HSA had conducted limited reconnaissance geophysical investigations on property in this area previously. Further work toward identifying both sand and gravel and bedrock well targets was recommended based on those initial investigations, which suggested promising conditions for development of productive wells.

Key Properties: 417-012 417-013

A3 - This Zone is in the same general area as Zones A1 and A2. It overlies the Upper Suncook Recreation Area that is adjacent to Upper Suncook Lake.

Several high-yield bedrock wells are located along the shore of Upper Suncook Lake to the immediate southeast. These suggest that this area may overlie a prolific bedrock aquifer. They also indicate that the bedrock may have preferentially scoured and over-deepened here, signifying the potential for the development of thick overburden sediments. No well data is available to confirm the type of overburden sediments that may be present beneath this site; however coarse gravel was observed in a local streambed.

The chemical composition of water in either the sand/gravel or bedrock is expected to be comparable to that described for Zone A1. Recharge should also be ample to support high-rate pumping. The area could allow for up to a 400-foot protective radius depending upon where a well is developed, and access to and within the area for well drilling equipment appears to be very good as most of the area is dry and existing roads and/or trails are already available.

Key Property: 13-6

A4 - Zone A4 overlies the area of and near the Sun River Campground, located east of Route 28 and approximately 1,500 feet north of the Center Barnstead Elementary School. It is an area HSA had recommended considering for groundwater source development in its 1996 report to Integrated Water Systems.

The area is mapped by the USGS as being underlain by a stratified drift aquifer, although the USGS reports that the aquifer is likely to be relatively thin. Test pits performed in the area in 1996 showed a wide variety and distribution of glacial deposits, and a number of sand/gravel pits are present is the surrounding vicinity.

As explained in HSA's 1996 report, bedrock exposures occur nearby on the north side of the Suncook River. The bedrock surface appears to drop off to the south under the Suncook River close to northern portion of the Campground area, and bedrock contour data generated from nearby wells, and preliminary geophysical surveying HSA conducted at the site in 1996, indicate the possible presence of an over-deepened area in the vicinity of Route 28. The bedrock trough may be structurally controlled and could host either water-bearing overburden deposits and/or bedrock fractures. As described in HSA's 1996 report, the exact location of the trough has not been determined and it may be too close to Route 28 to meet the protective radius requirements for the development of public water supply wells. Further geophysical testing would be required to determine its actual location.

It is possible that local recharge to deep overburden or bedrock wells could be impeded by the presence of lacustrine clay sequences. However, in general, available recharge should be substantial given the extensive upgradient watershed of the Suncook River.

The chemical composition of water in either the sand/gravel or bedrock is expected to be comparable to that described for Zone A1.

Other than the Campground, the area is mostly forested and undeveloped. Gravel mining operations, fuel storage tanks, leach fields, and industrial facilities are located in the surrounding area, but they are all fairly substantial distances away, and almost entirely downgradient. Fuel and salt storage at the Barnstead Town Garage presents perhaps the most significant contaminant threat in the area. It is located about 1,000 feet to the southwest.

Access to the Sun River Campground area, although extensively wooded, is expected to be reasonably good for well installation purposes as there are multiple existing accessways through the Campground area. However, if a well were to be developed here, Campground activities would most likely have to be significantly modified or eliminated in order to meet State regulatory setback requirements.

Key Property: 7-72

A5 - This area overlies the intersection of the axes of the Suncook and Big River valleys. A prominent linear feature has been identified that coincides with the Suncook River drainage. There may also be one associated with the Big River; however, this valley is largely covered with relatively thick glacial drift deposits that obscure structural evidence, and well-sorted sand was observed overlying much of the area within and around this Zone. Thus, there is the possibility of developing either a sand/gravel or bedrock well in this area.

The USGS has mapped the overburden in this area as possessing up to 40 feet of saturated thickness, and shows a well roughly 1,000 feet to the north that encountered 30 feet of sand. A 10-foot deep dug well immediately to the north reportedly yields up to 30 gpm.

Again, our objective here would be to find a location where the sediments are coarsest and most permeable while also maximizing saturated thickness as a means of optimizing potential well yield.

The predominant rock type underlying this area is the Concord Granite, and it is possible that a bedrock aquifer in this formation could produce water that is lower in iron, manganese and hydrogen sulfide in comparison to those in the Rangeley Formation. Because it is a two-mica granite, it occasionally can produce water with elevated levels of radionuclides. Elevated radionuclide occurrence above established MCL's is usually highly location-specific, however, and is not usually ubiquitous throughout the formation.

Similar to other Zones above, the sand and gravel is likely to yield water that is generally of acceptable quality, with the possibility of elevated iron or manganese depending upon the nature and chemical composition of the local sand/gravel deposits, and the physical location of the well and degree of connection with nearby surface water bodies. A sufficiently thick overburden deposit that offers ample filtration and a more muted connection and/or greater infiltration path/distance from nearby sources of surface water recharge would be expected to present the least chance for elevated iron and/or manganese levels.

The area is limited in size, but may be able to accommodate up to a 400-foot protective radius depending upon where a well may ultimately be located. A smaller radius required for a well yielding less than 100 gpm should certainly be possible.

Recharge should be more than ample to support high-rate pumping given the size of the upgradient watersheds and the fact that the area is at the confluence of two river systems. Access for well installation equipment from Sandy Point Road appears very good and the area within the Zone is all relatively dry.

The area within the Zone is undeveloped, and the surrounding area is residential, but only modestly populated. A former industrial facility, Timco Inc., is located between 600 and 1,000 feet away, across the Suncook River to the northwest. According to online sources, Timco, Inc. was formerly known as Pittsfield Box and Lumber and changed its name to Timco, Inc. in 1981 as a result of its acquisition by Aquarion Company. We understand that as of 2003, Timco, Inc. went out of business. Timco, Inc. reportedly engaged in lumber manufacturing and timber processing, and was cited for PCE and fuel contamination in the past. The USEPA lists that the site has since been remediated, and has received a 'no further action' designation.

The USEPA environmental databases also lists a brownfields site at 72 South Barnstead Road, at a site known as the "Rogers Property". There have reportedly been past fuel and chromium releases at this location. This site is roughly 2,500 to 3,000 feet from Zone A5, and across the Big River. As such, it is unlikely to present a significant risk of contamination to a groundwater source here. However, the current status of the brownfields redevelopment process is unclear and it would be prudent to make a preliminary assessment of its status prior to undertaking further groundwater development activities in this Zone.

Key Property: 7-31-1

A6 - No significant structural or linear features are apparent in this area. Hence, this area is considered solely for the purposes of sand/gravel well development, although it does overlie the axis of the Big River valley, and thus there could be fracture networks associated with the valley present beneath the area. Regardless, the gravel observed in this area appears to be coarse, well-sorted and highly permeable. A well near the western edge of the Zone is reported to have penetrated 40 feet of coarse sand and gravel, and the USGS has mapped the stratified drift aquifer beneath this area as having the greatest transmissivity in comparison to all other sand/gravel areas in the Town of Barnstead. This suggests a very high likelihood of developing a very productive sand and gravel well in this area.

An access road and structures are visible within the Zone on aerial photography; however, nearly all other buildings and local residences are over 1,000 feet away. Gravel mining operations are present in the vicinity, the closest being about 1,500 feet from the center of the Zone. Otherwise the area is undeveloped and should easily accommodate a 400-foot protective buffer.

Water quality in the sand and gravel is expected to be similar to that described for other Zones. In regard to aquifers in the bedrock, the area is underlain by the Perry Formation, which is comprised partly of quartzites, and may yield water that is slightly better in overall quality than the Rangeley Formation.

Recharge potential is considered excellent as the area is within the Big River valley. Access for well installation equipment should be very good to large portions of the Zone as the area appears to be traversed by multiple dirt roads and trails.

Key Properties: 7-65-1 7-43 7-60

"B" and "C" Zones

Nearly all of the following "B" and "C" ranked Zones are considered solely areas where bedrock aquifers may exist. With the possible exception of Zone B2, sand and gravel aquifers are not expected to be present in these areas. In general, the "B" Zones overlie areas where the combination of hydrogeologic factors required to support a productive fractured bedrock groundwater source appear to be more favorable, such as number and strength of linear/structural features suggesting underlying bedrock fracturing, recharge potential, source protection, etc. Note also that the bedrock formations that underlie each of the "B" and "C" Zones are generally similar in chemical composition. Hence, the quality of water produced by wells developed in each of them is also expected to be comparable.

The "C" Zones are similar in most respects to one another when it comes to their hydrogeologic and logistical characteristics. In general, lineaments over which they are situated are less strong, suggesting the yield potential in these areas, while still enhanced in comparison to most areas, is still less than in the "A" or "B" Zones. Available recharge to the "C" Zones is also expected to be more limited in most cases. For these reasons, we recommend that the "C" Zones be considered as alternate areas that should be pursued only if other "A" or "B" Zones cannot be developed for some reason. As such, we do not include detailed summaries of the "C" Zones.

B1 - This area overlies an undeveloped piece of property at Camp Fatima on the northwest shore of Upper Suncook Lake. While the USGS has mapped a stratified drift aquifer as overlying this area, local well data indicates that the overburden primarily consists of very fine sand and silt that is relatively thin, and thus is not expected to be capable of supporting a highly productive screened well. The overlying sand should provide ample groundwater storage and allow for a relatively high rate of infiltration of recharge to an underlying fractured bedrock aquifer, however; and this Zone straddles an over-deepened trough through which a prominent structural lineament extends, suggesting a heightened possibility that the underlying bedrock could be fractured. Recharge to support groundwater withdrawals should be abundant given the Zone's physical location, and the area should easily accommodate up to a 400-foot protective radius. Access for well installation equipment to much of the Zone should also be good as there are existing roads and trails that traverse the area.

Key Properties: 14-23 14-20

B2 - This area is across White Oak Road from Zone A3 and the Upper Suncook Recreation Area. It is considered primarily an area that may overlie a productive bedrock aquifer. Sand and gravel may be present beneath the area, although it is likely to be too thin to support a high-yielding well. It straddles a prominent structural lineament, and is adjacent to multiple wells that report yields ranging from 25 to 60 gpm.

The area is limited in size, but may be able to accommodate up to a 400-foot protective radius depending upon where a well may ultimately be located. A smaller radius required for a well yielding less than 100 gpm is more likely. Several residences are located in the surrounding area that presumably have private septic systems and domestic wells that will need to be addressed were a production well to be developed here. Access for well drilling equipment to much of the area should be relatively straightforward.

Key Properties: 14-20 14-18

B3 - This general area was recommended for consideration in regard to developing additional groundwater resources by HSA in its 1996 report to Integrated Water Systems. Zone B3 straddles an intersection between strong structural lineaments that extend through the area northwest of Halfmoon Lake. Two wells have been identified immediately to the north of one of the lineaments that presumably yield 20 and 25 gpm. Several wells are present along the projection of the lineament to the southeast, across Halfmoon Lake, that are reported to range in yield from 20 to as much as 100 gpm. These wells are in the vicinity of Pennichuck's Airstrip source.

The upland watershed area above the Zone is modest in size, and could limit the amount of recharge available here. However, recharge could be greatly enhanced if the structural feature shown in this area corresponds with an underlying fracture network that extends through Halfmoon Lake.

A wetland is present between the southeastern edge of the Zone and Route 28. Thus, access would have to be via Bartlett Road, Olde Farmington Road or N Road. The area is forested, the local valley is wet in places, and moderately steep slopes occur is some of the area, as well, which could make access for equipment somewhat challenging depending upon where a well may be located. The surrounding area is only sparsely developed and should offer very good source protection as well as accommodate up to a 400-foot protective radius.

Key Properties: 14-19 14-22

B4 - This area is located adjacent to Zone B3 above, on a roughly parallel but somewhat less prominent lineament, and the same hydrogeologic and logisitical characteristics described for Zone B3 apply here, although access to the area is expected to be less burdensome as this area is positioned closer to N Road, and the slopes of the local ground surface as less severe.

Key Property: 13-9

B5 - This Zone overlies a large tract of undeveloped land across Route 28 from the Locke Lake area through which an extensive, prominent linear feature extends. The upland watershed area above the Zone is modest in size, and could possibly limit the amount of recharge available to a well here. However, recharge could be greatly enhanced if the structural feature we have identified corresponds with an underlying fracture network that extends some distance, as suggested by the lineament. A low-yielding well that used to serve the Locke Lake system is present on Danbury Road across Route 28 from this Zone's northeastern edge.

The area should be able to accommodate up to a 400-foot protective radius, and given the undeveloped nature of the area, source protection should be very good. A wetland is present between the southeastern edge of the Zone and Route 28. Otherwise, the area appears to be reasonably accessible for equipment.

Key Properties: 417-023 9-1

B6 - This area is on the peninsula that separates the southern shores of Upper and Lower Suncook Lakes. It is along two strong structural lineaments, and several wells reporting yields of 30 to 100 gpm have been mapped nearby. In fact, there are reported to be a 50-, 90- and two 100-gpm wells clustered within about 1,000 of this area, indicating that the underlying bedrock is highly fractured.

This Zone is limited in size due to the Lake to the north and residences to the south. The Zone itself, however, appears to be undeveloped, and thus should provide good source protection. Although the area is limited in size, it may be able to accommodate up to a 400-foot protective radius if the protective area were allowed to overlap onto the lake. A smaller radius required for a well yielding less than 100 gpm should be possible. Its location near the lake should also offer excellent recharge potential to support high-rate groundwater withdrawals.

Key Property: 9-302(?)

CONCLUSIONS AND RECOMMENDATIONS

There appear to be multiple opportunities within the study area for development of new groundwater sources with the potential to produce substantial, sustainable additional source capacity for the Locke Lake system. In addition, there are many promising areas for exploration that appear well protected from potential sources of contamination, and that could satisfy the well-siting requirements of the NHDES regulations. Access for well drilling equipment to most areas also appears to be relatively straightforward. Ample amounts of water in the form of recharge should also be available given the size of the local watersheds.

The areas described above each possess a combination of hydrogeologic and physical characteristics indicating a high likelihood that productive aquifers are present in the earth's subsurface beneath these areas. We recommend Pennichuck focus their future water supply development efforts in these areas, and that the "A" Zones be a primary focus of these efforts, if possible and practical, given the increased groundwater supply development potential these areas appear to clearly offer over the others.

If Pennichuck chooses to conduct further well development work, the next step should be to acquire permission to access properties we have identified. This would be followed by well-siting geophysical surveys over the properties to assess subsurface conditions, and to precisely identify locations for installation of test wells.

Because we do not yet know which Zone(s) will provide the most advantageous combination of both yield and water quality, we recommend that Pennichuck pursue multiple areas. Experience has shown that project success is best assured by planning for and testing multiple targets in different hydrogeological environments. We recommend that Pennichuck plan for and make preparations to survey multiple properties that are distributed over at least two or three of the Zones we have identified.

Well siting surveys are recommended to evaluate the subsurface conditions beneath the surveyed properties. They are used to determine the most promising locations at which to install test wells on a specific property, as well as to compare candidate sites and conditions amongst multiple properties so that investment in well installation and development is directed to the most promising hydrogeologic environments available, as the surveys typically show that some properties offer better conditions for developing a productive well than others.

Overall, the favorable confluence of individual hydrogeological factors assessed as part of this evaluation indicates that there are a number of specific areas within which development of new, highly productive groundwater sources can be achieved. Based on the information researched as part of this evaluation, we are confident that new groundwater sources capable of providing the yield sought by Pennichuck for the Locke Lake system can be developed in one or more of the areas we have identified.

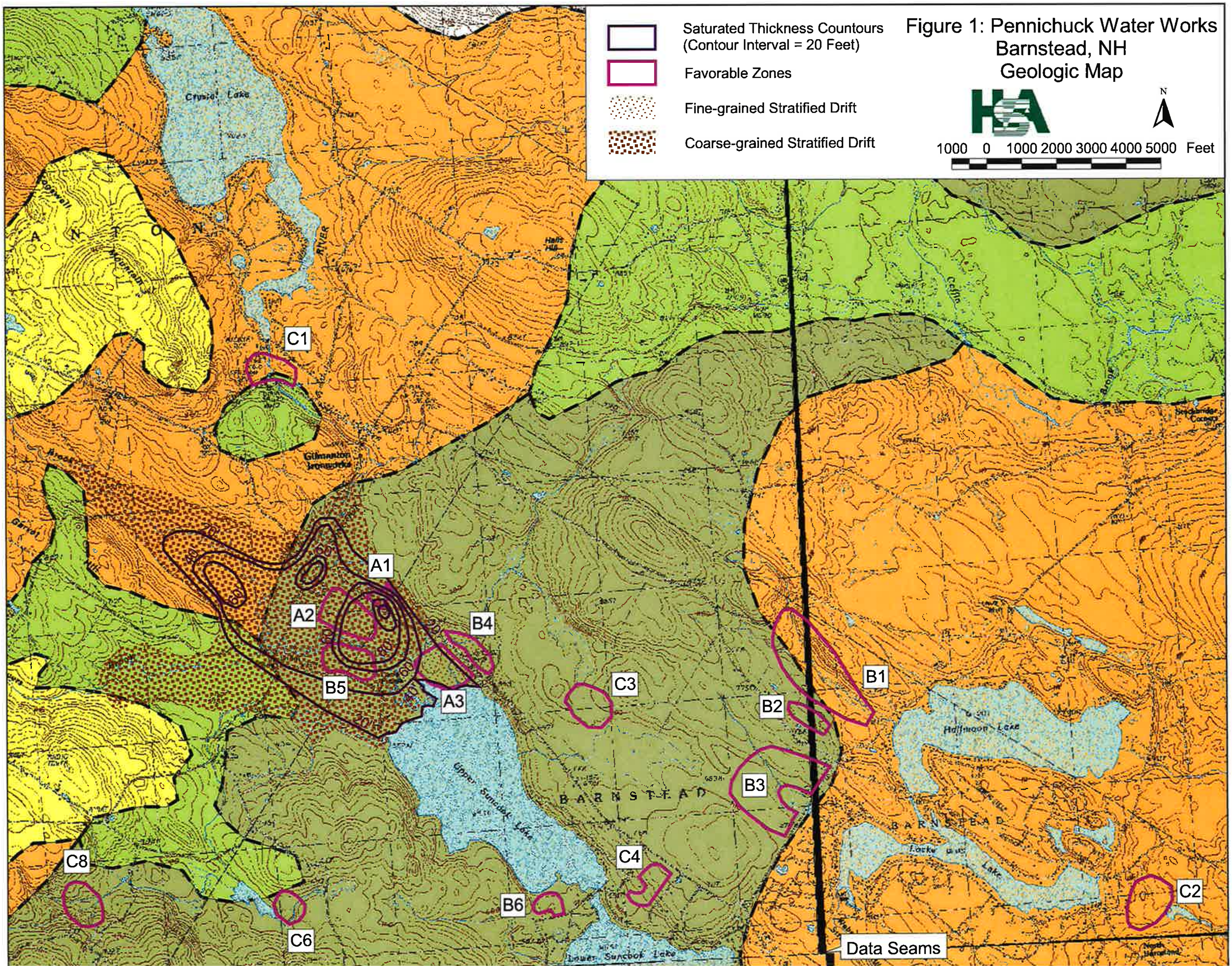


Figure 1: Pennichuck Water Works
Barnstead, NH
Geologic Map

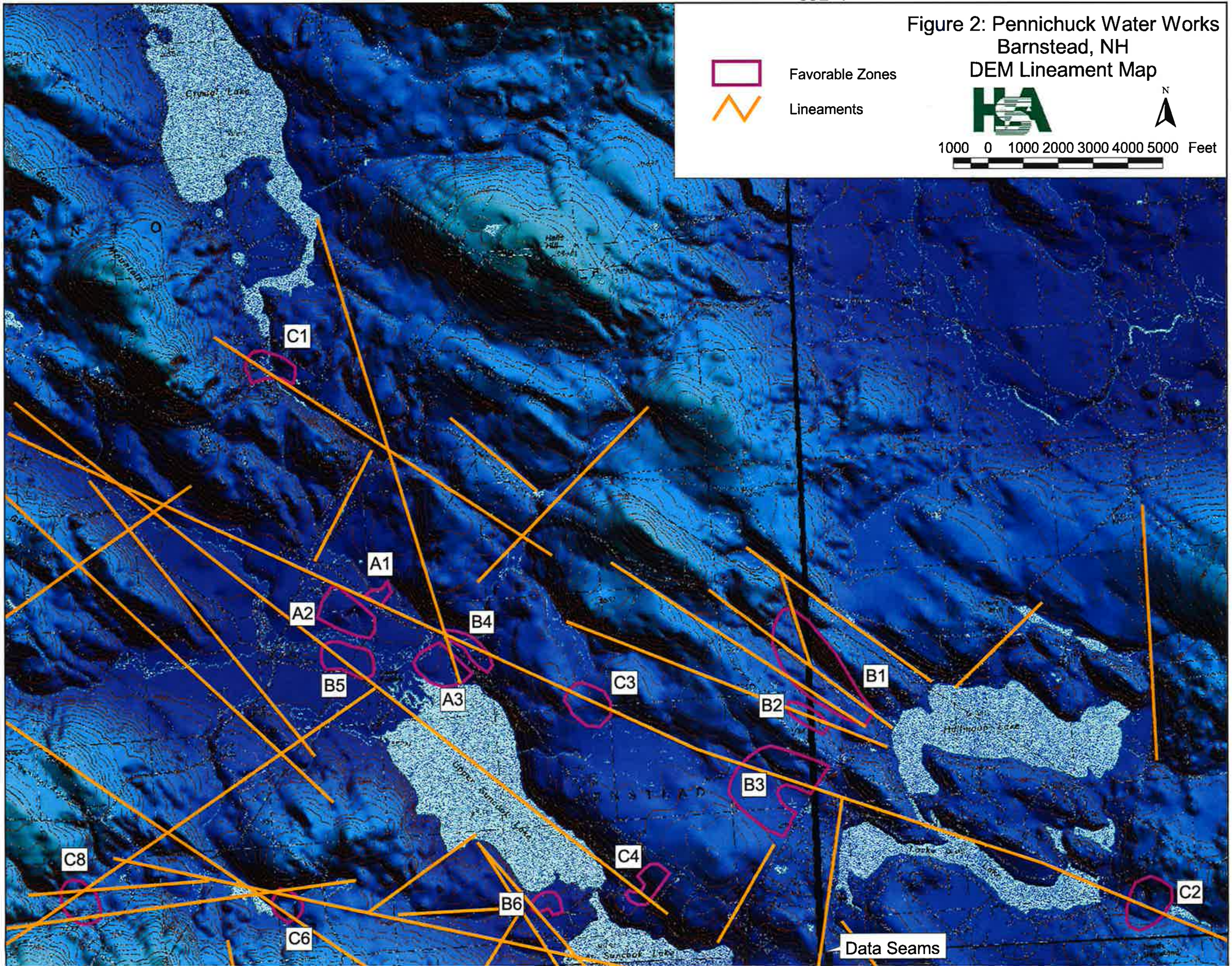


Figure 2: Pennichuck Water Works
Barnstead, NH
DEM Lineament Map
Favorable Zones
Lineaments
1000 0 1000 2000 3000 4000 5000 Feet
N
C1
A1
A2
B4
B5
A3
C3
B1
B2
B3
C4
C8
B6
C6
C2
Data Seams

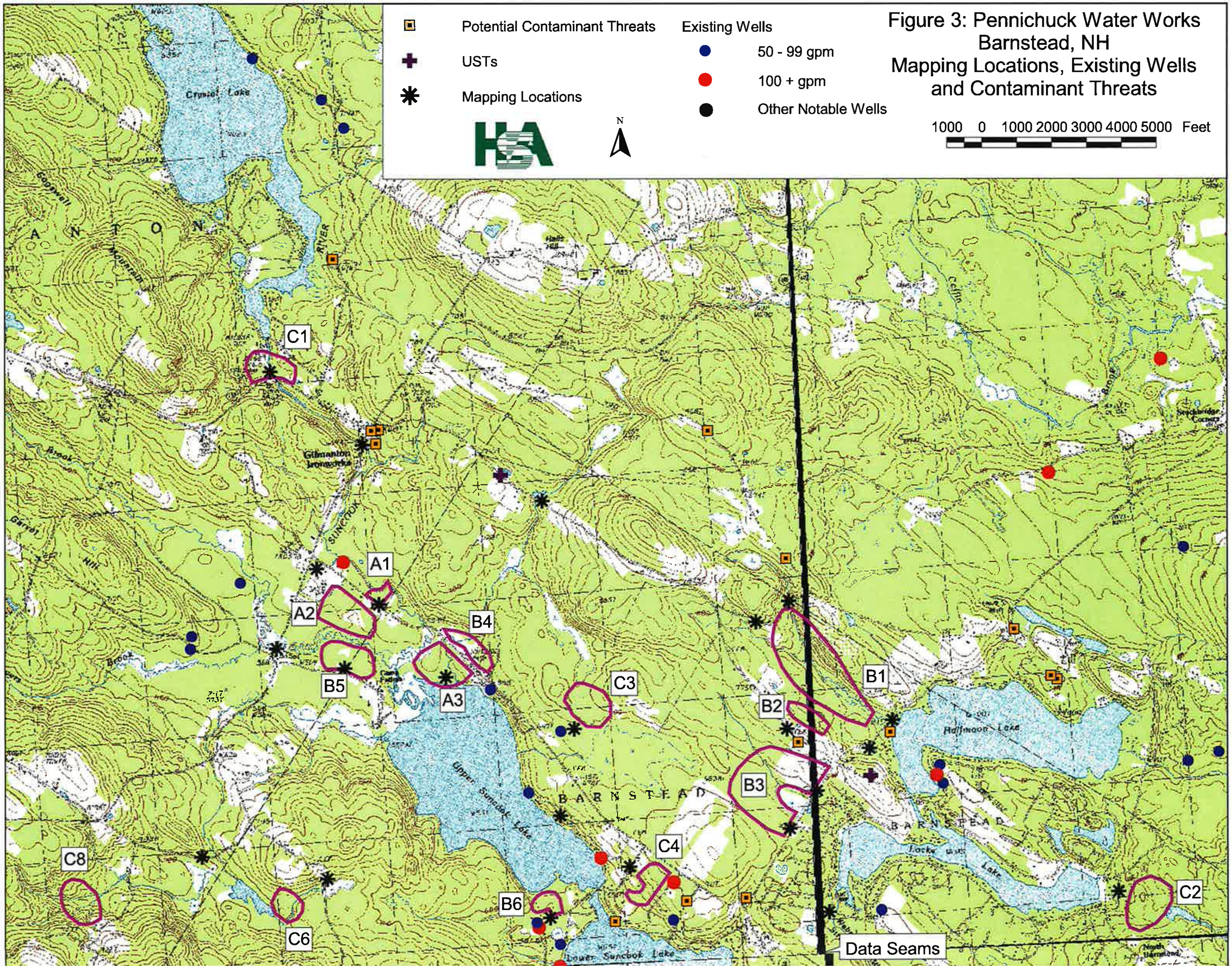


Figure 3: Pennichuck Water Works Barnstead, NH Mapping Locations, Existing Wells and Contaminant Threats

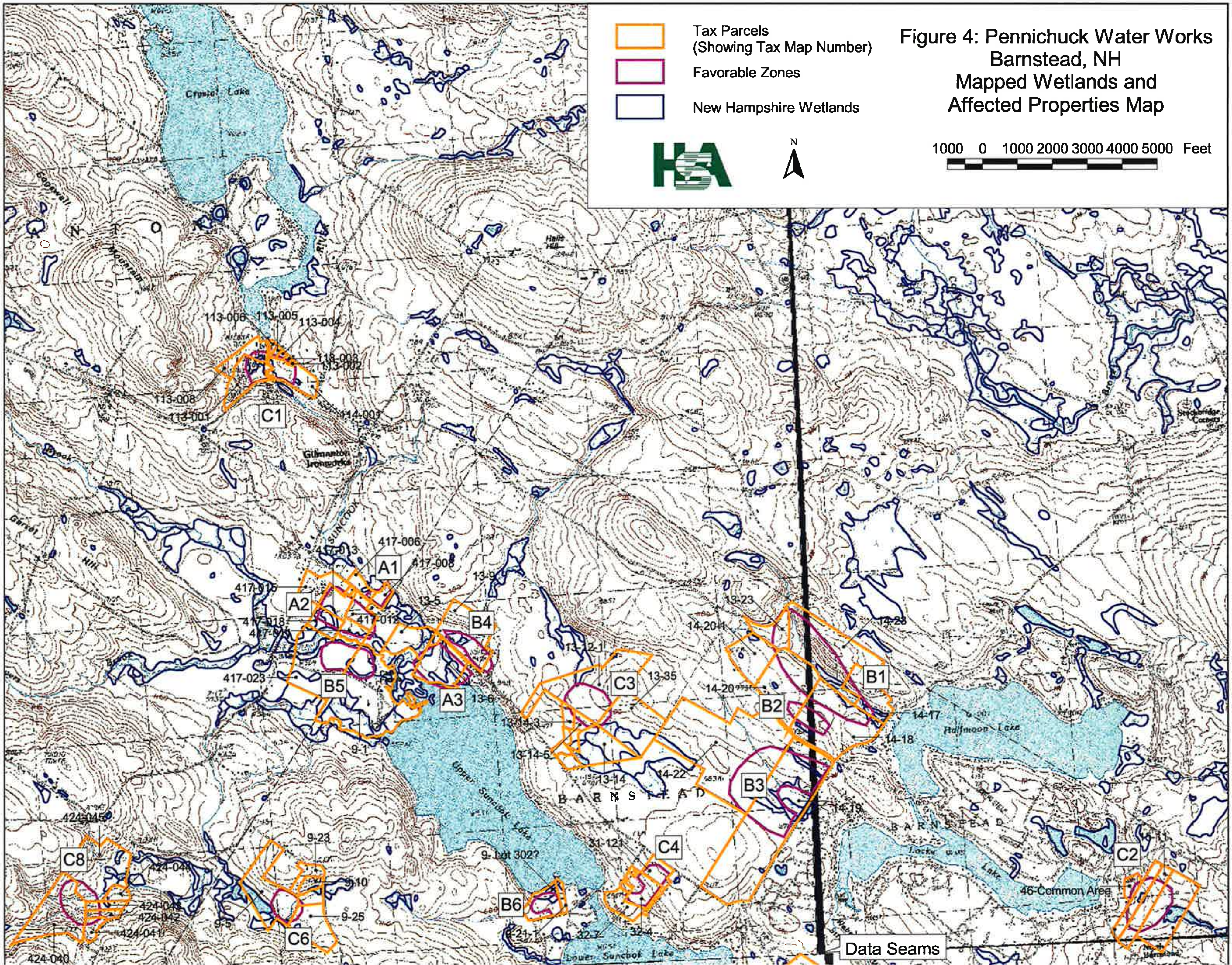


Figure 4: Pennichuck Water Works
Barnstead, NH
Mapped Wetlands and
Affected Properties Map

Flow Duration Curve and Low Flows for Locke's Lake

Joel Ballestero

Tom Ballestero

Revised 23 August, 2017

Two methods were proposed to determine both the flow duration and low flows for the outlet of Locke's Lake for annual and seasonal periods. The first method was simply to use the USGS website StreamStats for New Hampshire, which provides these flows based on regionally derived, empirical equations. The second method was to locate one or more nearby USGS stream gages, determine the values for the duration of the gage data, and to transform the values to data at Locke's Lake by weighting them by the ratio of the watershed drainage areas.

Using StreamStats, the location of the outlet to Locke's Lake was identified, and from that point, the program defined the flow duration values and those for the low flows. These results may be found in Tables 1 and 2.

Table 1. Locke's Lake Flow Duration Values from StreamStats						
P_e	Flow ID	Annual	Winter	Spring	Summer	Fall
-	-	cfs	cfs	cfs	cfs	cfs
0.98	Q98	0.66	2.59	4.34	0.24	1.48
0.95	Q95	0.57	3.33	6.11	0.31	2.26
0.90	Q90	0.93	4.24	8.12	0.45	3.29
0.80	Q80	1.86	5.71	11.20	0.72	4.94
0.70	Q70	3.23	6.86	14.50	1.04	6.49
0.60	Q60	4.92	8.04	18.20	1.44	8.39

In Table1, P_e is the *daily* exceedance probability since the values were derived from average daily streamflows

Table 2. Locke's Lake Low Flow Values from StreamStats							
Pe	Tr	Flow ID	Annual	Winter	Spring	Summer	Fall
-	yrs	-	cfs	cfs	cfs	cfs	cfs
0.5	2	7Q2	0.54	5.49	6.67	0.51	4.82
0.1	10	7Q10	0.20	3.11	3.69	0.19	2.07

In Table2, P_e is the *annual* exceedance probability since the values were derived from annual streamflow data series

StreamStats also determined the drainage area at the outlet to Locke's Lake to be 9.28 square miles. Nearby gages within 40 miles of the site were then identified after a search through USGS websites. A total of 17 nearby gages were identified, and each gage had their drainage area, distance to the site, and data duration noted. Gages were then judged on their properties, with desirable gage properties being: gages with 10 or more years of recorded data (and within the past 40 years); with drainage areas within a range of ½ to 2 times the size of Locke's Lake watershed ($4.6\ mi^2 < DA_{gage} < 18.6\ mi^2$); and within 25 miles to the site. The full list of the 17 assessed USGS gages may be found in Table 3.

Of these 17 gages, only one satisfied all the desirable properties: USGS Gage *01073000 – Oyster River near Durham, NH*. This gage has a drainage area of 12.1 square miles (1.3 times larger than the drainage area at the site), is approximately 24 miles away to the south and east of Locke's Lake, is currently in operation, and has over 82 years of data.

The average daily flows for the Oyster River gage were then obtained from the USGS website. These flows were then analyzed by seasonal and annual periods for flow duration values and low flows.

Table 3. Reference USGS Gages				
Gage Number	Gage Name	Drainage Area	Distance to Site	Years of Data
		(mi^2)	(mi)	(yrs)
SITE	SITE	9.28	-	-
01072800	Cocheco River near Rochester, NH	79.9	15.77	22.2
01072870	Isinglass R at Rochester Neck Rd, Dover, NH	73.6	17.74	14.3
01089500	Suncook River at North Chichester, NH	157	10.50	98.9
01089925	Suncook River at NH28 near Suncook, NH	240	17.17	1.5
01089100	Soucook River at Pembroke Road near Concord, NH	81.9	16.40	29.1
01081500	Merrimack River at Franklin Junction, NH	1507	20.55	113.7
01081000	Winnipesaukee River at Tilton, NH	471	17.58	80.2
01076500	Pemigewasset River at Plymouth, NH	622	34.15	113.5
01076000	Baker River near Rumney, NH	143	41.45	88.5
01077400	Cockermouth River Below Hardy Brook at Groton, NH	21.4	36.86	9.1
01078000	Smith River near Bristol, NH	85.8	28.19	98.9
01087000	Blackwater River near Webster, NH	129	23.17	71.4
01086000	Warner River at Davisville, NH	146	25.94	77.5
01073319	Lamprey River at Langrod Road at Raymond, NH	55.7	23.50	8.7
01091000	South Branch Piscataquog River near Goffstown, NH	104	32.09	76.7
01073000	Oyster River near Durham, NH	12.1	24.08	82.3
01068910	Mousam River at Route 4 near Sandford, Maine	44.6	25.73	9.0

The New Hampshire DES defines annual and seasonal periods for water withdrawals, based around similarities in the climate. For low flows, the climate year starts on the first of April, and continues until March 31st of the following year. The seasonal time periods may be found in Table 4.

Using the average daily flows obtained for USGS gage 01073000 and the seasonal and annual time periods defined in Table 4, the flow duration and low flow values at the Oyster River gage were determined. These may be found in Tables 5 and 6.

Table 4. Seasonal Date Ranges			
Season	Month	Day	# Days
Winter	January	1	74
Spring	March	16	77
Summer	June	1	153
Fall	November	1	61

These results were then transformed to flows at the site by weighting the flows against the ratio of the drainage areas, with a ratio of the drainage area at the site to that at the gage of about 0.77. The resulting flows at the site may be found in Tables 7 and 8.

Table 5. Flow Duration Values for USGS Gage on Oyster River in Durham						
Pe	Flow ID	Annual	Winter	Spring	Summer	Fall
-	-	cfs	cfs	cfs	cfs	cfs
0.99	Q99	0.50	2.30	4.04	0.34	1.00
0.98	Q98	0.63	2.77	5.10	0.49	1.20
0.95	Q95	0.87	3.80	7.60	0.64	2.00
0.9	Q90	1.20	5.50	10.00	0.83	3.00
0.85	Q85	1.65	7.00	12.00	0.97	3.88
0.8	Q80	2.30	8.10	14.00	1.10	5.00
0.75	Q75	3.10	9.00	16.40	1.30	6.12
0.7	Q70	4.10	10.00	18.50	1.49	7.30
0.6	Q60	6.92	12.00	23.00	1.98	10.00
0.5	Q50	10.00	15.00	29.00	2.70	13.00

Table 6. Low Flow Values for USGS Gage on Oyster River in Durham							
P_{ne}	Tr	Flow ID	Annual	Winter	Spring	Summer	Fall
-	(yrs)	-	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
0.5	2	7Q2	0.86	7.74	10.49	0.86	5.17
0.2	5	7Q5	0.56	4.29	5.44	0.56	2.57
0.1	10	7Q10	0.43	2.94	4.59	0.43	1.47
0.05	20	7Q20	0.27	2.07	3.83	0.27	1.06
0.04	25	7Q25	0.18	1.84	3.67	0.18	1.02

In Table 6, P_{ne} is the *annual* non-exceedance probability since the values were derived from annual streamflow data series. The annual and summer 7q values are identical since the lowest yearly value from each time series is used to develop the statistics, and invariably the summer season provides the lowest flows in each year of the records.

In each of the tables of results, there are Flow IDs which have a few different definitions between the flow duration values and the low flow values. In the tables for flow duration values, the Flow IDs have the format of Q##. The number after 'Q' defines the percent of time over the entire span of the recorded data (for annual or seasonal periods) where the average daily flow is expected to be exceeded (e.g. Q99 means the flow at which 99% of all other average daily flows during the time period are larger than Q99). For the tables of low flow values, the Flow IDs have the format of 7Q##. In this ID, the 7 represents the number of consecutive days used in a moving window where an average of the daily flows is calculated. For each annual and seasonal period, the lowest value seen per year or season is recorded. The two number(s) following 'Q' in the ID refer to the return period of this 7Q flow; or, on average, the number of years during which the 7Q flow or lower is expected to occur only once. As an example, the NHDES (New Hampshire Code of Administrative Rules, *Env-Wq 1902.01*) defines the 7Q10 flow as, "...the lowest average flow rate for a period of 7 consecutive days on an annual basis with an expected recurrence interval of once in every 10 years, determined at a fixed location on a river or stream, and expressed in terms of volume per time period."

Of particular interest to water use and withdrawals is the *de minimis* flow, which is defined by NHDES (New Hampshire Code of Administrative Rules, *Env-Wq 1902.07*) as the "...aggregate water use at any river location equal to 5 percent of 7Q10 at that location."

Table 7. Locke's Lake Flow Duration Values from USGS Gage Flow Transformation (Oyster River gage data)

Pe	Flow ID	Annual	Winter	Spring	Summer	Fall
-	-	cfs	cfs	cfs	cfs	cfs
0.99	Q99	0.38	1.76	3.10	0.26	0.77
0.98	Q98	0.48	2.12	3.91	0.38	0.92
0.95	Q95	0.67	2.91	5.83	0.49	1.53
0.9	Q90	0.92	4.22	7.67	0.64	2.30
0.85	Q85	1.27	5.37	9.20	0.74	2.98
0.8	Q80	1.76	6.21	10.74	0.84	3.83
0.75	Q75	2.38	6.90	12.58	1.00	4.69
0.7	Q70	3.14	7.67	14.19	1.14	5.60
0.6	Q60	5.31	9.20	17.64	1.52	7.67
0.5	Q50	7.67	11.50	22.24	2.07	9.97

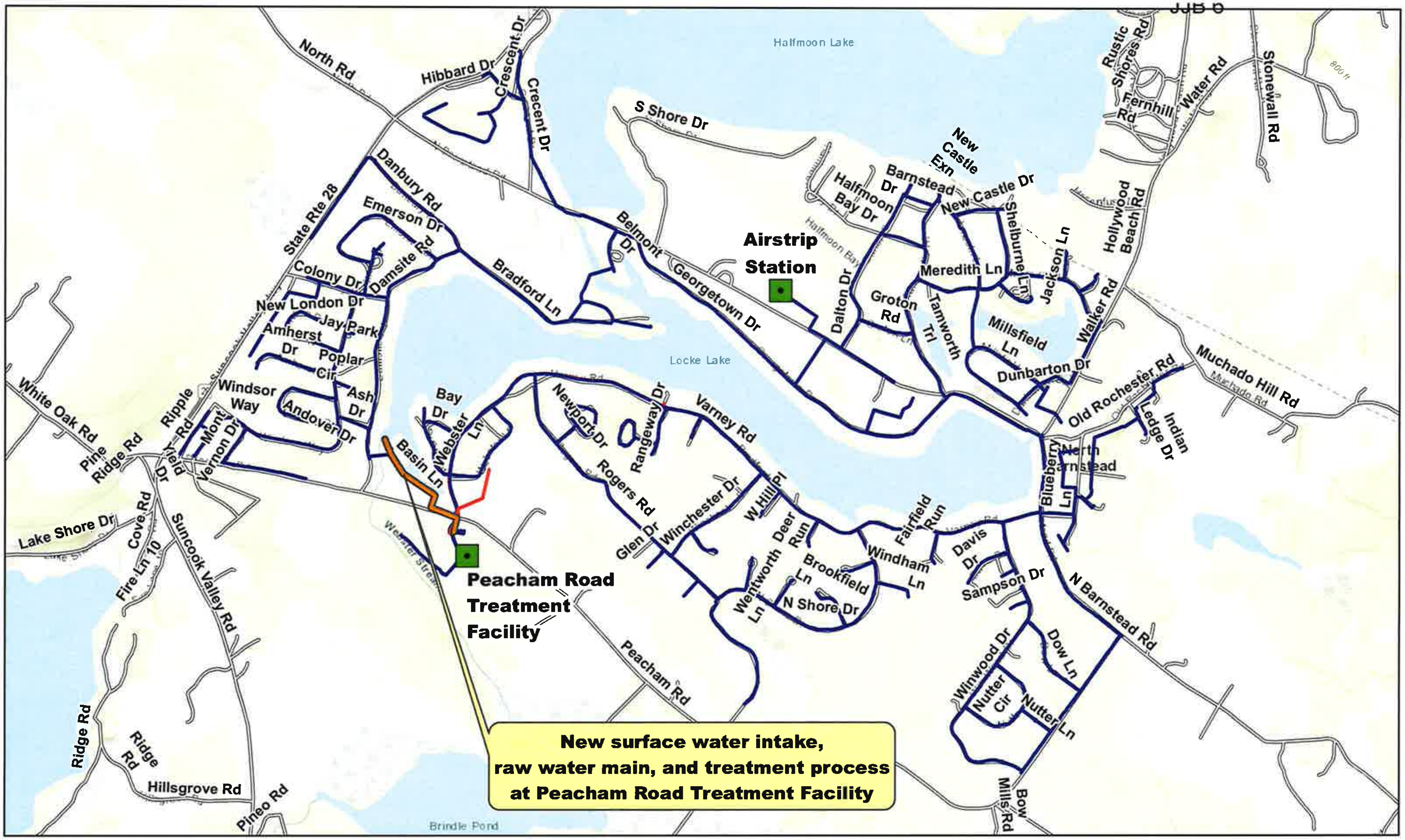
Table 8. Locke's Lake Low Flow Values from USGS Gage Flow Transformation

P_{ne}	Tr	Flow ID	Annual	Winter	Spring	Summer	Fall
-	(yrs)	-	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
0.5	2	7Q2	0.66	5.94	8.04	0.66	3.97
0.2	5	7Q5	0.43	3.29	4.17	0.43	1.97
0.1	10	7Q10	0.33	2.26	3.52	0.33	1.13
0.05	20	7Q20	0.21	1.59	2.94	0.21	0.82
0.04	25	7Q25	0.14	1.41	2.82	0.14	0.78

Therefore, using the values determined for 7Q10 from both methods, the *de minimis* flows may be estimated. These results may be seen in Table 9.

Table 9. Specific Flow Results		
Method	Flow (cfs)	
	7Q10	*De Minimis*
StreamStats	0.20	0.010
USGS Gage	0.33	0.017

The Table 9 values are similar. The StreamStats estimate is based upon regional regressions from all nearby gages, and therefore without any specific gage data available, are used as a planning tool. In the absence of site data, nearby gages are always a stronger estimate than StreamStats as long as the watershed areas are similar. The StreamStats 7Q10 estimate for the Oyster River gage is 0.182 cfs whereas the value estimated directly from the Oyster River dataset is 1.64 cfs (Table 6), almost an order of magnitude higher than StreamStats. This comparison underscores the weakness of StreamStats. Therefore, for the purposes of moving forward and in lieu of data collected at Locke's Lake, the estimated Locke's Lake 7Q10 and *de minimis* flow values for future water supply planning purposes are the values found in the last row of Table 9.



Type

Station

Proposed Water Main

Existing Mains

Potable Water

Raw Water

0 1,000 2,000 4,000 Feet

N

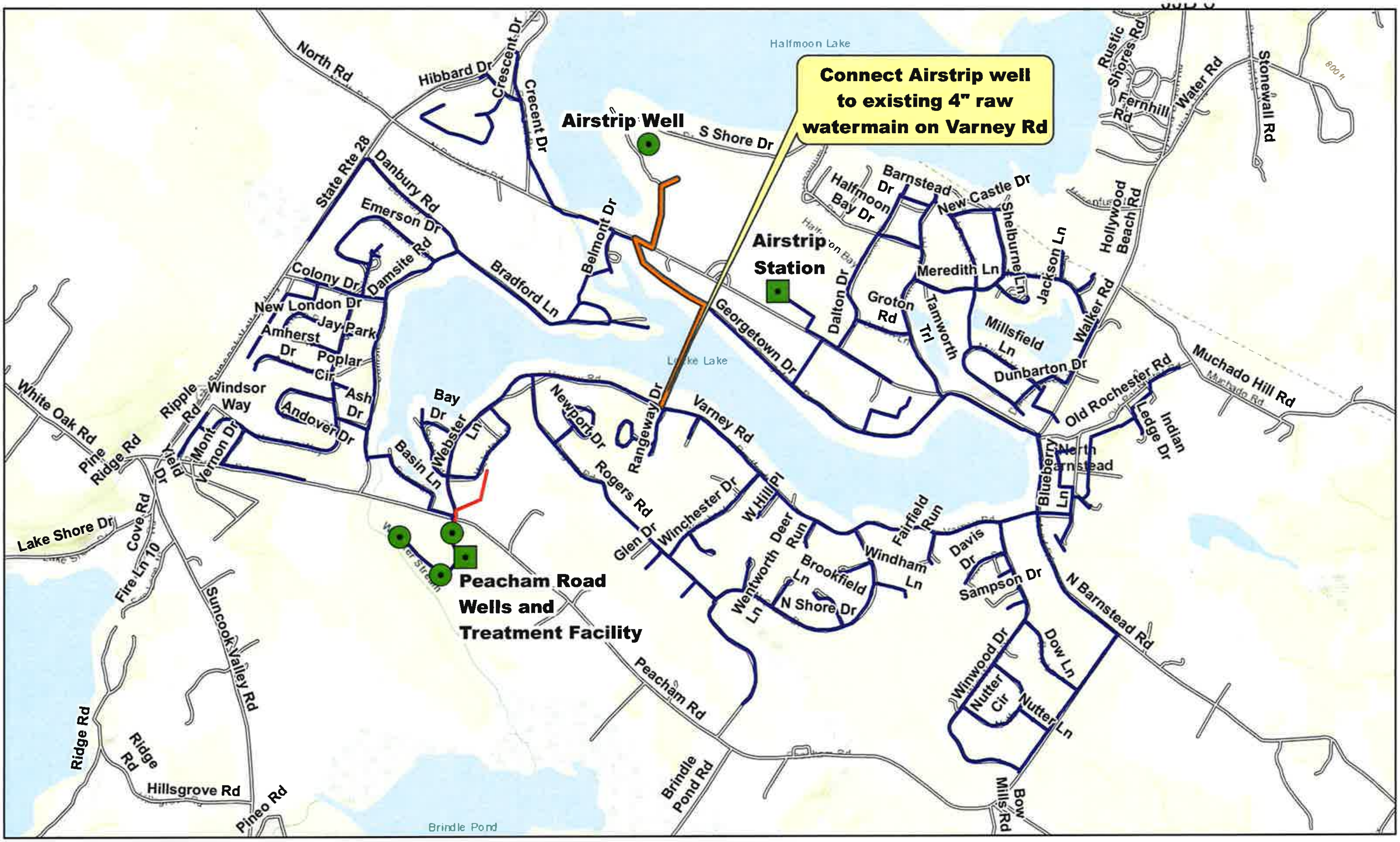
Exhibit JJB Figure 1A

Surface Water Supply Development

Pennichuck State Revolving Fund Application

Barnstead - Locke Lake

2018PEU-SRF00082



Type

- Station
- Existing Well
- Proposed Water Main

Existing Mains

- Potable Water
- Raw Water

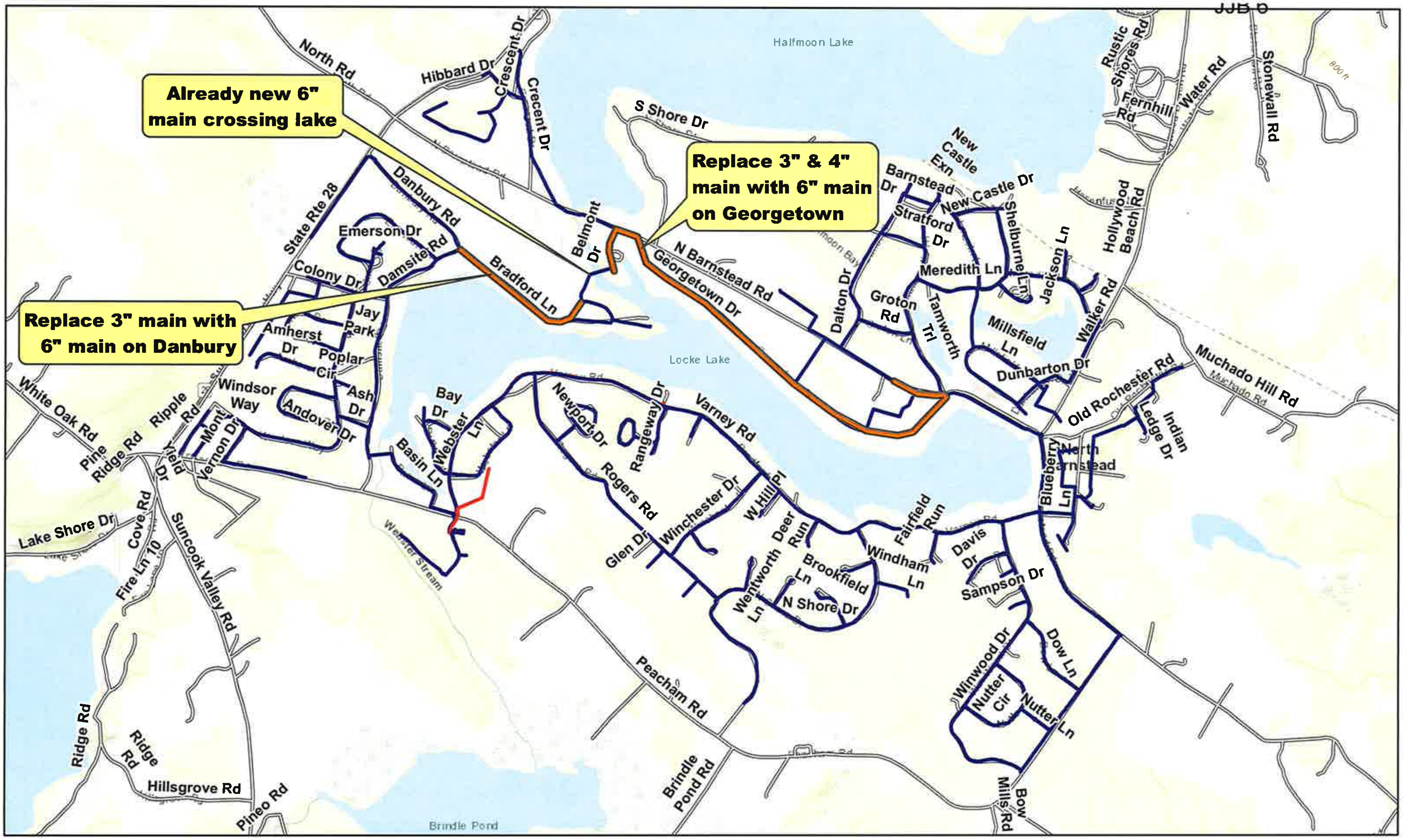
Feet: 0, 1,000, 2,000, 4,000

N

Exhibit JJB Figure 1B
Airstrip Well Alternative Treatment
Pennichuck State Revolving Fund Application

Barnstead - Locke Lake

2018PEU-SRF00083



Proposed Water Main

Existing Mains

Potable Water

Raw Water

0 1,000 2,000 4,000 Feet

N

Exhibit JJB Figure 1C
Georgetown Drive Area Main Replacement
Pennichuck State Revolving Fund Application

2018PEU-SRF00084

Barnstead - Locke Lake

Projected Revenue Impact of Locke Lake CAP project

		P&I x 1.1	Local	State	Total Revernue Requirement
Total Projected SRF Loan	$ 4,240,000.00				
Projected Surface Water Treament Capex	$ 2,865,000.00	$206,075.78	$ 76,294.95	$ 18,909.00	$301,280
Projected Airstrip Well interconnection to Peachum Road Capex	$ 400,000.00	$28,771.49	$ 10,652.00	$ 2,640.00	$42,063
Projected Georgetown Area watermain Capex	$ 975,000.00	$70,130.50	$ 25,964.25	$ 6,435.00	$102,530
Less current Revenue requirement associated with Arsenic Treatment of the Airstrip well -					$ 54,536
Total additional required revenues -					$391,337
Projected 2018 Approved PEU Revenue requirement (exclusive of NC Capital Recover Surcharge) -					$8,276,261
Projected % Increase on PEU rates from impact of Locke Lake CAP -					4.73%

Current Annual Expenses of treating Airstrip well for Arsenic

Cost per Arsenic Media Changeout-one vessels only:

	qty.	unit:	unit cost:	Total:	OH rate:	Total w/OH
Labor	8	hrs	$ 30.48	243.84	66.8%	$ 406.68
Resin Tek Media	10	cubic ft	$ 405.00	4050	0%	$ 4,050.00
equipment: truck	8	hrs	$ 11.00	88	0%	$ 88.00
						$ 4,544.68
				times performed in 2018		12
				Projected 2018 Arsenic Removal Treatment Costs -		$ 54,536

Projected Annual expenses associated with treating Air Strip well arsenic via intereconnection with Peachum Road WTP

Peacham Road Treatmemt Ratio:	0.1
Projected Peacham Road Treatment Cost of Airstrip well flows:	$ 5,454

Interconnection Annual Expenses

Estimted cost to interconnect the Airstrip Well to Peachum Road WTP	$ 400,000.00		
Projected SRF Interest Rate	2.704%		
Srf Loan Term	20 years	Annual P&I x 1.1	$28,771
		Local Tax at $26.63/$1,000:	$10,652
		State Tax at $6.60/$1,000:	$2,640
		Project 2018 Arsenic Removal Treatment costs if treatment occurs at Peachum road -	$42,063
		Reduced State and Local Taxes on existing Airstrip Building (To be demolished) -	($333)
		Revenue requirement associated with interconnection of Airstrip well with Peachum Treatment Facility -	$41,730