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Final Report: Watershed Assessment of New Boston Air Force Station

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Project: Watershed Assessment of New Boston Air Force Station to be completed by Emily DiFranco of the University of New Hampshire under the direction of Dr. William H. McDowell

Problem Statement:

New Boston Air Force Station (NBAFS), located in a rapidly-growing region of southern New Hampshire, has a history of past use that has potentially contaminated the water resources on the site as well as altered the site's hydrology. Past use includes a landfill as well as training operations during WWII, primarily for use as a target site for bombing runs. Both live and inert ordnance were used during training, with thousands of bombs dropped. Many bombs detonated during training exercises, but some live ordnance remained on site after training ceased. Most of this ordnance has been identified and detonated in place over the last few decades. The impacts of these past land uses on water resources are largely unknown. Alteration of soils and groundwater flow paths in the basin, as well as contamination from the ordnance and landfill leachate may have occurred. In the region, the uncertainty over the possible impacts of Air Force operations poses a water resources management challenge. Thus, better understanding of the hydrology and water resources issues on NBAFS will benefit regional management of water resources.

Overall Objective: Assess the quantity, quality, and distribution of surface and groundwater resources of NBAFS.

Specific Objectives:

1). Evaluate surface water flow and develop a delineated watershed profile showing surface water movement.

2). Inventory the annual inputs (precipitation) and outputs (evapotranspiration and streamflow) for NBFAS using the hydrologic model BROOK90.

3). Identify groundwater flow paths and lake level fluctuations throughout the year.

4). Identify potential contaminant migration through ground and surface water flow paths using water quality data from Shaw Environmental.

Objective 1: Evaluate the surface water flow and develop a delineated watershed profile showing surface water movement.

Deliverable 1: Watershed delineation and surface water flow maps:

1). Watershed delineation: Aerial and topographic views

2). Surface water flow map: Aerial, topographic, and water body view

Summary:

The New Boston Air Force Station watershed is approximately 3,454 acres or 5.4 miles^2 in area and includes the towns of New Boston, Amherst, and Mont Vernon, NH (Figures 1-1 and 1-2). The watershed drains to the southeast with most of the surface water on the base reaching Joe English Pond (JEP) and draining into Joe English Brook (JEB) (Figures 1-3 and 1-4). The upper northeast and northwest corners of NBAFS fall outside of the watershed boundaries.

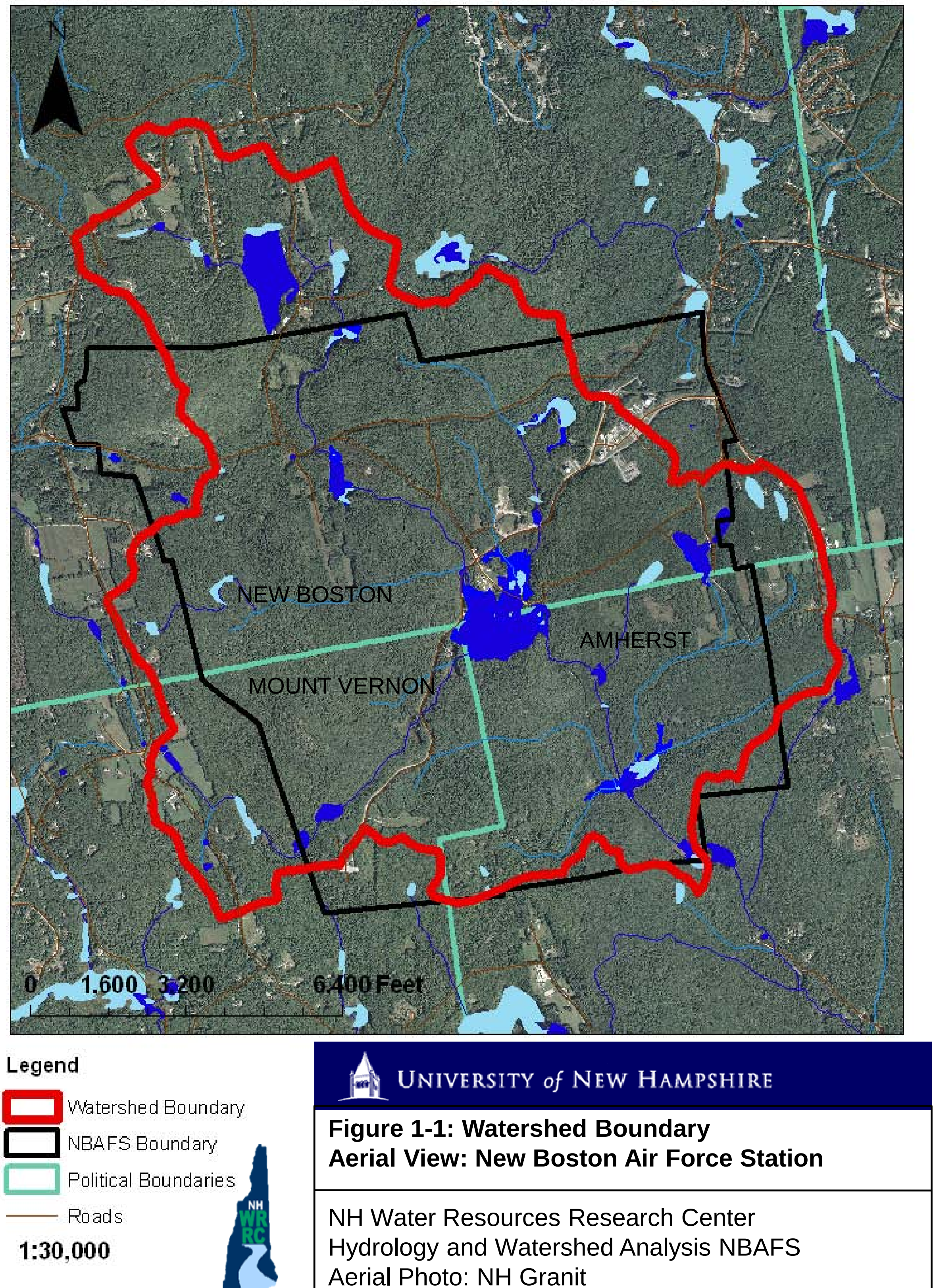

Figure 1-1: Watershed Boundary
Aerial View: New Boston Air Force Station

NH Water Resources Research Center
Hydrology and Watershed Analysis NBAFS
Aerial Photo: NH Granit

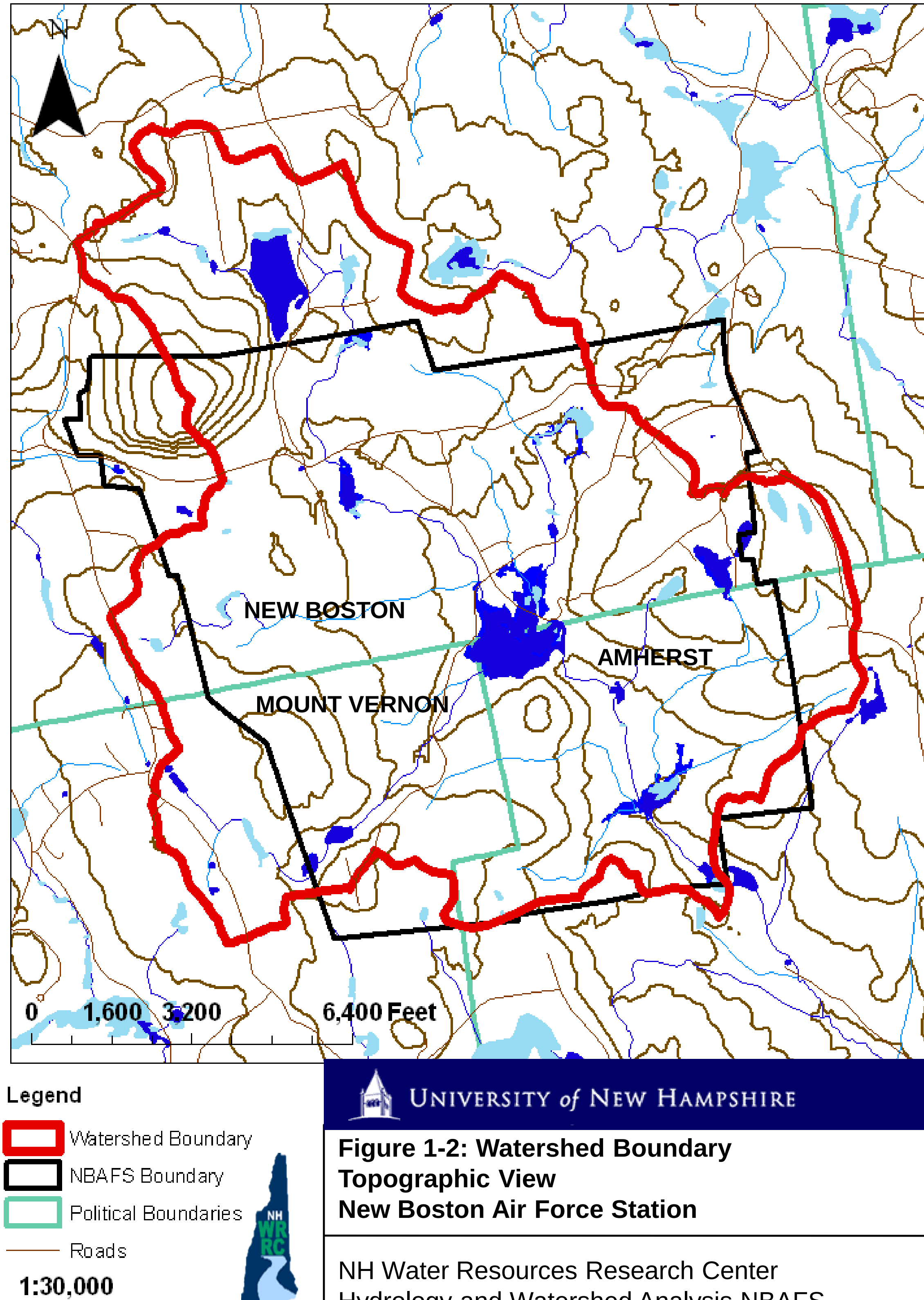

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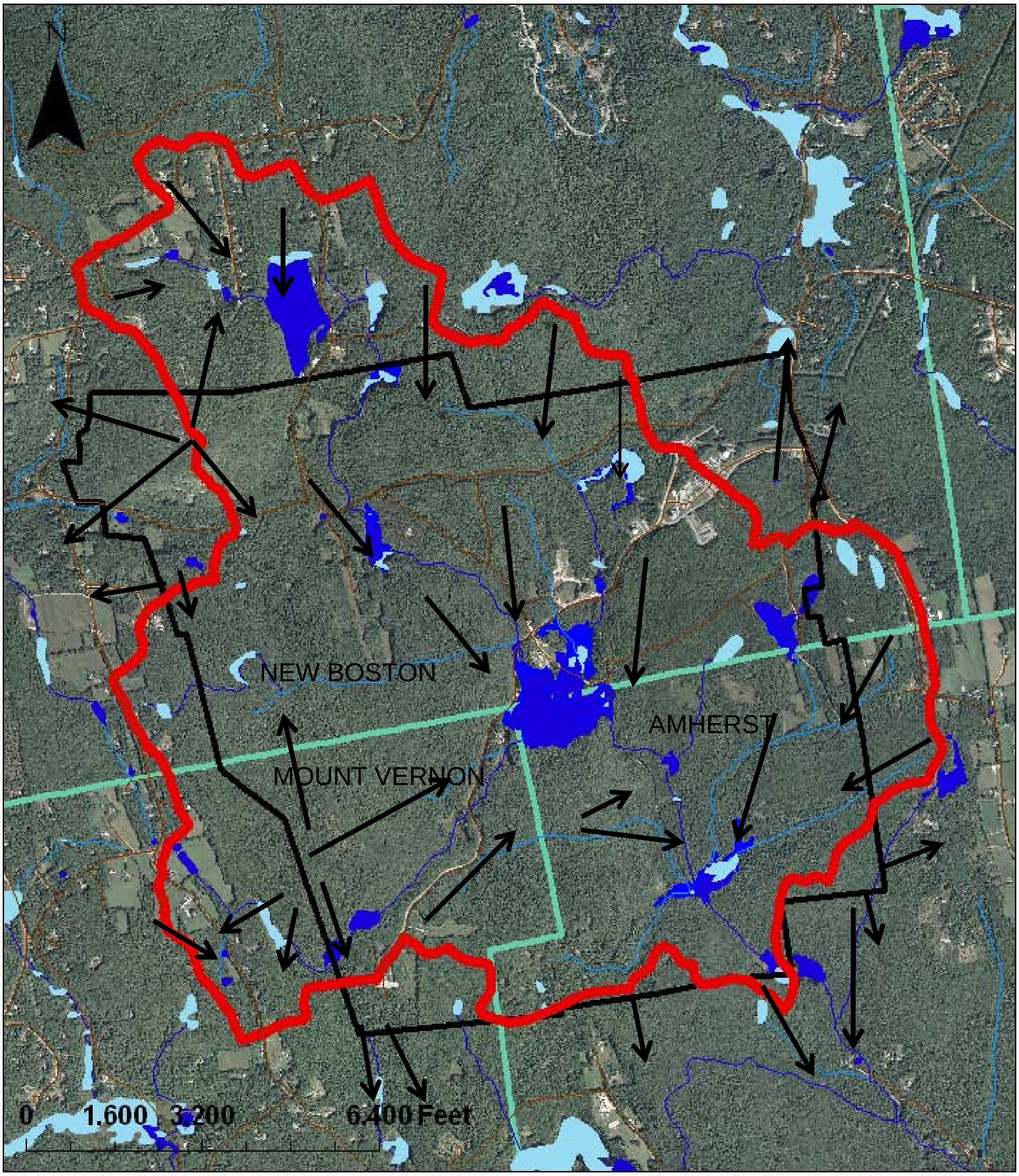
Figure 1-2: Watershed Boundary
Topographic View
New Boston Air Force Station

NH Water Resources Research Center
Hydrology and Watershed Analysis NBAFS
100 ft Contours: Shaw Environmental, Inc.



Legend

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- Roads

1:30,000

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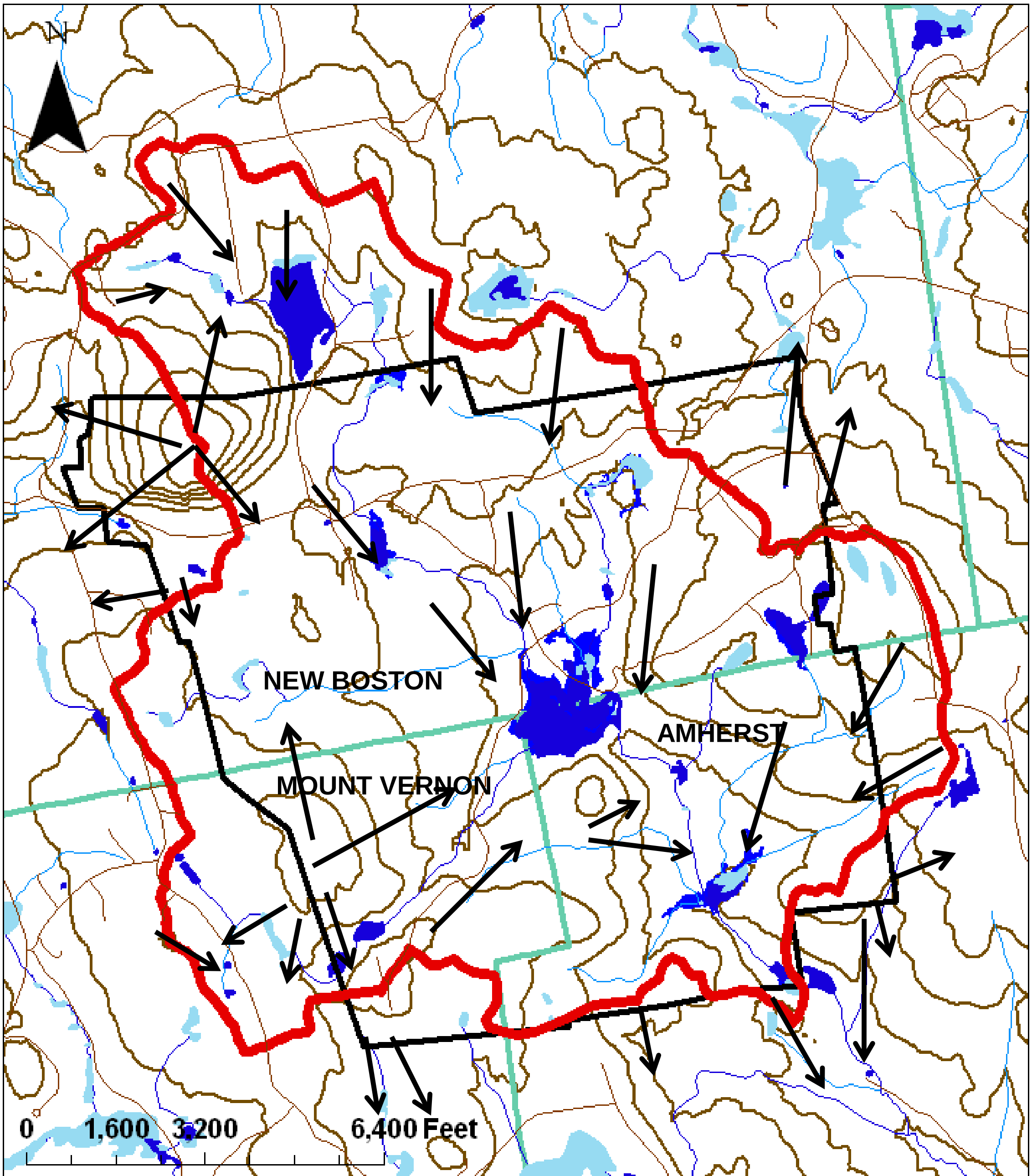
Figure 1-3: Surface Flow
Aerial View: New Boston Air Force Station

NH Water Resources Research Center
Hydrology and Watershed Analysis NBAFS
Aerial Photo: NH Granit



Legend

Watershed Boundary

NBAFS Boundary

Political Boundaries

Roads

1:30,000

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Figure 1-4: Surface Flow
Topographic View
New Boston Air Force Station

NH Water Resources Research Center
Hydrology and Watershed Analysis NBAFS
100 ft Contours: Shaw Environmental, Inc.

Objective 2: Inventory the annual inputs (precipitation) and outputs (evapotranspiration and streamflow) for NBAFS using the hydrologic model BROOK 90.

Deliverable 2: Completion of BROOK 90 model

1). Detailed description of model and parameters

2). Graphical and tabular presentation of the water budget for NBAFS from 11/07- 2/09

Model Summary:

BROOK 90 is a simulation model for evaporation, soil water, and streamflow developed by C. Anthony Federer. It was originally designed for use at the Hubbard Brook Experimental Forest in New Hampshire, but has since been used in watersheds in places as diverse as Arizona, California, Pennsylvania, and New England. BROOK 90 has been cited in over 30 publications. This model is parameter-rich and provides estimates of difficult to measure variables of a local water budget, such as evapotranspiration and soil water movement, at a daily-time step. Streamflow can be modeled making BROOK 90 particularly useful in areas that may be inaccessible to continuous on-site field work provided there is some background knowledge of watershed characteristics.

Input variables:

BROOK 90 input files allow for the input of the following variables (only starred variables are required:

1). Year*
2). Month*
3). Day of the month*
4). Solar radiation on a horizontal surface (MJ/m^2)
5). Maximum temperature for the day (Celsius)*
6). Minimum temperature for the day (Celsius)*
7). Average vapor pressure for the day (kPa)
8). Average wind speed for the day (m/s)*
9). Precipitation for the day (mm)*
10). Measured streamflow for the day (can be predicted by the model if there is no measured streamflow available).

For this study, starred variables were obtained from the weather station already in place on NBAFS. The weather station was calibrated for local latitude and elevation in November 2007 and a heating element was installed to allow for winter precipitation to be measured. Monthly data was checked against local weather data from Manchester Airport. Any gaps in data were filled in from this data set.

Input Parameters:

Location Parameters: These parameters are site specific. Latitude, slope (overall slope of watershed from highest to lowest point) and aspect (direction the watershed faces) of the watershed are required and were estimated from topographic and watershed maps of NBAFS.

Flow Parameters: These parameters are also site specific and affect infiltration and drainage. The initial values provided in the model were designed for Hubbard Brook Watershed 6, a moderately steep, forested watershed. Parameters were changed only slightly, as most of the parameters were within a range of values appropriate for NBAFS. Many of these parameters were determined from suggestions provided in the BROOK 90 documentation for specific types of geographic locations. The percent of impervious surfaces influence the timing of peak flows and were estimated from land cover maps of the installation.

Canopy Parameters: These parameters depend on the type and height of the dominant vegetation within the watershed and are necessary to determine the amount of water lost to transpiration. Many of these parameters were determined from provided tables in the BROOK 90 documentation for specific types of land cover.

Soil Parameters: These parameters are important to determine infiltration rates and were determined from soil maps created by Shaw Environmental, Inc.

Fixed Parameters: These parameters were set in the original model, and it was not advised to change them for a specific location.

Output Variables:

BROOK 90 uses the inputted weather data to produce modeled estimates for the following variables:

- **Discharge** (mm/day, month, year): amount of water leaving the watershed through a stream outlet (in this case, JEB)
- **Evapotranspiration** (mm/day, month, year): amount of water returned to the atmosphere through a combination of evaporation and transpiration (from plants)
- **Soil water** (mm/day, month, year): amount of water stored in the soil
- **Groundwater** (mm/day, month, year): amount of water stored in the groundwater

Conclusions:

This model allows for an understanding of the water budget of a watershed and allows for predominant pathways of water movement throughout the year to be determined. Assuming water enters the watershed solely through precipitation (measured), the major losses are due to discharge and evapotranspiration (modeled) and the major storage reservoirs are soil water and groundwater (modeled).

Most water that enters the base leaves as discharge through the outlet JEP (Table 2-1). Precipitation is highest in the spring and fall (2008). Highest discharge occurs in March 2008 which can be expected due to the spring melt. Lowest discharge occurs in the summer months (2008) as more water is removed from the soil by plants and evapotranspiration is highest (due to increased solar radiation and temperatures). In general, evapotranspiration is lowest in the winter months, as plants are dormant and temperatures are low. Soil water and groundwater are lowest in the summer which is expected due to lower precipitation and higher demand from plants.

Table 2-1: Monthly water budget for New Boston Air Force Station (November 2007-February 2009)

Month	Year	Precipitation (mm/month)	Discharge (mm/month)	Evapotranspiration (mm/month)	Soil Water (mm/month)	Groundwater (mm/month)
November	2007	87.86	73.24	9.11	186.98	5.39
December	2007	55.5	45.14	5.51	189.82	6.27
January	2008	44.2	52.52	7.25	179.14	2.5
February	2008	191.76	110.2	13.86	188.38	5.94
March	2008	125.73	165.52	13.9	189.47	5.83
April	2008	23.1	38.72	17.32	161.93	0.79
May	2008	14.16	7.39	35.97	133.6	0.22
June	2008	105.65	4.06	116.38	119	0.03
July	2008	158.48	9.37	96.62	169.32	2.21
August	2008	121.91	53.54	107.36	132.22	0.32
September	2008	227.04	73.24	91.92	188.51	5.9
October	2008	71.12	41.84	24.77	190.51	8.41
November	2008	108.71	82.11	9.45	194.13	11.62
December	2008	108.71	123.75	7.99	185.54	5.64
January	2009	51.29	28.92	6.86	172.13	1.3
February	2009	35.29	38.77	9.82	190.62	4.6

Graphical representation of the water budget for NBAFS throughout the study period is shown in Figures 2-1, 2-2, and 2-3.*

Figure 2-1: Water budget for NBAFS watershed for November and December 2007

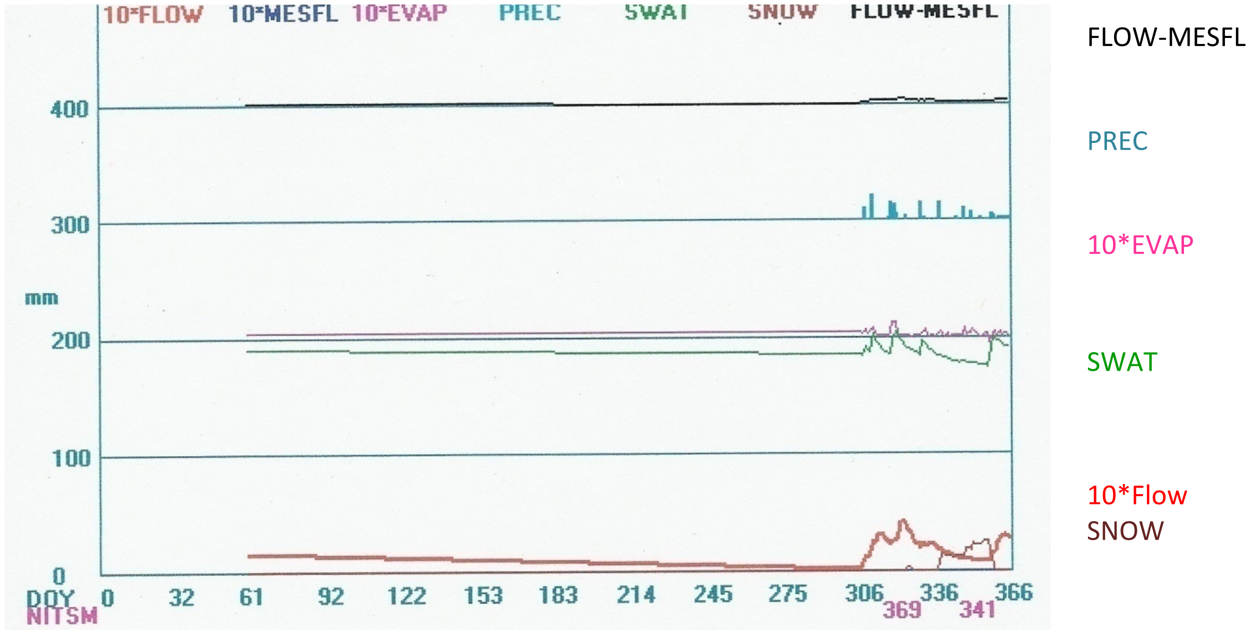


Figure 2-2: Water budget for NBAFS watershed for 2008

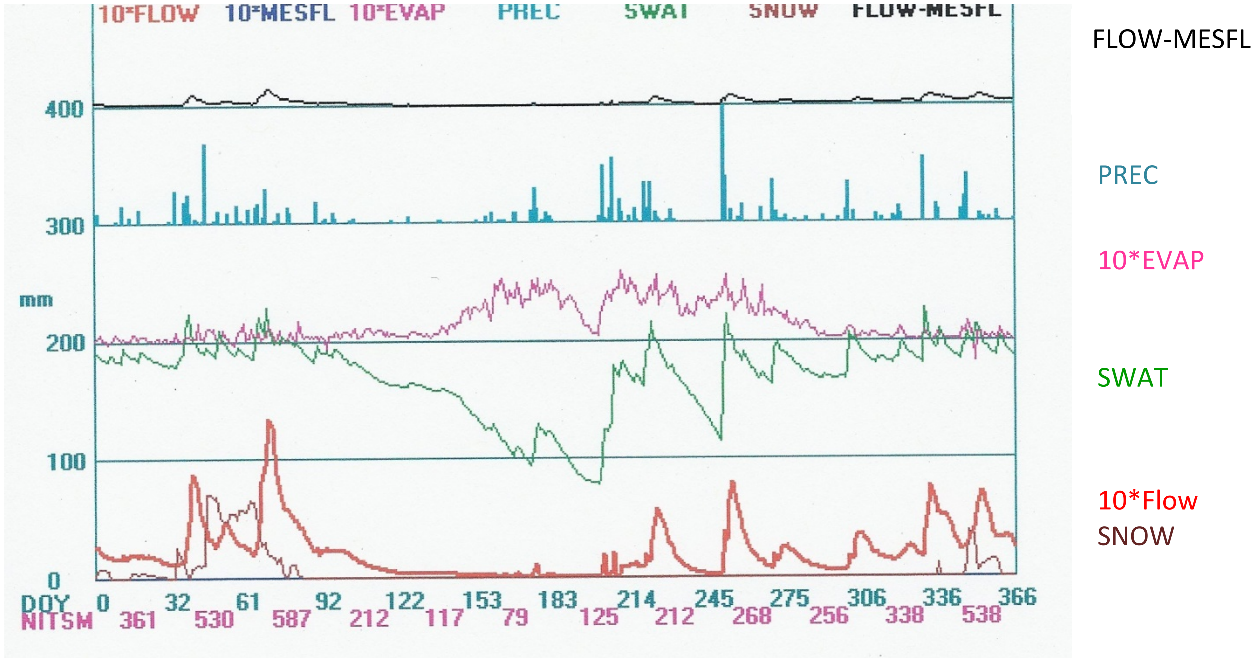
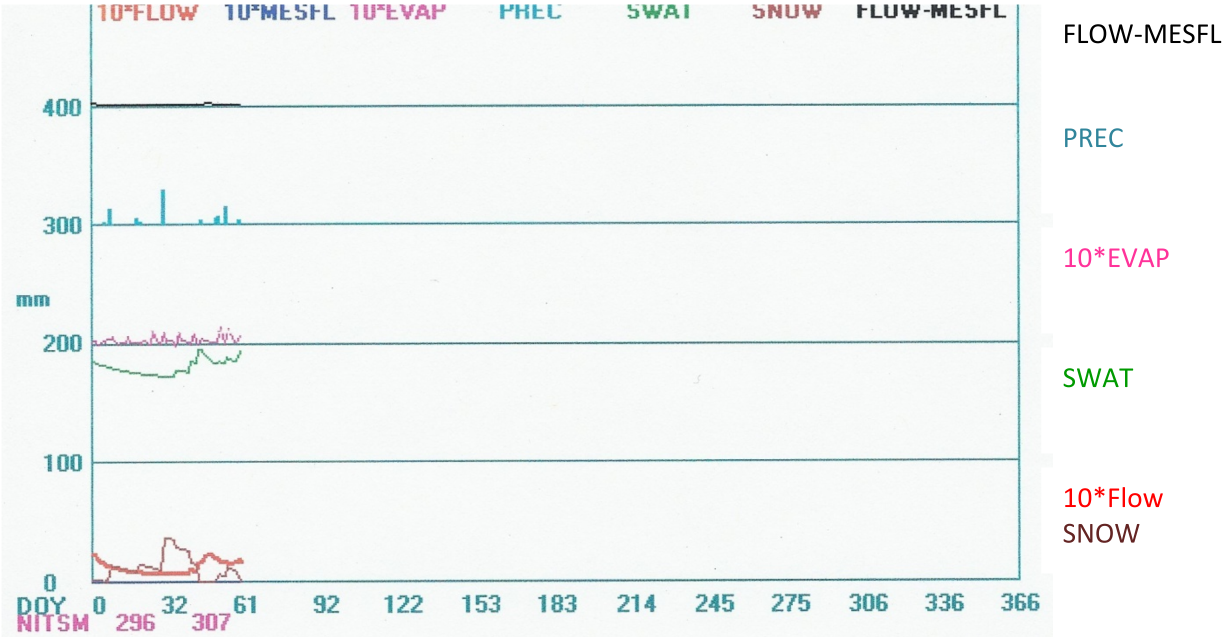


Figure 2-3: Water budget for NBAFS for January and February 2009



* 10*FLOW = 10 * Discharge at the outlet; 10* MESFL = 10 * any measured flow at outlet (as this variable is always 0 for this case, it is absent from the graph); 10* EVAP = 10 * water lost to evaporation; PREC = amount of precipitation; SWAT = amount of stored in the soil; SNOW = amount of water held as snowpack; FLOW-MESFL = difference between the estimated discharge and measured discharge (as there was no measured discharge, this variable can be ignored).

Objective 3: Identify groundwater flow paths and JEP level fluctuations throughout the year.

Deliverable 3: Completion of identification of groundwater flow paths

1). Graphical presentation of annual JEP surface level fluctuation

2). Graphical presentation of monthly groundwater depths relative to JEP surface elevation

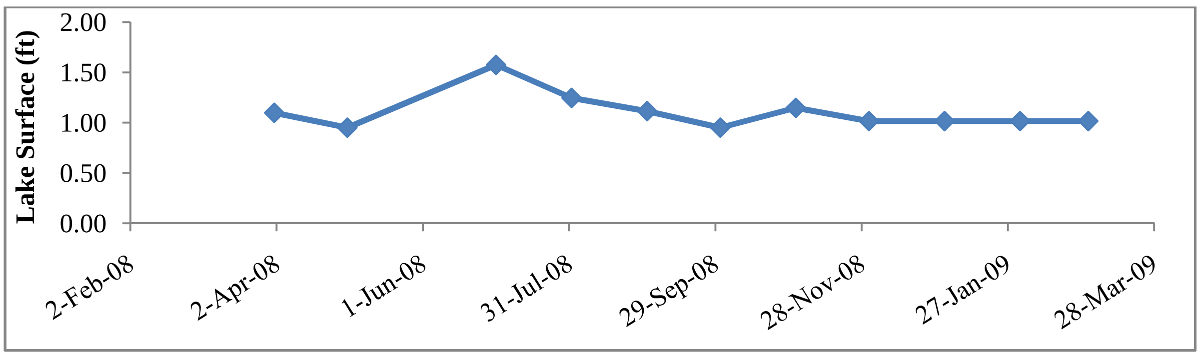
3). Map of monthly groundwater flow paths within watershed

4). Map of surrounding private and public wells (wells that may be affected will be noted)

Annual lake surface level fluctuation:

The surface of JEP fluctuated 0.623 ft from April 2008 to March 2009. JEP was highest in July 2008 and lowest in May and October 2008. From December 2008 to March 2009, JEP was visibly frozen and did not fluctuate (Figure 3-1).

Figure 3-1: JEP Surface Fluctuation from April 2008 to March 2009 (measured at Daughton's Landing)



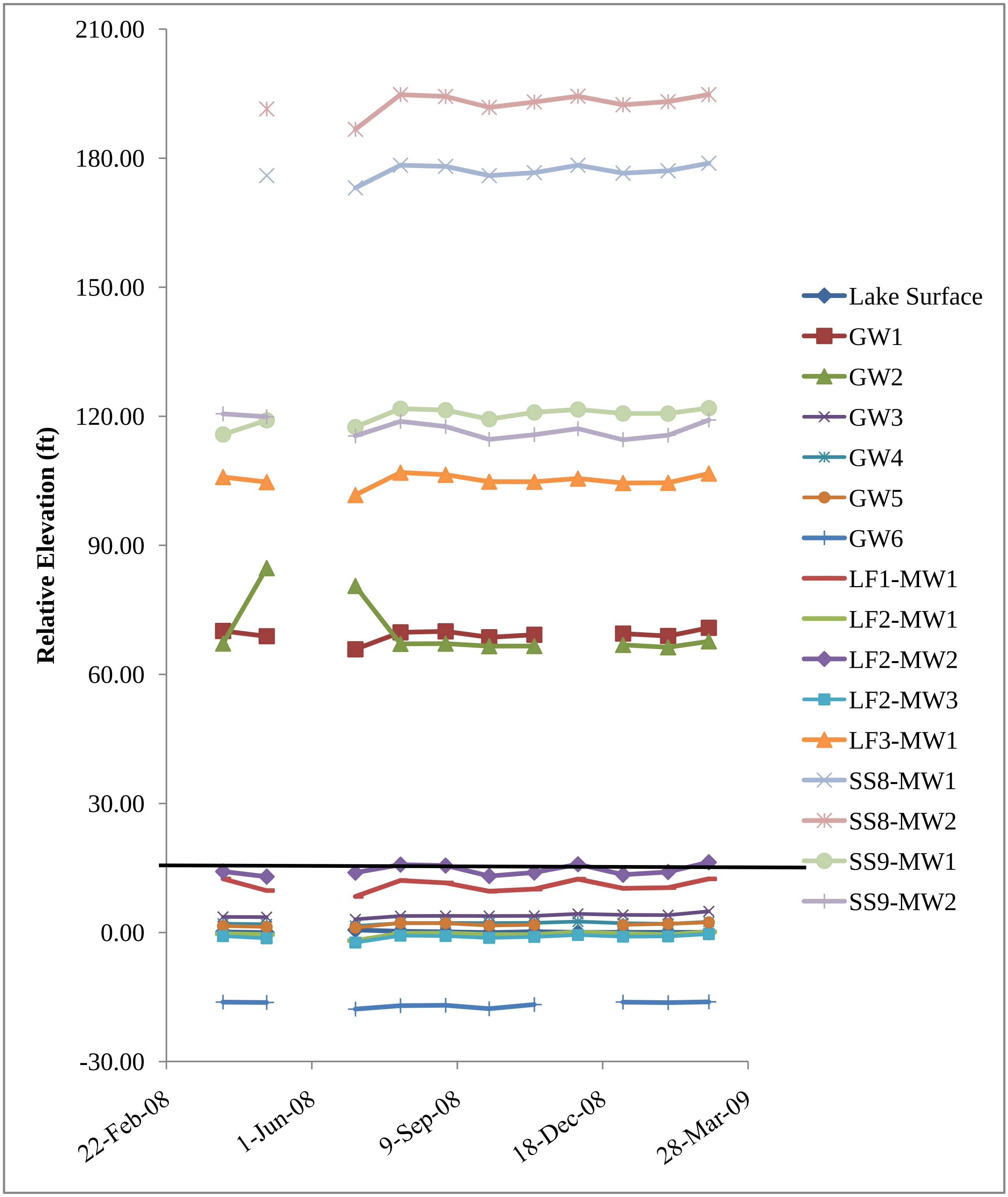
Annual relative groundwater elevation fluctuations:

The depth to groundwater (DTWT) was measured once a month from April 2008 to March 2009 from fifteen wells scattered throughout the NBAFS (Figure 3-4). Surface level of Joe English Pond was also measured throughout this period. Wells located close to JEP as well as the lake itself were surveyed together to determine relative elevation of groundwater throughout the year. Wells located farther uphill in the watershed were not surveyed as their locations were well above JEP, and the accuracy of surveying was not necessary in these cases as a margin of error of ± 10 ft was deemed acceptable for these wells. Previous elevation data from Shaw Environmental (determined to have a margin of error of ± 10 ft) was used to determine relative elevation to the lake surface for these wells.

Relative elevation of groundwater to JEP surface can be used as an indication of groundwater flow direction. If the relative elevation of the groundwater for a sample date is above the relative elevation of JEP for that date, water is expected to flow from the well towards the lake. If the relative elevation of the groundwater for a sample date is below the relative elevation of JEP for that date, water is expected to flow from JEP towards the well. In the graphs below, most of the groundwater in the studied wells flows towards JEP on the base for most of the year (Figures 3-2 and 3-3). However, by examining the wells closer to JEP, three wells (GW-6, LF2-MW1, LF2-MW3) consistently have groundwater below the level of the lake, indicating these wells receive water from JEP (Figure 3-3).

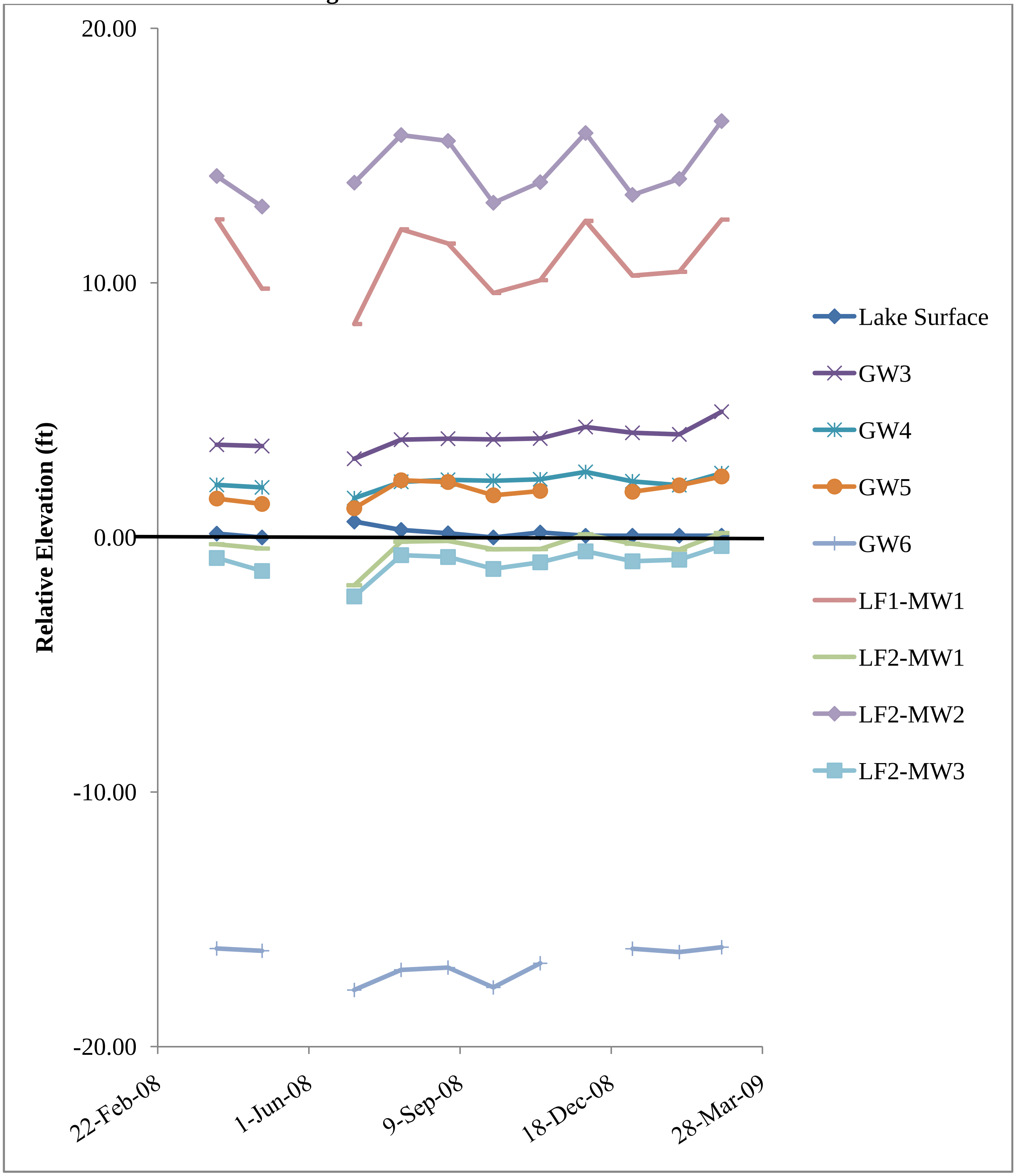
The DTWT varies throughout the year due to changes in precipitation, water removal by plants, and evaporation. The DTWT generally decreases (water table becomes closer to the surface) in the spring as snow melts and precipitation increases. The DTWT generally increases (the water table lowers) in the summer and fall as more water is removed by plants and processes such as evaporation increase. In the late fall, the DTWT often decreases from the summer as there is less demand from plants and less evaporation. There is also often more precipitation at this time. Groundwater in all fifteen wells on the NBAFS followed a similar temporal pattern (Figure 3-2) though this pattern did not cause changes in groundwater flow direction.

Figure 3-2: Relative elevation of groundwater level in each well to the elevation of Joe English Pond*



*** From April 2008 to March 2009 (if relative groundwater elevation is below relative lake elevation (approximately 0 ft, note reference line), water drains from Joe English Pond towards that well)**

Figure 3-3: Relative elevation of groundwater level in each well located near Joe English Pond to the elevation of Joe English Pond*



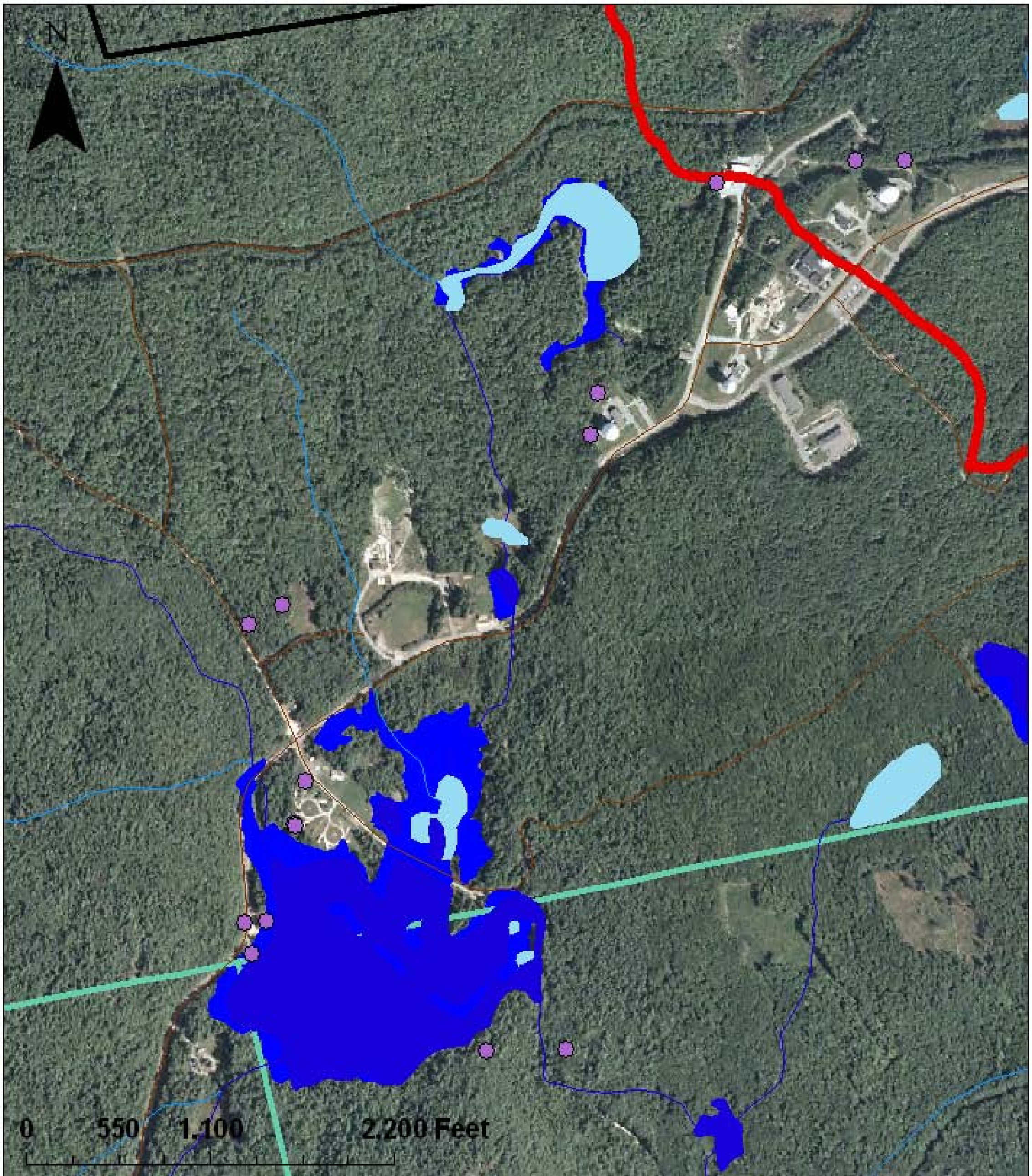
*** From April 2008 to March 2009 (if relative groundwater elevation is below relative lake elevation (approximately at reference line), water flows from Joe English Pond towards that well)**

Monthly groundwater flowpaths within the NBAFS watershed:

Overall, groundwater flow direction determined from DTWT in the monitoring wells appears to follow topographic contours and flows southeast towards the outlet (Figure 3-5). As such, most groundwater within the northern section of the NBAFS installation boundaries drains towards JEP. However, as the watershed boundary does not match up exactly with the installation boundaries, it is likely that some groundwater is leaving NBAFS. The southeast corner of NBAFS includes the outlet of JEP and most likely transfers both surface and groundwater off-site. Further, the northeast corner of the base, near wells SS9-MW1 and SS9-MW2, is located outside of the watershed boundary. Though it is clear that water from JEP is not flowing towards those wells, it is unclear with the data collected if the groundwater in those wells is flowing towards the lake by crossing the watershed boundaries, or if the groundwater is flowing northeast (similar to surface flow) and off of the boundaries of NBAFS. Based on the direction of flow determined for NBAFS, it is more likely that the groundwater is flowing offsite and follows surface flow paths.

Surrounding Private and Public Wells:

The location of private and public wells in New Boston, Amherst, and Mont Vernon were obtained from the New Hampshire Department of Environmental Services (Figure 3-6). Though most wells lie outside of the watershed boundary, it is likely that groundwater originating on the base may be affecting public and private wells in some areas. For instance, the outlet of the watershed (and the southeast corner of NBAFS) carries with it both surface and groundwater from the entire watershed. Any of the wells located along the stream outlet of the watershed are likely receiving water from the river at some point throughout the year. Further, any well located directly outside of the NBAFS boundaries that lie outside of the watershed boundary may also be affected. All wells potentially receiving water from NBAFS are noted on the groundwater map (Figure 3-7).



Legend

Watershed Boundary	
NBAFS Boundary	
Political Boundaries	
NBAFSWells	
Roads	**1:10,000**

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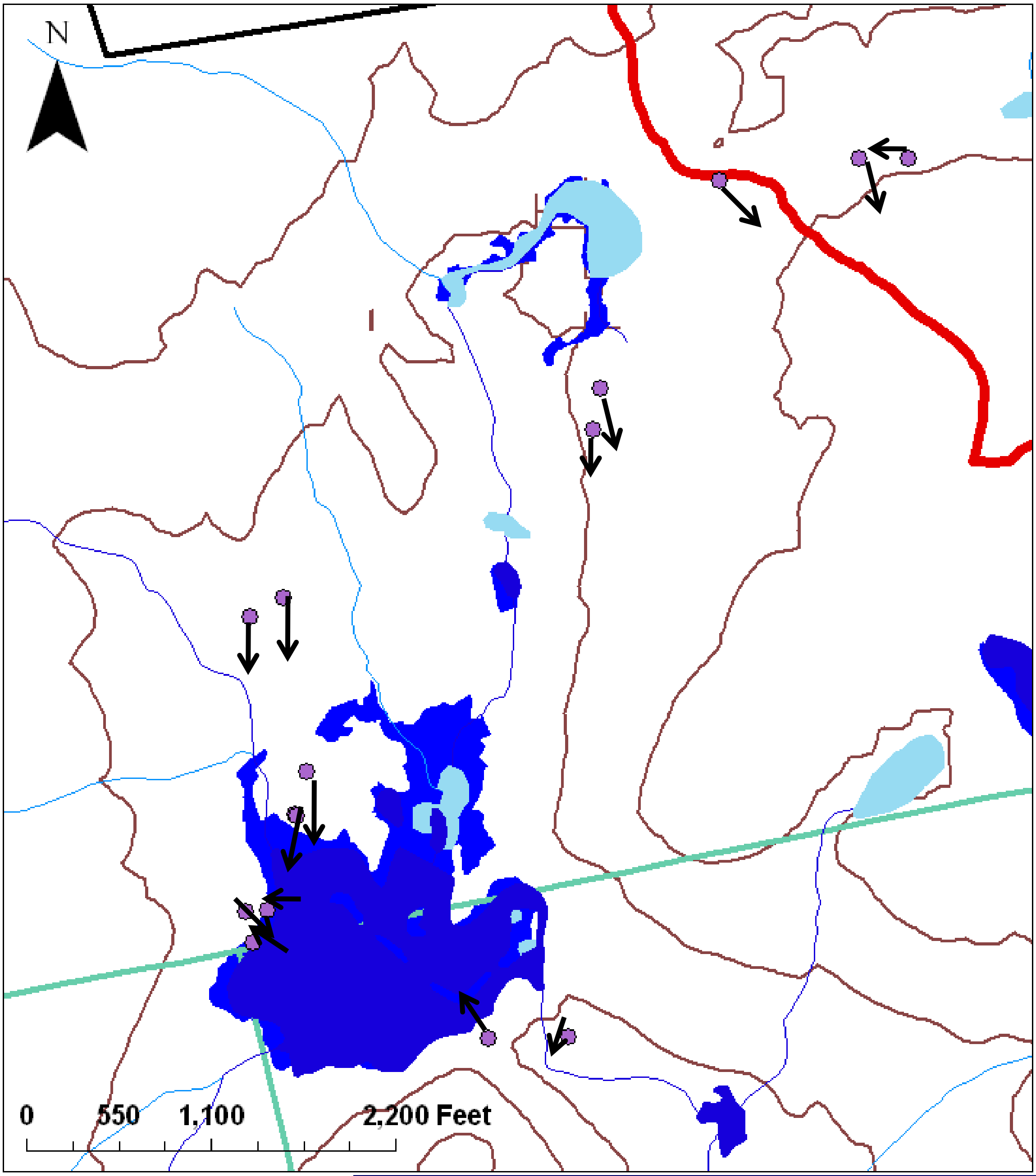
Figure 3-4: Groundwater Monitoring Wells Location: Aerial View
New Boston Air Force Station

NH Water Resources Research Center
Hydrology and Watershed Analysis NBAFS
Aerial Photo: NH Granit



Legend

Watershed Boundary

NBAFS Boundary

Political Boundaries

NBAFSWells

1:10,000

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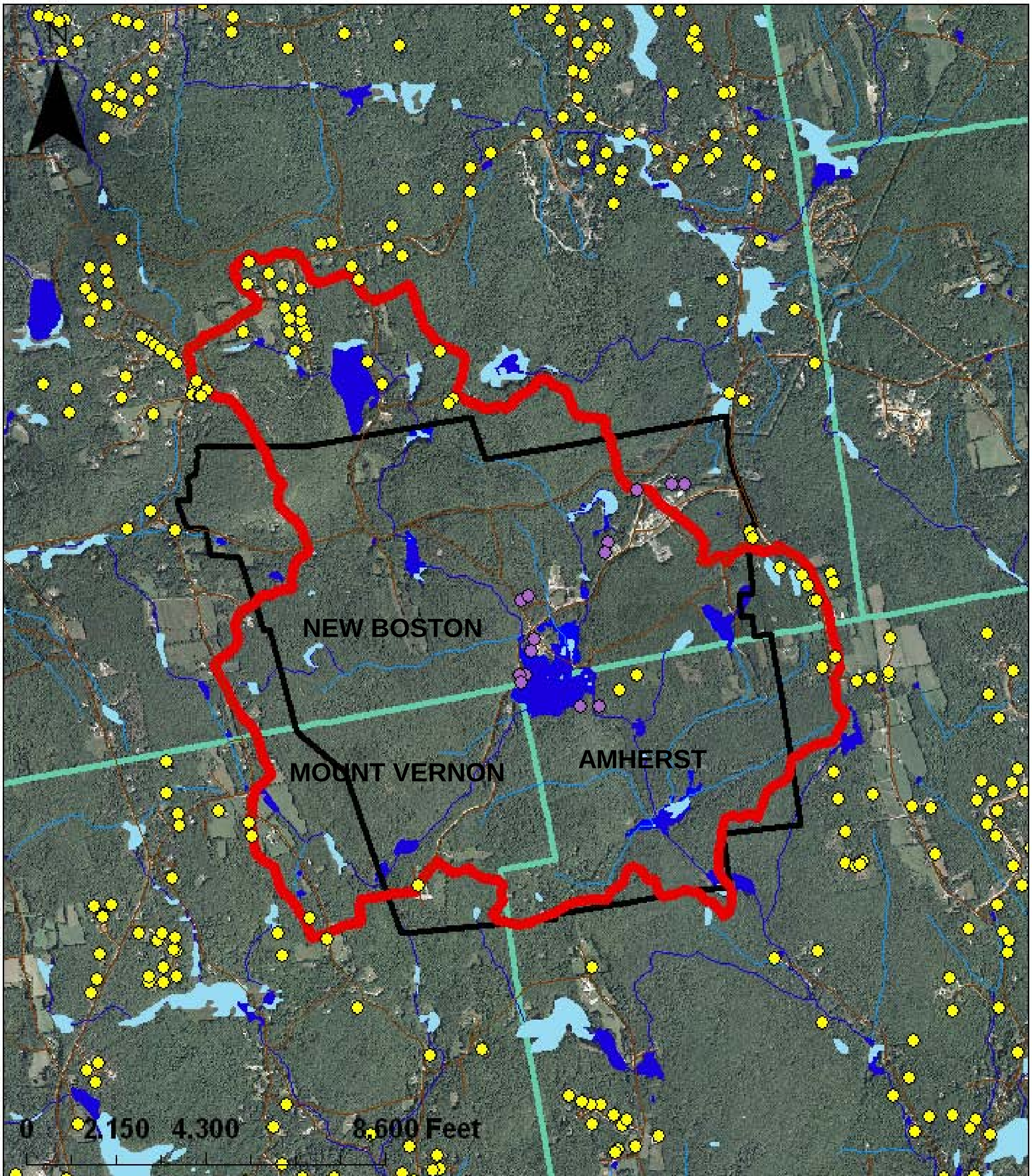
Figure 3-5: Groundwater Monitoring Wells Flow Direction: Topographic View
New Boston Air Force Station

NH Water Resources Research Center
Hydrology and Watershed Analysis NBAFS
100 ft Contour Intervals: Shaw Environmental, Inc.



Legend

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- NBAFSWells
- Public and Private Wells
- Roads

1:40,000

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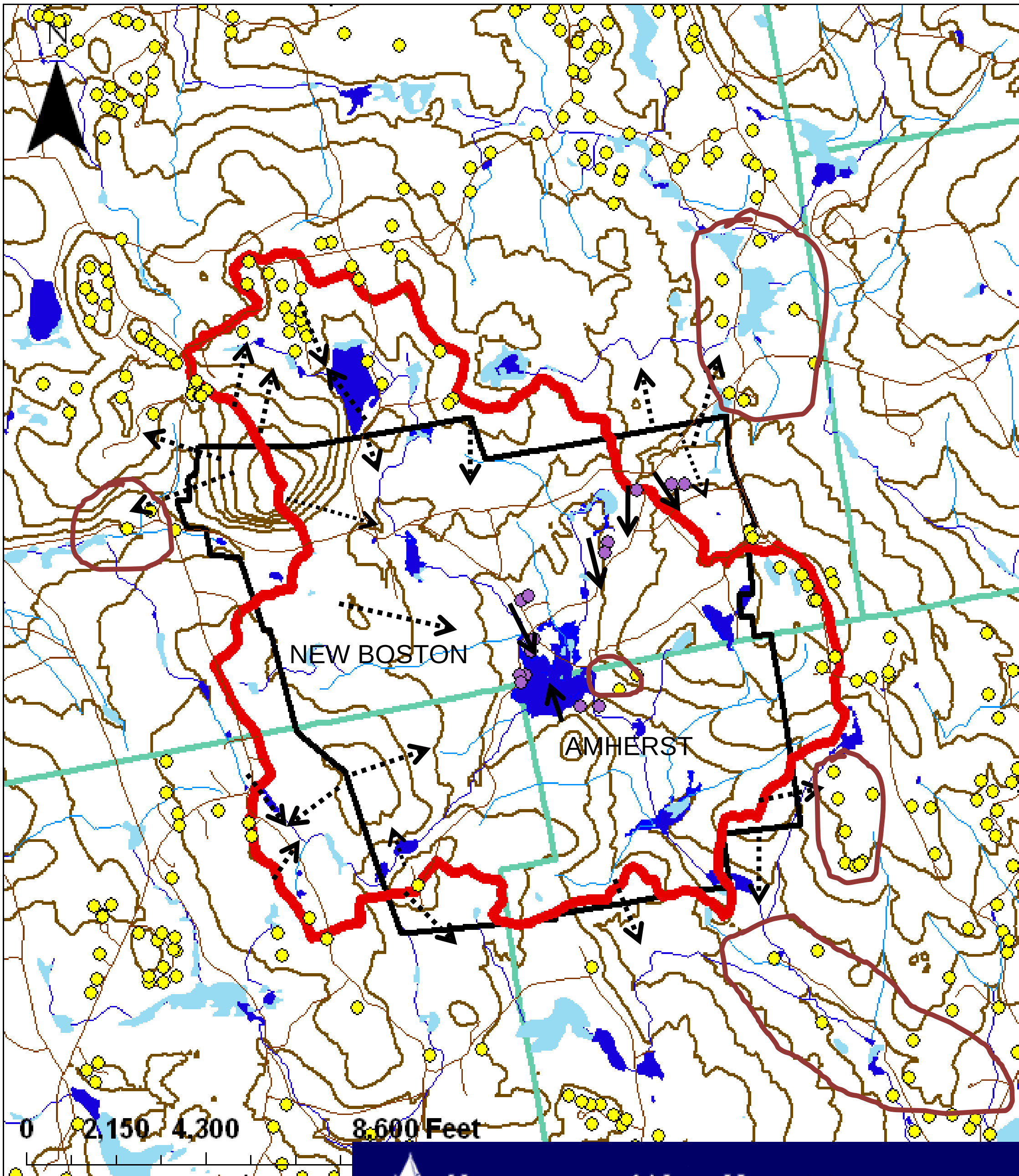
Figure 3-6: Location of Public and Private Wells: Aerial View
New Boston Air Force Station

NH Water Resources Research Center
Hydrology and Watershed Analysis NBAFS
Aerial Photo: NH Granit



Legend

- Watershed Boundary
- NBAFS Boundary
- Political Boundaries
- NBAFSWells
- Public and Private Wells
- Roads

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Figure 3-7: Groundwater Flow Direction: Public and Private Wells: Topographic View
New Boston Air Force Station

NH Water Resources Research Center
Hydrology and Watershed Analysis NBAFS
100 ft Contour Intervals: Shaw Environmental, Inc.

Estimated Groundwater Flow — Measured Groundwater Flow — Wells Potentially Receiving Water from NBAFS

Objective 4: Identify potential contaminant migration through ground and surface water flow paths using water quality data from Shaw Environmental, Inc.

Deliverable 4: Completion of water quality assessment and contaminant migration/transport.

1). Written report assessing water quality data obtained by Shaw Environmental, Inc. with respect to identified ground and surface water flow paths.

Methods:

Through analysis of the NBAFS Comprehensive Site Evaluation (CSE) Phase II report and NBAFS Site Investigation (SI) report completed by Shaw Environmental, Inc. and received from Jeff Oja on June 16, 2009, an evaluation of the ground and surface water quality on NBAFS was undertaken. Two pieces of this report, entitled "IRP Site Descriptions and Investigation Results" and "Munitions Response Site Characteristics," provided current groundwater quality data from three wells near JEP (GW3, GW4, and LF001-MW1), and surface water quality data from JEPand JEB, respectively. For the purposes of this study, only water samples from the wells used in this study, as well as those from JEP and JEB were obtained from the report. The regulatory limits of any potential contaminants were then obtained from established EPA Maximum Contaminant Levels (MCLs), EPA Secondary MCLs, EPA Health Advisory Levels, EPA Water and Fish Ingestion Guidelines, and NHDES Ambient Groundwater Quality Standards. Many of the potential contaminants had no published regulatory limit.

Overall, most potential contaminants of concern found in the ground or surface water on NBAFS originated from unexploded ordnance, oil, landfill leachate, and degraded metals from machinery. Human health effects range from short-term nausea and skin irritation, to long term damage to major bodily organs and cancer (EPA, 2009). A list of potential contaminants, their concentrations found in ground and surface water on NBAFS, and established regulatory limits for each potential contaminant are listed in Table 4-1. These standards were used as a benchmark for water quality as nearby residents relying on private wells should be notified if any water originating from NBAFS that enters their wells exceeds regulatory limits so residents can determine if their well is also contaminated and poses health risks.

In previous deliverables, it has been shown that both ground and surface water leave NBAFS through the outlet at JEB as well as through other groundwater flow paths. "Location" in Table 4-1 is arranged along a flow path (Figure 4-1) beginning in the three wells located upslope of the pond (LF001-MW1, GW-3, and GW-4), to JEP and JEB. Water quality data was available from 2006 and 2007.

Data Summary:

Based on the most recent data available for an individual location (Table 4-1), it can be seen that one contaminant exceeded the established regulatory limits in surface water. For surface water, JEP was analyzed for 11 explosives on 1 date, and of these, 1 exceeded regulatory limits. JEB was analyzed for 11 explosives on 2 dates, and of these, none exceeded regulatory limits. JEP and JEB were analyzed for 11 metals on 2 dates, and of these, 3 exceeded the regulatory limit. For groundwater, six wells were sampled for 21 metals and of these, 2 exceeded regulatory limits. However, as discussed in the CSE Phase II report, theses analytes were determined to be attributable to background concentrations. Groundwater was not analyzed for explosive contaminants.

Future Sampling Recommendations:

A background determination for metal concentration in surface and groundwater was carried out by Shaw Environmental, Inc. on conservation lands that border the installation. They found that concentrations of aluminum, chromium, copper, iron, manganese, lead, and mercury were attributable to background. Because one explosive contaminant was found to exceed regulatory limits in surface water, it is recommended that monitoring of this site continue. Further, though many potential contaminants were below detection limits, some detection limits were above a set regulatory limit. As such, it is recommended that future sampling of both ground and surface water for these potential contaminants should be conducted with lower detection limits.

The temporal and spatial variability in water quality may not be accounted for in this study as individual wells or surface water sites were sampled only once. Water quality, particularly surface water quality, can vary with season and during precipitation events which cause a flushing of nearby soils. It is likely that the concentrations of potential contaminants vary both annually and throughout a given year. Further, many of the sampling locations were not analyzed for the same list of potential contaminants (i.e. groundwater was not sampled for explosives). As such, it is possible that not all potential contamination was identified with this current sampling analysis. It is recommended that a more regular and extensive sampling regime of groundwater wells, JEP, and JEB be implemented to account for both spatial and temporal fluctuations in water quality as well as to monitor current locations where concentrations exceed the regulatory limit.

Though this study notes the water quality of water leaving the base through JEB, water was also found to leave the base via groundwater at the northeast, northwest, and southeast corners of NBAFS (Deliverable 3, Figure 3-7). No water quality data is available for these areas, and it is recommended that groundwater in these areas be sampled for potential contamination.

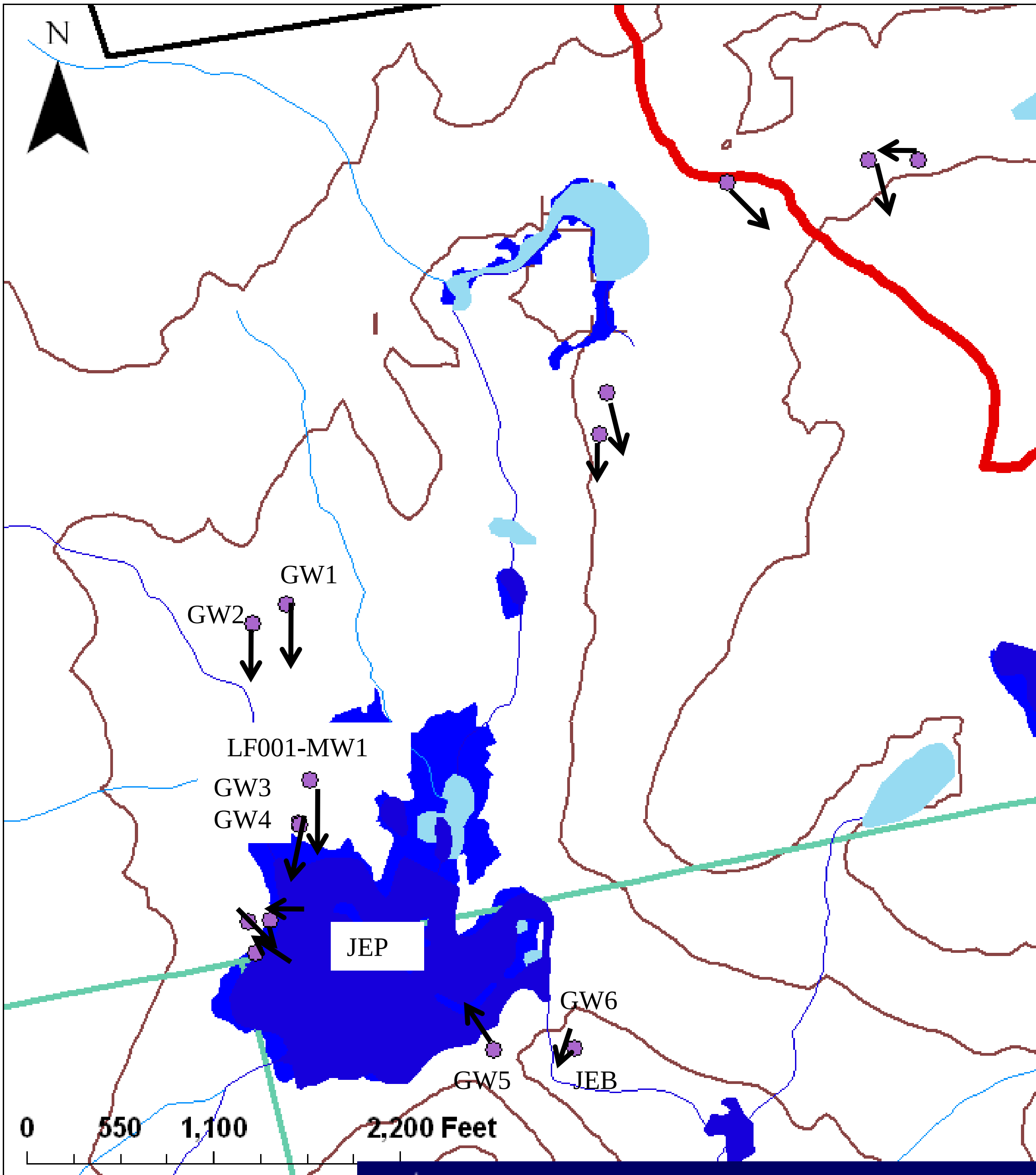

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Figure 4-1: Groundwater Monitoring Wells Flow Direction and Water Quality Flowpath: Topographic View: New Boston Air Force Station

NH Water Resources Research Center
Hydrology and Watershed Analysis NBAFS
100 ft Contour Intervals: Shaw Environmental, Inc.

Table 4-1: Ground and surface water concentrations (µg/L) of potential contaminants on NBAFS

Analyte	Location Water Type Regulatory Limit (µg/L)	LF001-MW1 Ground Results	GW-3 Ground Results	GW-4 Ground Results	JEP Surface Results	JEB Surface Results
Explosives (µg/L)						
2,4,6-Trinitrotoluene	NEL				BDL!	BDL!
2,4-Dinitrotoluene	0.11				0.33!	BDL!
2,6-Dinitrotoluene	0.11				BDL!	BDL!
2-Amino-4,6-Dinitrotoluene	0.11				BDL!	BDL!
4-Amino-2,6-Dinitrololuene	0.11				BDL!	BDL!
Nitrocellulose	NEL				BDL!	BDL!
Nitroglycerin	NEL				BDL!	BDL!
RDX	NEL				BDL!	BDL!
Tetryl	NEL				BDL!	BDL!
Perchlorate	15				BDL!	
Metals (µg/L)						
Aluminum	50	BDL*	BDL*	BDL*	828!	BDL!
Antimony	6	BDL*	BDL*	BDL*	BDL!	BDL!
Arsenic	10	BDL*	BDL*	BDL*		
Barium	2000	BDL*	BDL*	BDL*		
Beryllium	4	BDL*	BDL*	BDL*		
Cadmium	5	BDL*	BDL*	BDL*		
Calcium	NEL	4610*	14100*	11000*	2120!	2100!
Chromium	100	BDL*	BDL*	BDL*	BDL!	BDL!
Copper	1300	BDL*	BDL*	BDL*	BDL!	BDL!
Iron	300	BDL*	BDL*	BDL*	2660!	384!
Lead	Action Limit 15	BDL*	BDL*	BDL*	BDL!	BDL!
Magnesium	NEL	BDL*	BDL*	BDL*	BDL!	BDL!
Manganese	50	15.1*	BDL*	BDL*	206!	69!
Mercury	2	BDL*	BDL*	BDL*	BDL!	BDL!
Potassium	35000	BDL*	BDL*	BDL*		
Selenium	50	BDL*	BDL*	BDL*		
Silver	100	BDL*	BDL*	BDL*		
Sodium	100-250 mg/L	BDL*	16700*	BDL*		
Thallium	2	BDL*	BDL*	BDL*		
Vanadium	NEL	BDL*	BDL*	BDL*		
Zinc	5000	BDL*	BDL*	BDL*	BDL!	BDL!

Sample Dates: October 2006!; August 2007*

NEL: No established limit

BDL: Below Detection Limits

EPA 2009 Maximum Contaminant Level (national drinking water standards) (EPA, 2009)

EPA 2009 Secondary Maximum Contaminant Level (contamination level that affects aesthetic characteristics of drinking water (EPA, 2009a)

NHDES Ambient Groundwater Quality Standards (Shaw Environmental, Inc. 2009)

EPA Health Advisory Level (EPA, 2009b)

EPA Water and Fish Ingestion Standard (EPA, 2009c)

Exceeds regulatory limit

BDL, however detection limit exceeds regulatory limit

Exceeds regulatory limit, however below background levels

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Title: Watershed Assessment of New Boston Air Force Station (NBAFS)

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Study Purpose:

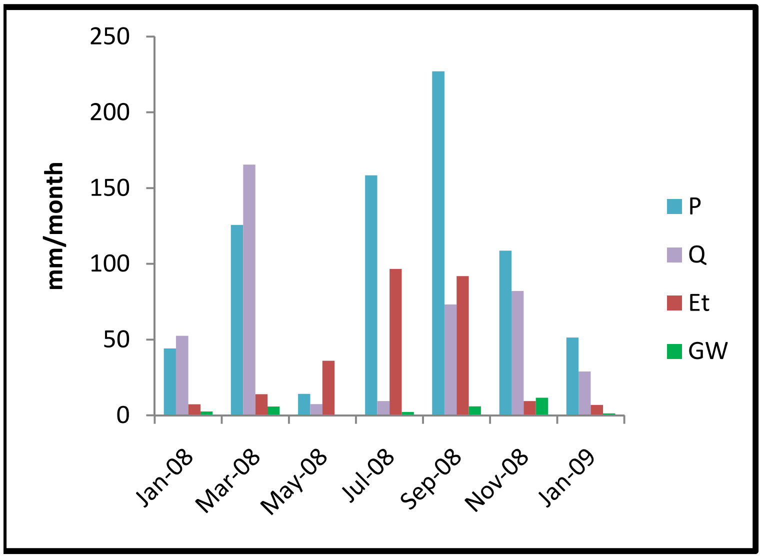
- Assess the quantity and distribution of surface and groundwater resources of NBAFS

Research Objectives:

- Delineate the watershed on NBAFS
- Determine surface and groundwater flow paths within NBAFS
- Create an annual hydrologic budget using the model BROOK 90
- Evaluate current water quality data

Hydrologic Budget:

Figure 1: Annual hydrologic budget for NBAFS

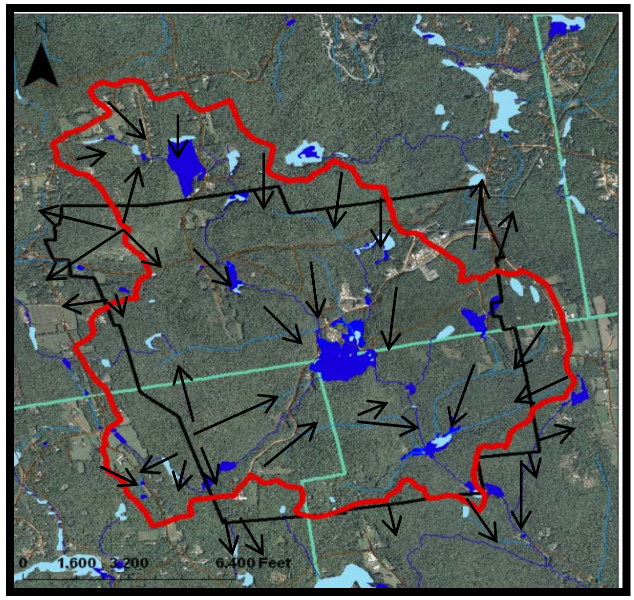


Summary of Hydrologic Budget:

Most water that enters the base as precipitation (P) leaves as discharge (Q) through Joe English Brook. Precipitation was highest in the spring and fall. Highest discharge occurred in March (spring melt). Lowest discharge occurred in the summer months. In general, evapotranspiration (Et) was lowest in the winter months. Groundwater (GW) was lowest in the summer due to lower precipitation and higher demand from plants.

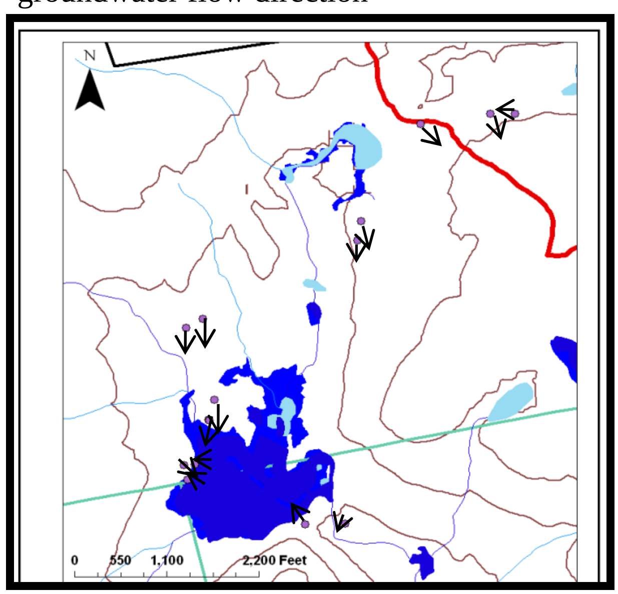
Surface Water Flow:

Figure 2: NBAFS watershed and surface water flow direction



Groundwater Flow:

Figure 3: NBAFS groundwater wells and groundwater flow direction



Summary of Surface and Groundwater Flow:

Most surface and groundwater on the base enters Joe English Pond and leaves the base through Joe English Brook. Sections of the base fall outside of the watershed boundary, indicating water flows off base in these areas.

References:

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