TerrAtlantic
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July 22, 2004

File: 384.02

David C. Whyte, M.Sc.
Project Manager
Project Assessment (EIA) Branch
Environment & Local Government
Marysville Place
P. O. Box 6000
Fredericton, NB
E3B 5H1

Dear Mr. Whyte:

***RE: Project Registration, Proposed Production Well Replacement, Town of Rothesay***

Thank you for your letter dated July 22, 2004 concerning the above project. The following information is provided as requested in that letter:

***Scope of the Project***

- Well 3 has to be replaced because its specific capacity has been reduced to less than 10 percent of original. The rehabilitation prospects are considered to be slight. It is located too close to the important production Well 6 for aggressive rehabilitation techniques to be considered.
- The purpose of the project was incorrectly stated. A better description would be: Provision of potable water to replace capacity lost due to screen encrustation/biofouling. The total daily withdrawal rate from the wellfield will not increase as a result of this project.
- No, there are no suitable replacements for Well 3.
- Water conservation initiatives have been taken by the Town in developing the supply. These have included metering of all users. No new measures have been instituted with respect to this well rehabilitation project.

***Existing Environment***

- See attached information (Chapter 3) from a preliminary report submitted to the Town by TerrAtlantic Engineering Limited (July, 2004).

### *Anticipated Environmental Impacts*

- No significant environmental impacts are anticipated. Access to drill sites will be made with care, minimizing cutting. Drill water and water from the pump test will be controlled. The area is remote from residential properties, therefore noise will not be an issue.

### *Proposed Mitigation*

- Pumped water will be discharged in vegetated areas and/or silt screens will be constructed. Drilling will be limited to daylight hours.

### *Public Involvement*

- An update of the wellfield rehabilitation project will be provided on the Town's website.

### *Submission Requirements*

- Attached is a copy of the Wellfield Protection Study mapping

- Five hard copies of the submission will be delivered to NBDELG.

### *Permit Requirements*

- Exploratory hole locations shown in Figure 1 of the submission are approximate only; such exploration being adjusted in the field based on early findings. No work will be undertaken within 30 metres of a watercourse without full compliance with Watercourse and Wetland Alteration permitting.

Should additional information be needed please advise.

Sincerely,

AARON ALDERMAN, B.Sc.(Eng), P.Eng.
PROJECT ENGINEER

c.c. Scott Hatcher, P.Eng.
c.c. Paul Vanderlaan

ATTACHMENTS:

1) Chapter 3 of the Preliminary Water Supply Assessment Report Submitted by TerrAtlantic Engineering Limited to the Town of Rothesay, NB (July, 2004)

2) Wellfield Protection Map, Figure 4.1 - Proposed Protection Zones, Wellfield Protection Study for the Town of Rothesay, TerrAtlantic Engineering Limited, (June, 2002)

# *3.0 THE CARPENTER POND WELLFIELD*

## *3.1 General*

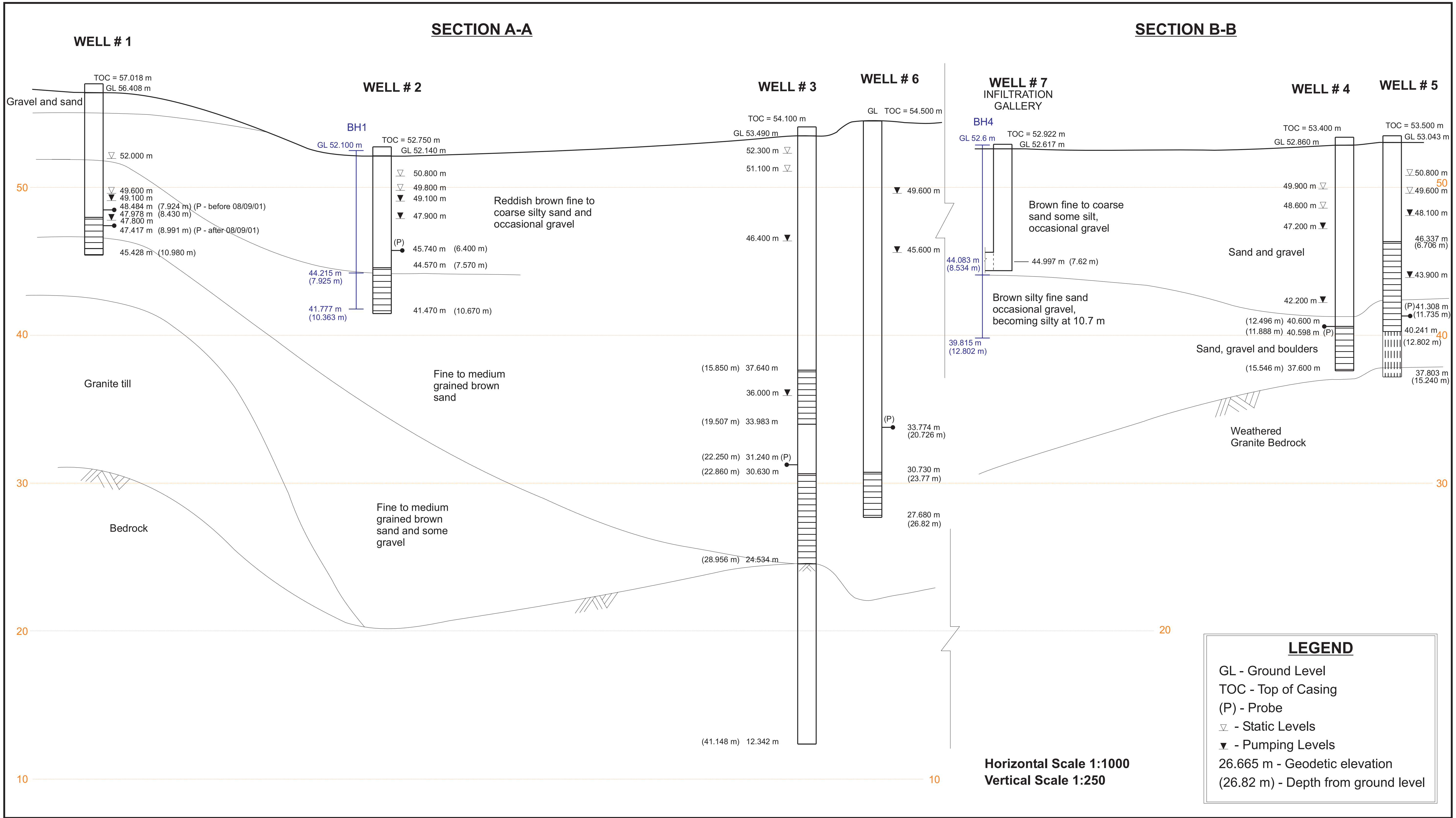
Six operational production wells (No.1 through 6) and an inactive horizontal infiltration gallery (No. 7) have been constructed in the granular overburden around Carpenter Pond as shown in Figures 1 and 2. The focus of the current work has been to examine Well 3, which appeared to have become plugged or clogged, perhaps beyond repair, and also to assess the viability of a potential replacement well (No. 8). When it became clear that biofouling was likely involved it was decided that the performance of all of the wells should be examined with this in mind. Following a discussion of the geologic setting (Section 3.2) we therefore examine each well in turn, from the construction details to the subsequent performance (Section 3.3).

## *3.2 Geologic setting*

The surficial deposits were described in the wellfield protection study (TerrAtlantic Engineering Limited, 2002), parts of which are repeated here.

At Carpenter Pond the overburden is thicker than average and comprises granular, glacio-fluvial and glacio-lacustrine material. The glacial history is complex, as documented by Finamore and Lohse (1977). The complexity is illustrated by their description of the ice retreat that would have lead to the deposition of granular materials in and around Carpenter Pond:

> *"West of Loch Lomond, ice retreat can be recognized by ice-contact deposits in the McCormac Lake and Carpenter Pond-Bradley Lake areas (Melvin, 1966). Ice apparently occupied the low-lying areas as outwash materials were channelled south from McCormac Lake into the meltwater channel and along Cold Brook into the Little River. With further ice retreat, drainage via Cold Brook was diverted along Taylor Brook into what is believed to be an estuarine environment of the Kennebecasis River. This sequence of deposits continuously extends northward towards the Hammond River and appears to have been the result of local wasting from a detached ice mass."*



**TerrAtlantic**
Engineering Limited

PROJECT
CARPENTER POND
PRODUCTION WELLS
ROTHESAY, NB

DRAWING
INTERPRETED SUB-SURFACE SECTIONS
THROUGH PRODUCTION WELLS

| DATE | DRAWING NO. |
|---|---|
| JULY, 2004 | FIGURE 2 |
| PROJECT NO. | FILE NO. |
| 384.02 | 38402003 |

The associated granular resources map indicates glacio-lacustrine and marine shallow water deposits near Carpenter Pond, with ice-contact stratified drift between Golden Grove and MacFarlane Lake. A cross section through the pond (Maritime Groundwater Investigations Inc., 1987) suggests that 10 metres or so of the marine shallow water deposit, comprising sand, silty sand and occasional gravel, is underlain by either silty sand, glacial outwash or granite till. Although the stratigraphy may still not be fully understood, based on the available borehole data, the overburden is known to be locally as thick as 30 metres by the pond.

## *3.3 The production wells*

### 3.3.1 Well 1

Well 1 was constructed in 1964. It is a gravel-packed well of 0.254 m (10 inch) diameter and 10.97 metres depth. The screen is 2.54 metre long; the slot size is unknown. The well sensor is reportedly located 8.53 metres from the top of the well and some 0.61 metres above the pump. The original yield of the well was reportedly 6.3 L/s (100 usgpm) (MGI, 1987) on which basis the initial specific capacity would have been about 3.2 L/s/m or 15.2 usgpm/ft[1].

The well was redeveloped in 1987 at which time the specific capacity had reportedly halved[2]. The reasons for the reduction in yield were attributed to “the invasion of silt and sand and the development of iron and manganese oxides in the gravel pack” (MGI, 1987). Redevelopment involved acid treatment and the addition of 5.35 cubic metres of gravel. Afterwards the well was pumped for three hours at 7.58 L/s (120 usgpm), this producing a drawdown of a little less than 3 metres. As a result of redevelopment, the specific capacity increased from a reported 0.67 L/s/m (3.2 usgpm/ft) to 2.55 L/s/m (12.3 usgpm/ft).

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[1] Assuming a pumping drawdown no greater than 2 metres.

[2] From the available data it seems likely that the specific capacity may actually have reduced to less than 25 percent of its initial value.

Static and pumping water levels in Well 1 for the last six years (i.e. from 1998 to 2003) are plotted in Figure 3. There have been normal seasonal changes in level, but the drawdown (the difference between pumping and static levels) has increased with time, leading to a reduction in the average pumping rate. The associated reduction in specific capacity has been dramatic, decreasing to a little over 0.4 L/s/m or 2.0 usgpm/ft.

Acidization of the well was evidently a successful treatment, but following redevelopment, the specific capacity decreased with time at about the same rate as it had done initially (i.e. between the years 1964 and 1987).

### 3.3.2 Well 2

Well 2 was also constructed in 1964. It is of similar (gravel-packed) construction to that of Well 1, being 0.254 m (10 inch) in diameter and 10.67 metres deep. The screen is 3.10 metre long (slot size unknown) and there is also a 1.7 metre long slotted pipe section. The well sensor is reportedly located 7.01 metres from the top of the well and some 0.61 metres above the pump.

There is not very much available information about this well, but the yield reportedly reduced with time from an estimated 3.8 L/s to 1.9 L/s (60 usgpm to 30 usgpm) by 1987 at which time the screen was pulled and cleaned. The reasons for the reduction in yield were attributed to the encrustation of the slots with iron and manganese oxides, and the reduction in the formation void space due to iron and manganese oxides, silt and sand. The stainless steel screen was reportedly "as clean as when it was first installed" but there was "an iron and manganese crust about 75 mm thick on the outside of the casing" (MGI, 1987). An iron and manganese crust was also reportedly bonded to some of the silica gravel pack.

We understand that acid treatment was not undertaken but that during redevelopment with air, 8.41 cubic metres of gravel was added. The yield of the well reportedly increased to 7.6 L/s (120 usgpm) but there was no pumping test carried out to verify this.

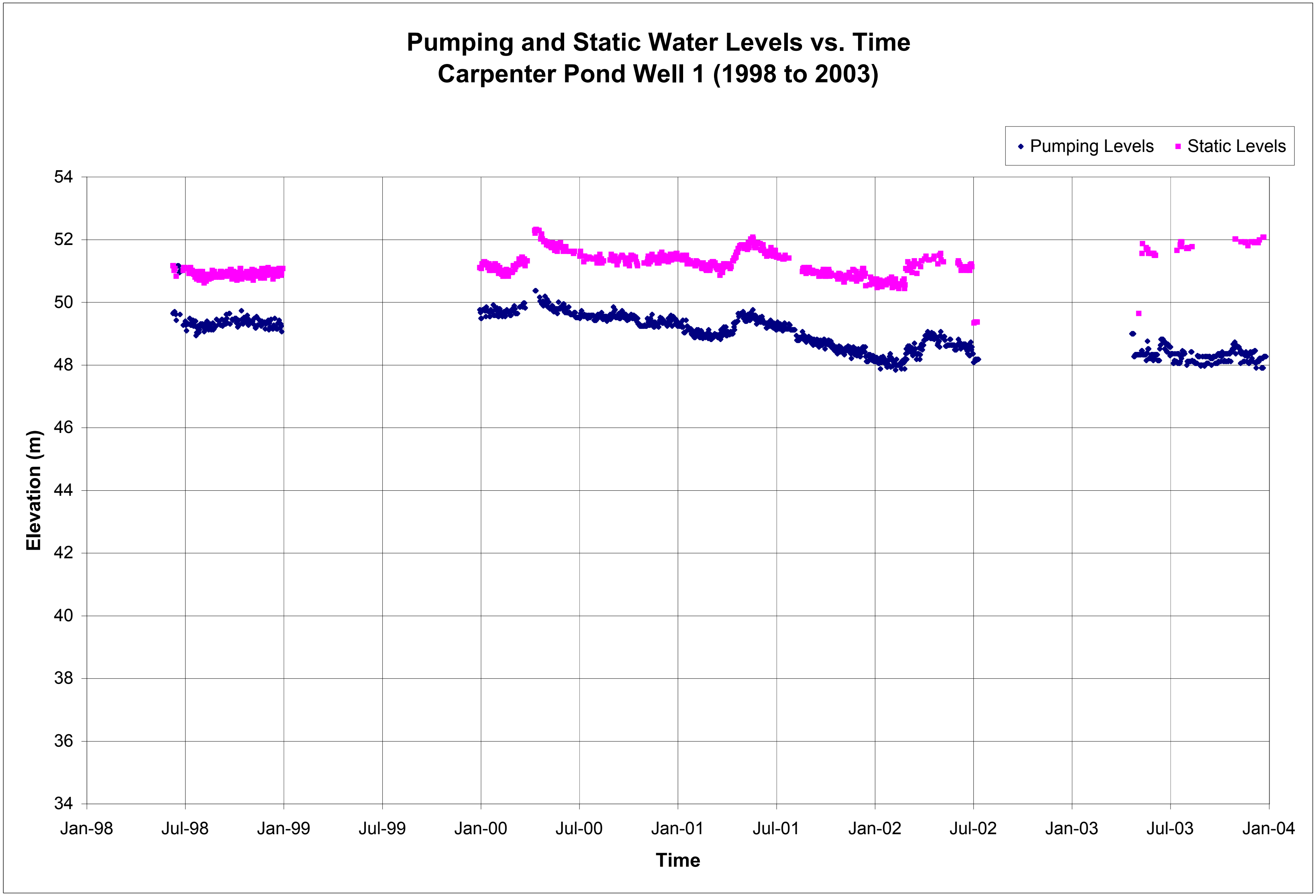
Pumping and Static Water Levels vs. Time
Carpenter Pond Well 1 (1998 to 2003)
◆ Pumping Levels
■ Static Levels
54
52
50
48
46
44
42
40
38
36
34
Elevation (m)
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Time

FIGURE 3

Static and pumping water levels in Well 2 for the last six years (i.e. from 1998 to 2003) are plotted in Figure 4. There were again seasonal changes in level but no dramatic increase in drawdowns. The average pumping rate was relatively consistent in this period, ranging from 3.3 to 3.7 L/s (52 to 58 usgpm. The specific capacity has fluctuated seasonally but there has not been a systematic reduction (of any significance) with time.

The screen removal, cleaning, and well redevelopment process was evidently very successful. There may have been some reduction in specific capacity with time but there are at least two more metres of available drawdown.

### 3.3.3 Well 3

Well 3 is the one of current concern. Constructed in 1974, this well is 41.2 metres (135 feet) deep of which 29.0 metres (95 feet) is in overburden and the balance (12.2 metres or 40 feet) is in bedrock. The overburden section is screened at two intervals; (a) one 3.66 metre section below 15.85 metres depth; and (b) a second 5.18 metre section below a depth of 22.86 metres. Both screens are 0.254 metres (10 inches) in diameter. The well sensor is located above the lower screen, some 22.86 metres from the top of the well and 1.52 metres above the pump.

After construction, Well 3 was pump tested at a rate of up to 20.8 L/s (330 usgpm) for 48 hours, at which time the drawdown was 14.9 metres, which would have been part way down the upper screen. The specific capacity in the early part of the test was in the order of 1.2 L/s/m (5.6 usgpm/ft). As with the test pumping of Well 1, recharge had been intercepted within 10 minutes of turning the pump on, and this high pumping rate would theoretically have been sustainable in the longer term. The well yield was accordingly rated at 20.8 L/s (330 usgpm) (Crandall, 1974).

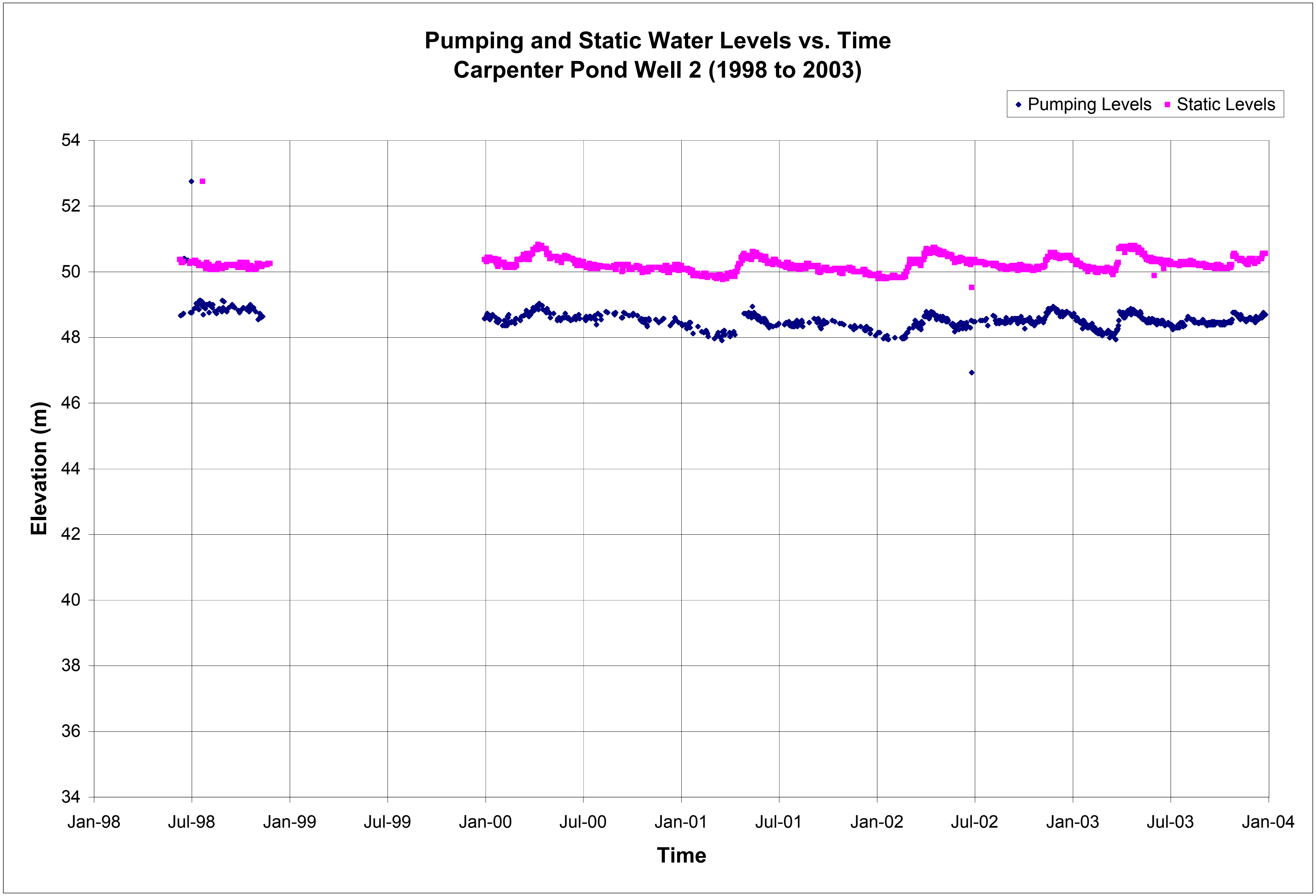
Pumping and Static Water Levels vs. Time
Carpenter Pond Well 2 (1998 to 2003)
◆ Pumping Levels
■ Static Levels
Elevation (m)
54
52
50
48
46
44
42
40
38
36
34
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Time

FIGURE 4

In practice, the well was not pumped for a prolonged period at this rate, and in 1989 a 3.0 L/s (48 usgpm or 40 igpm) submersible pump had been installed. In more recent years the feasible pumping rate has reduced further from 1.9 to 2.5 L/s (30 to 40 usgpm) in 1998 to between 0.6 and 1.5 L/s (10 and 24 usgpm) by 2003. The loss in specific capacity was attributed to construction details, but the 1979 redevelopment of the well by air surging was not successful. Since 1998, the static water level in Well 3 has fluctuated seasonally in a predictable way but the pumping level has been erratic, refer to Figure 5. The drawdown has typically ranged from 7 to 15 metres, and the specific capacity has been in the range 0.4 to less than 0.1 L/s/m (2 usgpm/ft to less than 0.5 usgpm/ft).

### 3.3.4 Well 4

Well 4 was constructed in 1985 (Water Management Services, 1985). It is a 200 mm (8 inch) diameter, 15.26 m deep gravel-packed well, with a 3.0 metre long 120 slot screen from 12.26 m to the bottom of the hole. The well sensor is set at the top of the screen, some 0.61 metres above the pump. When pumped[3] at the recommended safe yield of 7.6 L/s (120 usgpm), the drawdown and specific capacity were reportedly 5.5 m (~18 feet) and 1.4 L/s/m (6.6 usgpm/ft) respectively.

Water levels in Well 4 over the past six years are plotted in Figure 6. The drawdown has ranged from 3 to 5 metres reflecting variations in pumping rate of between 0.4 and 1.9 L/s (6 and 30 usgpm). The specific capacity has declined from about 0.3 to 0.2 L/s/m (1.5 to 1.0 usgpm/ft) which would be 10 percent of the initially reported value.

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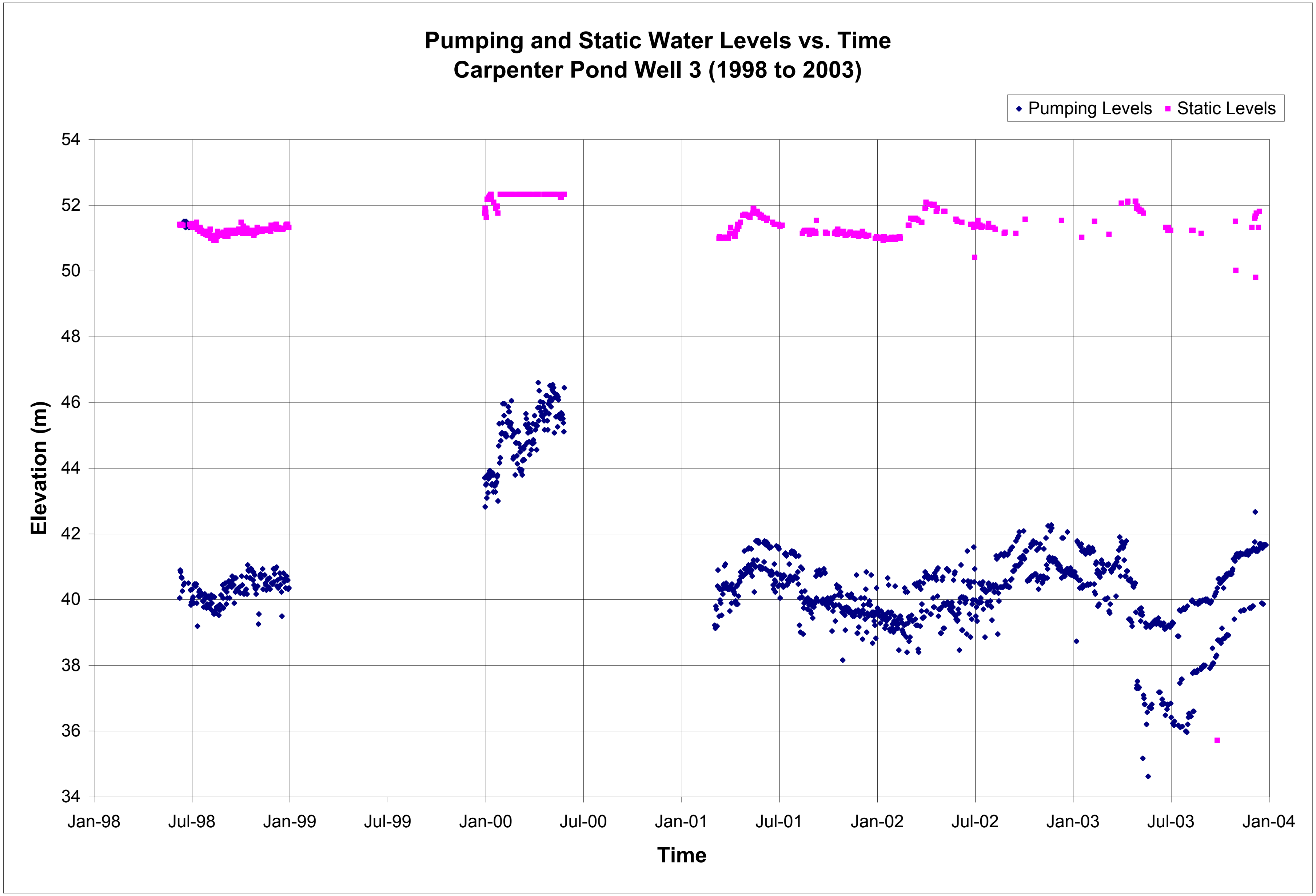
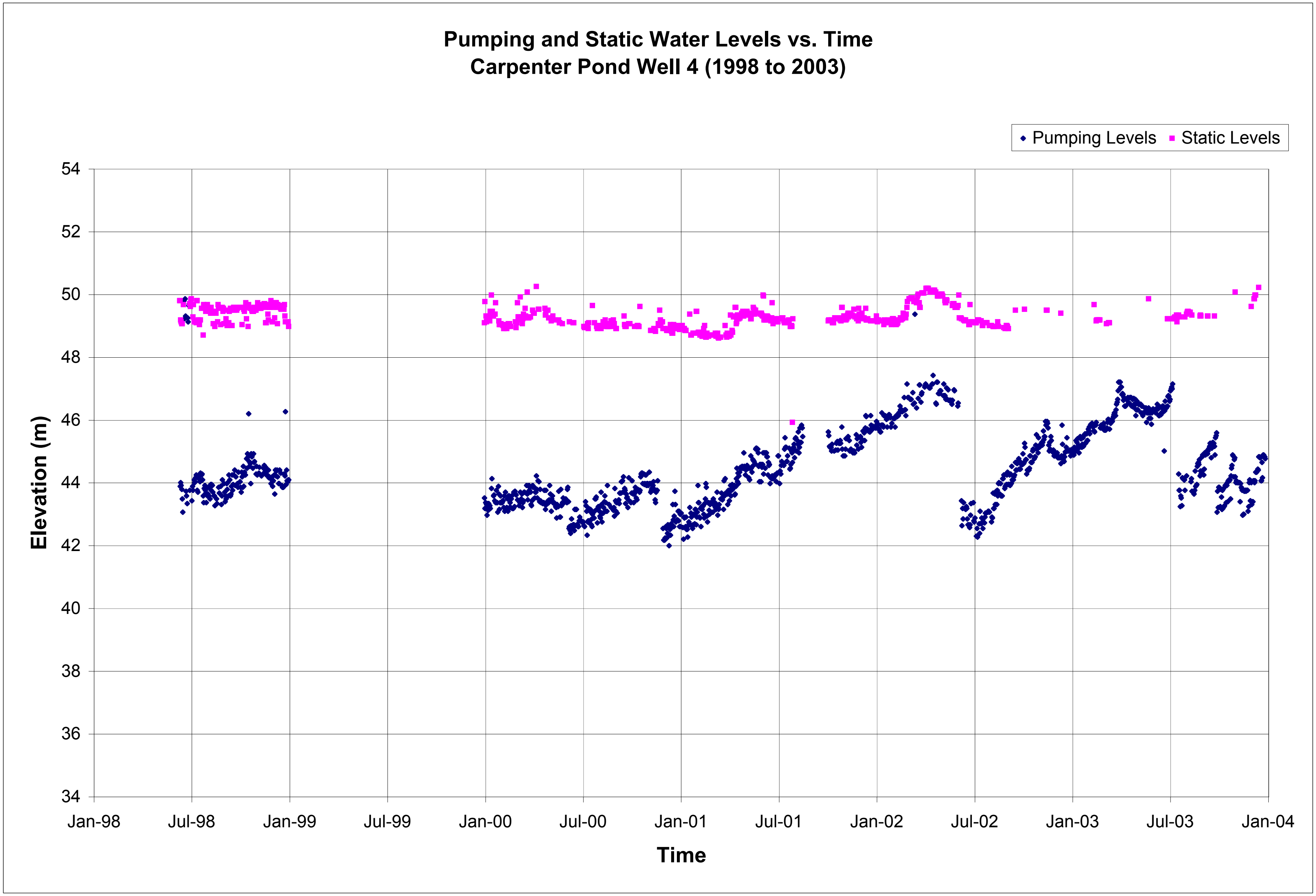
[3] For an unspecified time period.



Pumping and Static Water Levels vs. Time
Carpenter Pond Well 3 (1998 to 2003)

FIGURE 5



Pumping and Static Water Levels vs. Time
Carpenter Pond Well 4 (1998 to 2003)
◆ Pumping Levels
■ Static Levels
Elevation (m)
54
52
50
48
46
44
42
40
38
36
34
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Time

FIGURE 6

### 3.3.5 Well 5

Well 5 was constructed in 1992[4]. It is gravel packed, 15.24 metres deep, and consists of a 6.1 metre long, 254 mm (10 inch) diameter, 125 slot screen below 6.71 metres. Below the screen is 3.0 metre long section of slotted steel pipe. The well sensor is located 12.2 metres from the top of the well. After construction the well was pumped at 9.1 L/s (144 usgpm) for 3 days at which time the drawdown was 6.3 metres, corresponding to a specific capacity of 1.4 L/s/m (6.9 usgpm/ft).

Water levels in Well 5 over the past six years are plotted in Figure 7. There have been significant fluctuations in drawdown (in the range 2.5 to 4 metres), occurring primarily as a result of variations in pumping rate (between 1.8 to 4.5 L/s or 28 to 71 usgpm). The average pumping rate increased from 1998 to 2000 but has decreased each year since then. The specific capacity measured at the time of construction was evidently maintained for six or so years but has since gradually declined to about 0.6 L/s/m (usgpm/ft).

### 3.3.6 Well 6

Well 6 was constructed in 1989. It is a 26.8 metre deep gravel packed well with a 3 metre long, 254 mm (10 inch) diameter screen, set at a depth below 23. 77 m. The well sensor is located 20.7 metres from the top of the well, some 1.5 metres above the pump. After construction the well was pumped at 15.1 L/s (240 usgpm) for 78 hours at which time the drawdown was 6.93 metres. The corresponding specific capacity was 2.2 L/s/m (or 10.57 usgpm/ft).

The pumping levels in Well 6 over the past six years are plotted in Figure 8. Since there were only a limited number of static water level readings available for Well 6, the static levels at the nearby Well 3 (15 metres distant) were used where there were gaps in the dataset. The overall drawdown did not materially change (from 2 metres) in the period of record, but the pumping rate, typically in the range 4.1 L/s to 6.3 L/s (65 to 100 usgpm), has dropped a little with time. There has been

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[4] The original well 5 was the infiltration gallery constructed in 1986, later renamed Well 7.

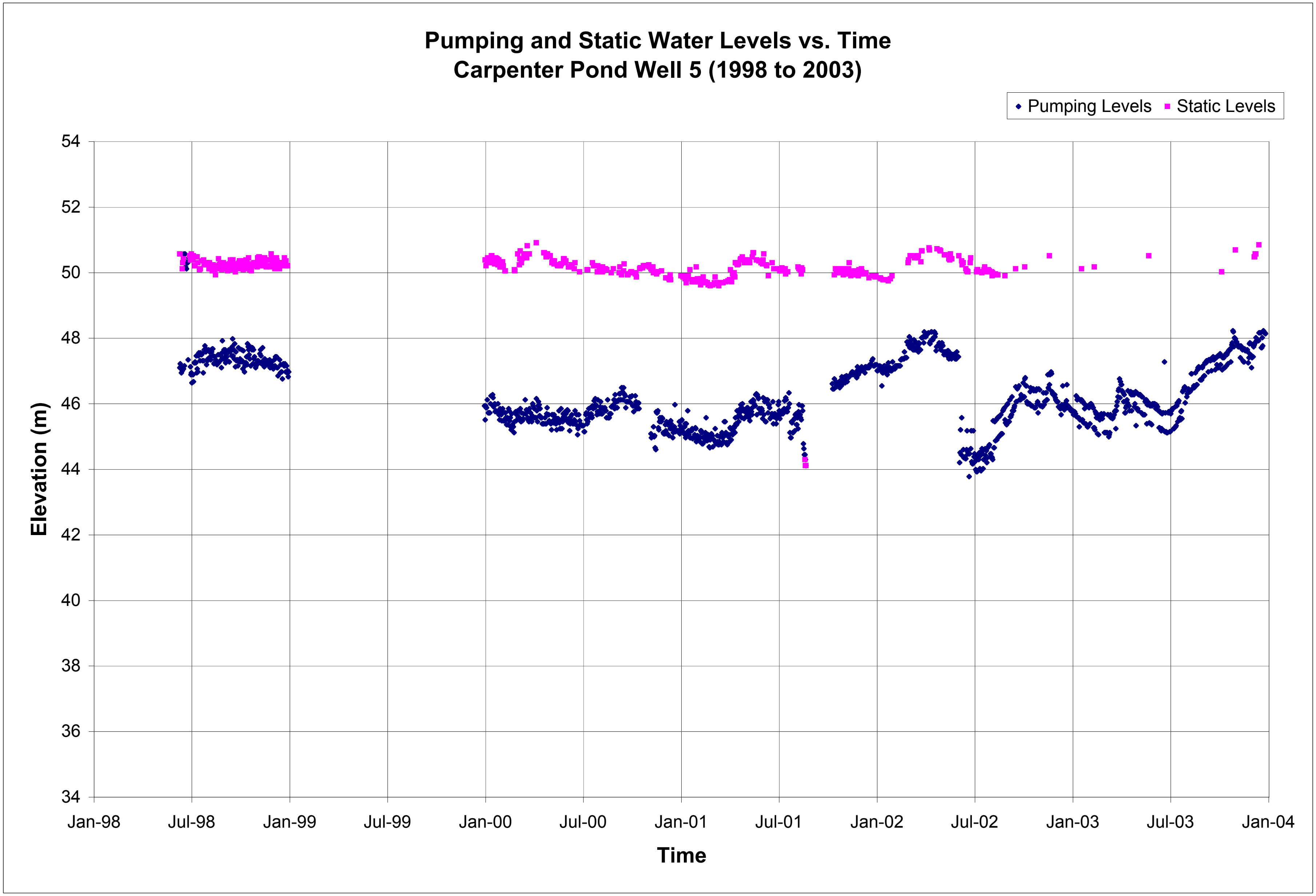
Pumping and Static Water Levels vs. Time
Carpenter Pond Well 5 (1998 to 2003)
◆ Pumping Levels
■ Static Levels
Elevation (m)
54
52
50
48
46
44
42
40
38
36
34
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Time

FIGURE 7

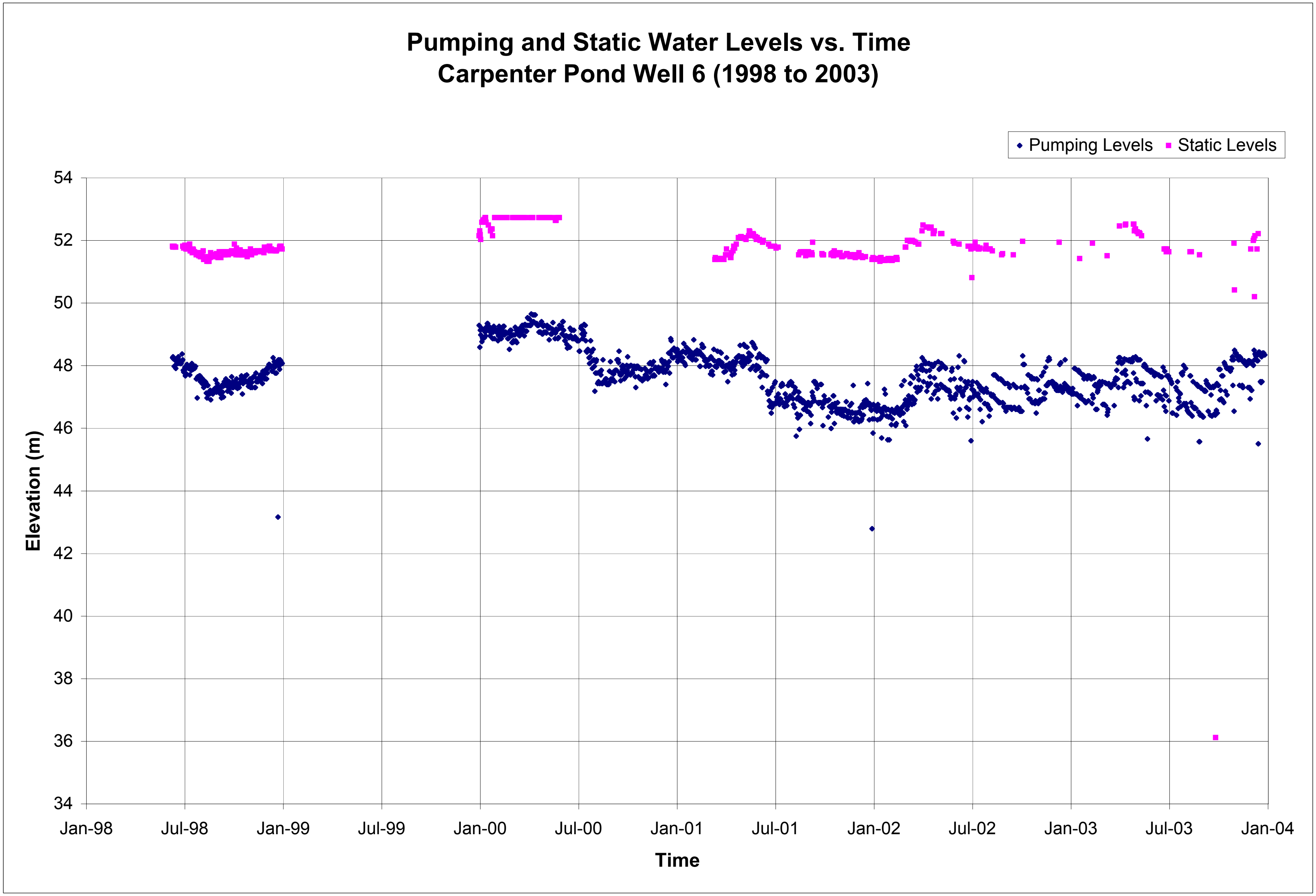
Pumping and Static Water Levels vs. Time
Carpenter Pond Well 6 (1998 to 2003)
◆ Pumping Levels
■ Static Levels
Elevation (m)
54
52
50
48
46
44
42
40
38
36
34
Time
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04

FIGURE 8

a corresponding slight reduction in the specific capacity, from about 1.3 to 1.0 L/s/sm (6.5 usgpm/ft) in 1998 to 5 usgpm/ft in 2003.

### 3.3.7 Well 7

Well 7 is a 61 metre long horizontal infiltration gallery constructed in 1986, accessed via a 7.85 metre deep shaft[5]. This well is presently not in service for reasons of water quality. The gallery is in particularly close communication with the pond and as such, colour and temperature have been at issue, at least in the summer months.

## *3.4 Biofouling*

For each production well, the pumping rate and the static and pumping water level data for the years 1998, 2000 to 2003 were analysed. Plots of specific capacity versus time for each of the wells are presented in Figures 9 and 10, the latter showing specific capacity as a percentage of initial (i.e. maximum) values. These data were used to calculate the average specific capacities prevailing each year in the various wells, as summarized in Table 1. All wells have exhibited some reduction in specific capacity with time. The most significant reductions have occurred in Wells 1 and 3 (represented by the blue diamonds and orange triangles respectively, in Figures 9 and 10).

There are a number of possible reasons for the loss in specific capacity including sand/silt pumping, chemical encrustation and biofouling. The available data suggest that biofouling is the most likely cause, but further investigation as discussed below is recommended to resolve this.

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[5] An 18 inch diameter slotted PVC pipe bedded in 1/4 inch to 3/4 inch washed beach gravel.

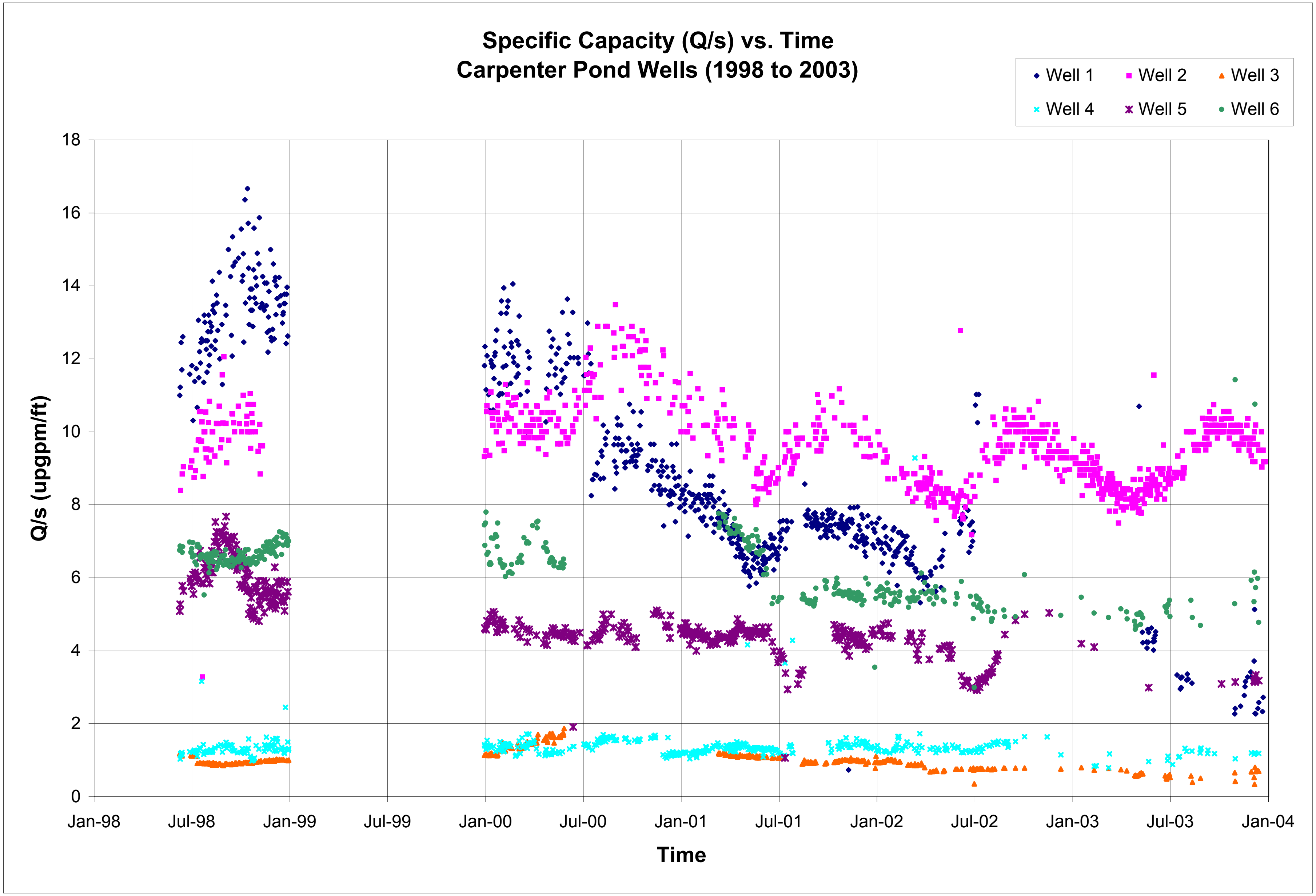

Specific Capacity (Q/s) vs. Time
Carpenter Pond Wells (1998 to 2003)
◆ Well 1
■ Well 2
▲ Well 3
× Well 4
✱ Well 5
● Well 6
Q/s (upgpm/ft)
0
2
4
6
8
10
12
14
16
18
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Time

FIGURE 9

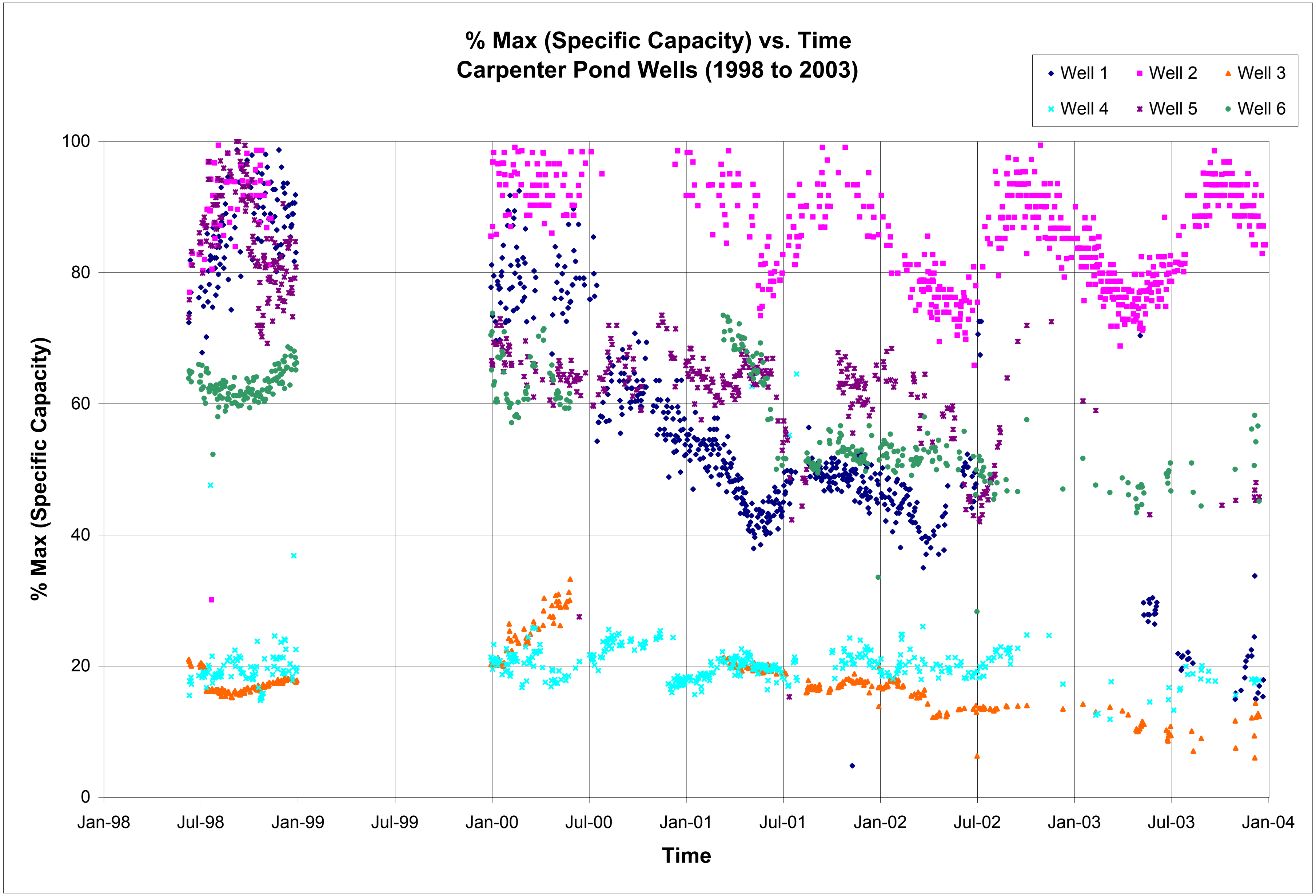

% Max (Specific Capacity) vs. Time
Carpenter Pond Wells (1998 to 2003)
Well 1
Well 2
Well 3
Well 4
Well 5
Well 6
% Max (Specific Capacity)
100
80
60
40
20
0
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Time

FIGURE 10

Biofouling is the term used to describe water well deterioration caused by microbiological activity (i.e.: bacteria). Well deterioration can take the form of:

- deteriorating water quality over time (including taste and odour, discolouration, turbidity);
- reduced well yield due to clogging of well screens or the aquifer itself (slimes, nodules, tubercles, encrustations, and foams); and
- red or black slime on pumps, well screens, or in the distribution system (leading to increased corrosion of steel well casings and screens.

Nuisance bacteria are naturally present in groundwater. Pumping a well increases the food supply for these bacteria, causing their population to rapidly expand in the vicinity of the well and in the distribution system. The bacteria form a slime or biofilm, that captures mineral scale and other deposits that move to the well during pumping. These deposits can reduce water quality, well yield, and well life expectancy (Agriculture and Agri-Food Canada, 2003).

Table 2 categorizes the critical thresholds for losses in specific capacity, based on work by Cullimore (Cullimore et. al. 2004). Where losses in specific capacity are less than 5 percent, it is thought that the well may be suffering from some minor degree of plugging and effective treatment can be expected to return the well to its original specific capacity. If the specific capacity falls to less than 20 percent of its original value (i.e. a loss of more than 80 percent) the well is likely plugged and rehabilitation treatments may be ineffective.

If biofouling is proven to be the prime cause, then three of the wells (1, 3 and 4) would be considered “high risk,” meaning that even radical rehabilitation measures may prove to be ineffective. Two other wells (5 and 6) would be classified as “medium risk” for which the rehabilitation prospects are better if not certain. Only Well 2 appears to be of ‘low risk” from a rehabilitation viewpoint, if biofouling is at work. The present performance of the production wells, and the prospects for rehabilitation based on the work by Cullimore, are presented in Table 3.

TABLE 1 - SUMMARY OF FLOW RATES AND SPECIFIC CAPACITIES

TABLE 1 - SUMMARY OF FLOW RATES AND SPECIFIC CAPACITIES

| | | Well 1 | | Well 2 | | Well 3 | | Well 4 | | Well 5 | | Well 6[2] | | Well 7[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Original Evaluation** | | 1964 (estimated) | | 1964 (estimated) | | | | | | | | | | |
| | Typical Pumping Rate, Q m3/d (usgpm) | 545.10 | 100.00 | 327.06 | 60.00 | | | | | | | | | - |
| | Typical Drawdown, s m (ft) | 2.01 | 6.60 | 1.68 | 5.50 | | | | | | | | | - |
| | Specific Capacity, Q/s m2/d (usgpm/ft) | 270.97 | **15.20** | 195.10 | **10.91** | | | | | | | | | - |
| **Pump Test 1974/86/87/89/92[1]** | Typical Pumping Rate, Q m3/d (usgpm) | 654.66 | 120.10 | | | 1440.21 | 264.21 | 654.66 | 120.10 | 785.54 | 144.11 | 1309.27 | 240.19 | - |
| | Typical Drawdown, s m (ft) | 2.99 | 9.81 | | | 14.35 | 47.08 | 5.52 | 18.10 | 6.32 | 20.75 | 6.93 | 22.73 | - |
| | Specific Capacity, Q/s m2/d (usgpm/ft) | 218.94 | 12.24 | | | 100.36 | **5.61** | 118.67 | **6.64** | 124.20 | **6.95** | 188.98 | **10.57** | - |
| **1998** | Typical Pumping Rate, Q m3/d (usgpm) | 364.94 | 66.95 | 236.46 | 43.38 | 189.91 | 34.84 | 126.03 | 23.12 | 318.77 | 58.48 | 477.18 | 87.54 | - |
| | Typical Drawdown, s m (ft) | 1.56 | 5.11 | 1.36 | 4.45 | 10.95 | 35.91 | 5.27 | 17.29 | 2.94 | 9.63 | 4.05 | 13.28 | - |
| | Specific Capacity, Q/s m2/d (usgpm/ft) | 234.31 | 13.10 | 174.34 | 9.75 | 17.35 | 0.97 | 23.91 | 1.34 | 108.60 | 6.07 | 117.89 | 6.59 | - |
| **2000** | Typical Pumping Rate, Q m3/d (usgpm) | 330.11 | 60.56 | 322.43 | 59.15 | 199.56 | 36.61 | 145.54 | 26.70 | 363.15 | 66.62 | 445.24 | 81.68 | - |
| | Typical Drawdown, s m (ft) | 1.71 | 5.60 | 1.67 | 5.48 | 7.38 | 24.20 | 5.85 | 19.20 | 4.53 | 14.86 | 3.55 | 11.65 | - |
| | Specific Capacity, Q/s m2/d (usgpm/ft) | 193.40 | 10.81 | 193.03 | 10.79 | 27.05 | 1.51 | 24.87 | 1.39 | 80.18 | 4.48 | 125.39 | 7.01 | - |
| **2001** | Typical Pumping Rate, Q m3/d (usgpm) | 292.94 | 53.74 | 303.08 | 55.60 | 204.19 | 37.46 | 110.16 | 20.21 | 307.11 | 56.34 | 466.22 | 85.53 | - |
| | Typical Drawdown, s m (ft) | 2.24 | 7.35 | 1.76 | 5.76 | 10.98 | 36.02 | 4.82 | 15.81 | 4.17 | 13.67 | 4.50 | 14.75 | - |
| | Specific Capacity, Q/s m2/d (usgpm/ft) | 130.76 | 7.31 | 172.63 | 9.65 | 18.60 | 1.04 | 22.86 | 1.28 | 73.71 | 4.12 | 103.70 | 5.80 | - |
| **2002** | Typical Pumping Rate, Q m3/d (usgpm) | 254.40 | 46.67 | 291.74 | 53.52 | 158.24 | 29.03 | 107.44 | 19.71 | 275.44 | 50.53 | 442.57 | 81.19 | - |
| | Typical Drawdown, s m (ft) | 2.48 | 8.14 | 1.80 | 5.90 | 11.41 | 37.44 | 4.03 | 13.23 | 4.11 | 13.49 | 4.85 | 15.91 | - |
| | Specific Capacity, Q/s m2/d (usgpm/ft) | 102.54 | 5.73 | 162.23 | 9.07 | 13.87 | 0.78 | 26.64 | 1.49 | 66.99 | 3.75 | 91.26 | 5.10 | - |
| **2003** | Typical Pumping Rate, Q m3/d (usgpm) | 191.11 | 35.06 | 297.79 | 54.63 | 125.92 | 23.10 | 90.16 | 16.54 | 234.99 | 43.11 | 405.44 | 74.38 | - |
| | Typical Drawdown, s m (ft) | 3.45 | 11.32 | 1.83 | 5.99 | 11.98 | 39.31 | 4.59 | 15.06 | 3.19 | 10.47 | 4.46 | 14.63 | - |
| | Specific Capacity, Q/s m2/d (usgpm/ft) | 55.39 | 3.10 | 163.10 | 9.12 | 10.51 | 0.59 | 19.64 | 1.10 | 73.64 | 4.12 | 90.92 | 5.08 | - |

[1] Well 1, 1987; Well 3, 1974; Well 4, 1986; Well 5, 1992; Well 6, 1989

[2] Due to the limited number of Well 6 static water level data, Well 3 static water levels were used to calculate drawdowns in Well 6.

[3] Well 7 - not in service.

Note: Bolded values used to calculate % Maximum (Specific Capacity)

## TABLE 2 - CRITICAL THRESHOLDS FOR LOSSES IN SPECIFIC CAPACITY

| LOSS IN SPECIFIC CAPACITY, % | COMMENTS |
|---|---|
| 0 - 5 | The well may be suffering from some degree of plugging that is minor. Effective treatment can be expected to return the well to its original specific capacity. |
| 5 - 20 | The well is now on slippery slopes to becoming plugged but effective treatment should return the well to its original specific capacity. |
| 20 - 40 | The well has now lost a significant part of its specific capacity and effective treatment may require radical rehabilitation techniques. |
| 40 - 80 | The well is in all probability losing production capacity rapidly and the potential to return the well to its original specific capacity is reduced. Effective treatments may be expected to return the production to only 10 to 30 % of original). |
| 80 - 100 | The well has now lost very significant production due to plugging and treatments to rehabilitate are likely to achieve very small improvements to original production specific capacity (e.g. 5 to 15 % improvements may be expected or none at all). |

SOURCE: Cullimore, D.R., Alford, G., Johnston, L. (2004) Observations on the Development of the Specifications for Water Well Rehabilitation and Preventative Maintenance Treatments, p 1-13.

## TABLE 3 - ASSESSMENT OF CARPENTER POND WELLS

| WELL | LOSS OF SPECIFIC CAPACITY BY 2003, % | ASSESSMENT (ALSO BASED ON CULLIMORE, 2004) | RATING (WORST = 1; BEST = 6) |
|---|---|---|---|
| WELL1 | >80 | Seasonal fluctuations in SC and a systematic reduction in SC with time (on a linear basis, at a high rate). Significant plugging likely present. Rehabilitation prospects slight. | 1, HIGH RISK |
| WELL 2 | <20 | Initial SC unknown. Seasonal fluctuations in SC but no obvious deteriorating trend. Treatment should be fully effective. | 6, LOW RISK |
| WELL 3 | >90 | SC increased somewhat in early 2000 for unknown reason, but thereafter has reduced systematically with time at a moderate rate. Rehabilitation prospects slight. | 2, HIGH RISK |
| WELL 4 | >80 | SC has reduced significantly but rate of SC loss now gradual. Rehabilitation prospects uncertain. | 3, HIGH RISK |
| WELL 5 | >50 | SC is reducing with time but at a moderate rate. Radical rehabilitation may be effective. | 4, MEDIUM RISK |
| WELL 6 | >50 | SC is reducing with time at a low rate. Radical rehabilitation may be effective. | 5, MEDIUM RISK |

The scope of further investigation required to resolve this issue should involve: (a) the hydraulic testing of each production well [a step-drawdown test to permit evaluation of formation and well losses at different pumping rates]; (b) down-hole videoing of each screen and casing and the observation of pulled pumps/columns; (c) evaluation of physicochemical parameters of the groundwater including total and ferric iron; total manganese; ions including sulphides, sulphates, carbonates, and bicarbonates; pH, Eh and conductivity, TDS and TSS; and (d) evaluation of total iron and manganese-related bacteria (IRB), sulphate reducing bacteria (SRB), slime-forming and other microbial types. This is broadly consistent with methods described by the U.S. Corps of Engineers (Department of the Army, U.S. Corps of Engineers, 2000) summarized in Table 4.

TABLE 4 - PARAMETERS USEFUL IN WELL MAINTENANCE MONITORING

| TYPE TESTS | PARAMETERS OBTAINED |
|---|---|
| Hydraulic testing | Flow and drawdown for specific capacity. |
| | Total amount of pumping time and quantity pumped per year. |
| | Periodic step-tests for well and pump efficiency. |
| | Power and fuel consumption for pump efficiency. |
| Physicochemical parameters (for changes due to deterioration) | Total and ferric iron, and total manganese (and other metals as indicated). |
| | Important anions as identified, including sulfides, sulfates, carbonates, and bicarbonates. |
| | pH, conductivity, and redox potential (Eh) where possible (instrument readings may be replaced by checking ratios of Fe (total) to Fe2+ (soluble)). |
| | Turbidity or total suspended solids calculation of product water. |
| | Calculation of corrosion/encrustation potential using a consistent method. |
| Microbial | Total Fe/Mn-related bacteria (IRB), sulphur reducing bacteria (SRB), slime-forming and other microbial types of maintenance concern as indicated. |
| Visual/physical | Pump and other equipment inspection for deterioration. |
| | Borehole TV for casing and screen deterioration. |

SOURCE: U.S. CORPS OF ENGINEERS, 2000

Longer term monitoring may allow the optimum time between well maintenance to be determined. In the Kneehill Alberta study (Agriculture and Agri-Food Canada, 2003) it was concluded that monitoring of sulphate reducing bacteria levels would be an effective means of determining the degree of biofouling in about 90 per cent of the wells. Simple monitoring tools for this bacterium (the Presence/Absence SRB-BART$^{TM}$ test) and for other bacteria (for example iron-related bacteria [IRB], heterotrophic aerobic bacteria ([HAB] and slime forming bacteria [SLYM BART] are available (Droycon Bioconcepts), and have reportedly been used to good effect in other jurisdictions.

### *3.5 The rehabilitation of Well 3*

As discussed in the previous section, the prospects of rehabilitating Well 3 appear to be slight, but this should be reviewed following confirmatory examination of the well, hydraulic evaluation and microbiological testing.

Rehabilitation measures should be designed and implemented when a diagnosis has been made. Options include conventional air surging, shock chlorination (perhaps once or twice a year), and acid / ultra acid base treatment. Examination of the other wells in the wellfield as part of a monitoring effort may lead to the institution of a broader rehabilitation program.

### *3.6 The construction of Well 8*

The stratigraphy of the wellfield area was interpreted from well construction records (for wells 1, 3, 4, 5, and 7) and borehole logs (for boreholes 1 and 4 located near wells 2 and 7, respectively). Interpreted sub-surface cross sections were presented earlier in Figure 2.

On the south side of Carpenter Pond, bedrock was encountered at a depth of 29 metres at Well 3; its depth was interpreted elsewhere. At wells 3 and 6, the overburden comprised fine sand. At Well 1, one metre of gravel and sand was underlain by 6 to 6.5 metres of sand and gravel, 10 metres of fine to medium grained brown sand, 8 metres of fine to medium grained brown sand and some gravel, and 11 metres of granite till above (presumed) bedrock. At Well 2, 15 to 16 metres of reddish brown fine to coarse silty sand and occasional gravel, rests on 18 metres of fine to medium grained brown sand above by fine to medium grained brown sand and some gravel extending to the bedrock.

One the north side of Carpenter Pond, bedrock was encountered at Wells 4 and 5 at depths of 16.4 and 15.2 metres respectively. In both instances, the overburden comprised 10.5 to 11.5 metres of sand and gravel above 4.5 to 5 metres of sand, gravel and boulders. The log of borehole BH4 located next to Well 7 indicated approximately 9 metres of brown fine to coarse sand with some silt and occasional gravel extending from the ground surface followed by brown silty fine sand with occasional gravel. Bedrock was not encountered at Well 7.

From the above understanding, six target areas have been identified for exploration. A three phase program is suggested as follows. It takes into account: (a) the stratigraphy [the requirement to intercept coarse materials and the preference to develop wells of significant available drawdown]; (b) the need to minimize interference with existing wells; and (c) the preference to be located near existing piping:

- First, one small-diameter exploratory borehole would be drilled by means of a geotechnical drill rig in each target area (see TW1, TW2, TW3, TW4, TW5, and TW6 in Figure 1). The holes would be sampled on a continuous basis to bedrock, providing much better stratigraphic information about the wellfield as a whole than is currently available. The estimated depth to the productive part of the aquifer and the depth to bedrock for each of the test wells is shown in Table 5.

TABLE 5 - ESTIMATED DEPTHS OF THE PROPOSED TEST WELLS

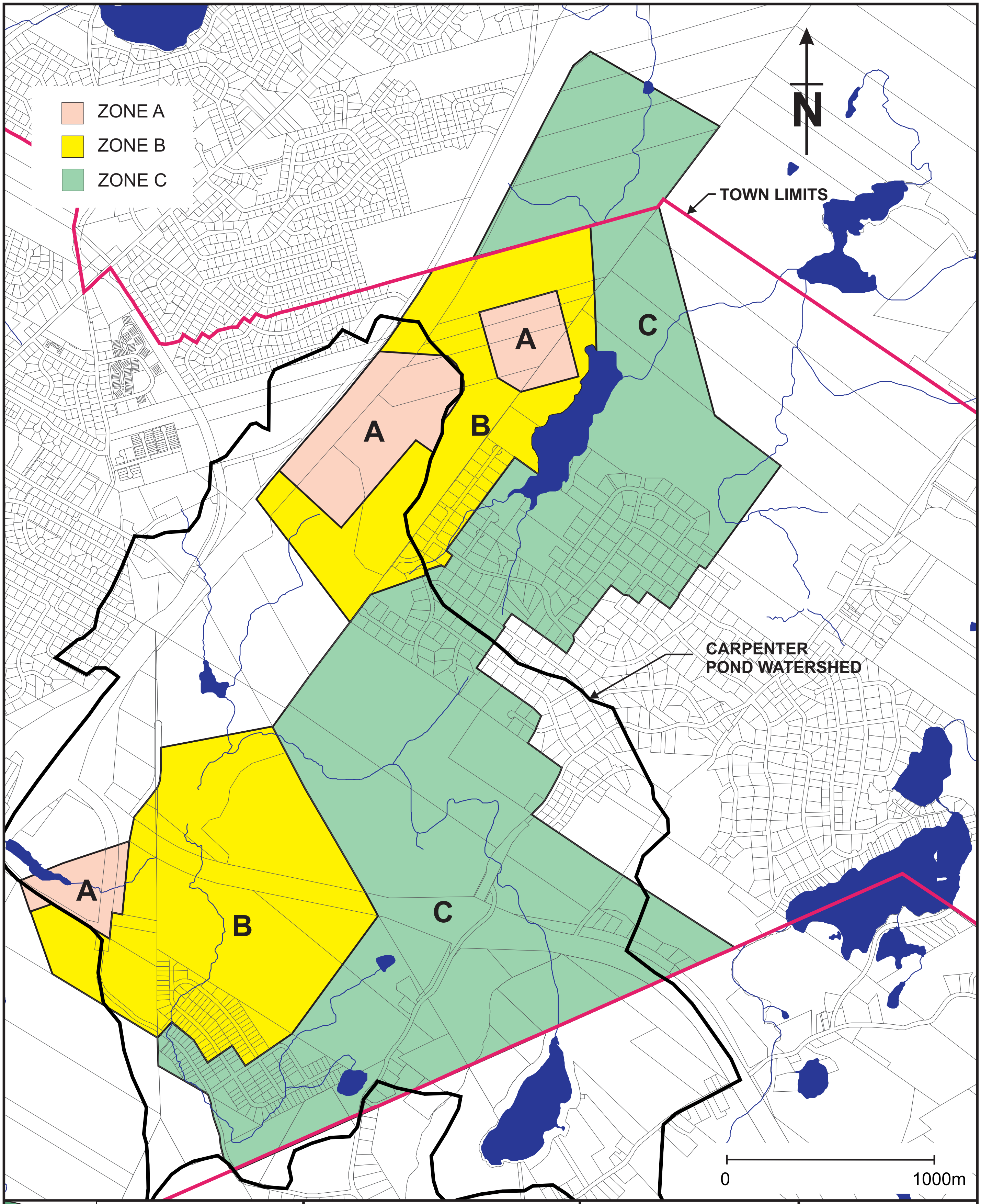
| TEST WELL | ESTIMATED DEPTH OF PRODUCTIVE PART OF AQUIFER (m) | ESTIMATED DEPTH TO BEDROCK (m) |
|---|---|---|
| TW1 | 24 | 30 |
| TW2 | 23 | 23 |
| TW3 | 19 | 25 |
| TW4 | 14 | 20 |
| TW5 | 14 | 25 |
| TW6 | 26 | 30 |

A 50 mm diameter PVC standpipe piezometer would be installed in each borehole, such installations acting as future monitoring wells for water quality and hydraulic evaluation purposes;

- Second, 150 mm diameter test wells would be drilled by air-rotary drill at the two most promising target sites. Telescopic screens would be installed in one or both of these wells (an alternative might be to perforate the casings) and short-term pumping tests (say 6 hours) would be conducted;

- Third, larger diameter gravel-packed wells would be drilled at one or two locations based on the findings of the first two phases. The effect of longer-term (72 hour) pumping from this production well (or wells) would be observed at the pumped wells and at the newly constructed monitoring wells. Water quality would be determined including evaluation of microbiological parameters (refer to Section 3.4).

From discussions held with NBDELG it is understood that a formal Environmental Impact Assessment (EIA) application, following the Guidelines to the Water Supply Source Assessment process, will not be required for a replacement well located near the Pond. It will simply be necessary to send details of the proposed work to the NBDELG Director of the Project Assessment Branch.



**TerrAtlantic**
Engineering Limited

PROJECT:
WELLFIELD PROTECTION STUDY
TOWN OF ROTHESAY, NB

FILE NO.:
38401014

DATE:
MARCH, 2002

DRAWING:
FIGURE 4.1 - PROPOSED PROTECTION ZONES