

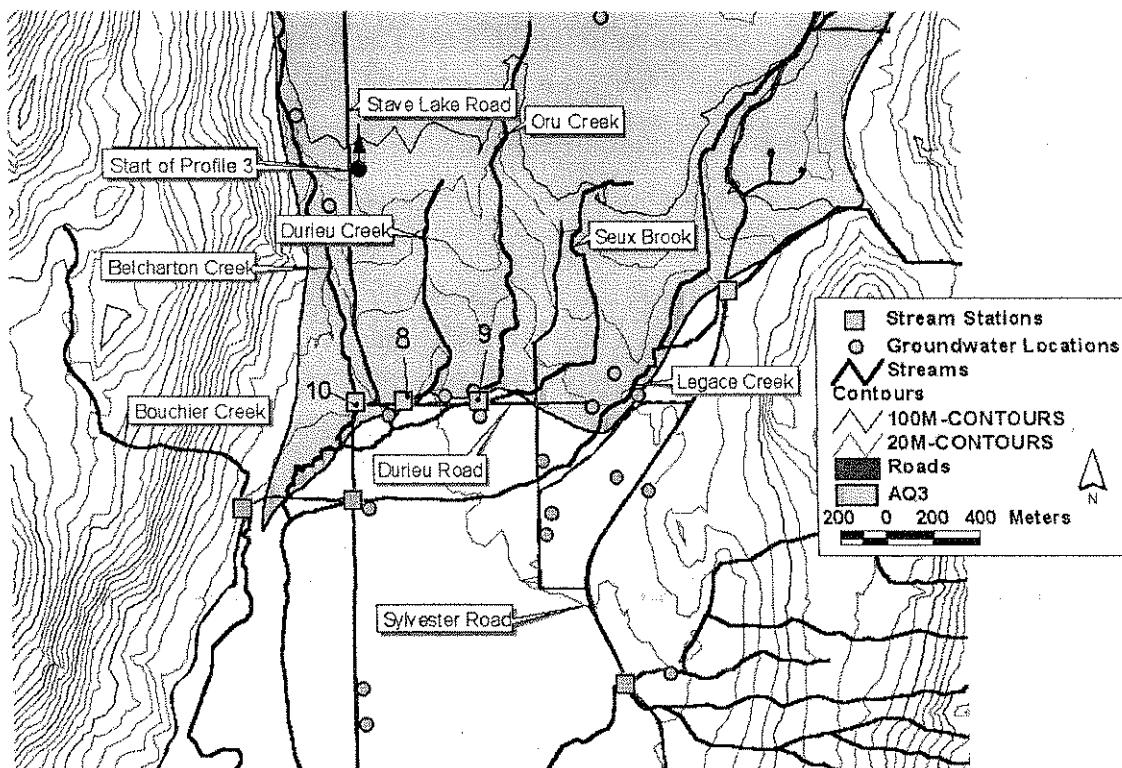


Figure 44. Area of sampling network where surface and groundwater interactions are most likely

It is well known that in the Fraser Valley, many streams rely almost entirely on groundwater flow to maintain their base flow in the summer (Wernick *et al.*, 1998). In Hatzic it was observed that at least one stream (MacNab Creek) and a small lake (Allan Lake) were seasonal in nature (see fig 6 in section 2.4.2 for the location of these water bodies). These bodies of water were completely dry for much of the sampling period (late July until October). All other streams sampled continued to flow throughout the summer suggesting that groundwater was providing some recharge to these streams at some point in their flow. It is assumed that the impacts of groundwater recharge on stream chemistry will decline as the stream runs further from the groundwater source.

In his 1994 report for John Conroy and Neighbours, Dakin (Piteau Associates, 1994) noted that there is a “prolific series of springs located ... in the banks of the upper reaches of Durieu Creek”. He also commented “we suspect that portions of Belcharton creek and the other southward draining creeks such as Durieu Creek are fed almost exclusively by discharge from the deep confined aquifer”. The aquifer he’s referring to is AQ3. Much of this aquifer flows southwards (Piteau Associates, 1994, PHCL, 2003) and based on the profile presented in chapter 3 (figure 10) it is easy to imagine that the edge of this aquifer could be exposed in the vicinity of Durieu and the other creeks with their headwaters on this hillside. The southernmost well log in profile 3 (on the far right of the diagram) has a much shallower layer of clay (20 m) than do the wells logged further north (on the left of the diagram) which have clay layers 40-55 m thick. Figure 44 shows the location of the southern most log in this profile on the top left

corner of the map. This location is over 60 m higher than the surface of the prairie. It follows that as the ground continues to slope downward, the clay layer would become ever thinner until it eventually exposes the gravel and sand of the aquifer in the side of the hill. This is what was observed by Dakin (1994) who, when visiting the springs near the source of Durieu creek remarked that “ these springs issue from a coarse sand and gravel unit which is exposed in the valley walls and... is discharging from the deep confined aquifer”. We can, therefore, speculate that the most direct groundwater influence on surface water will be occurring in those streams that are fed by discharge from AQ3. The next problem is to determine how this groundwater is influencing the stream water quality.

In some cases the influence of groundwater on surface water is obvious and is manifested as a decline in surface water quality. This is illustrated on the Sumas Prairie (another area in the Fraser Valley) where of a sharp increase in stream nitrate in Marshall Creek indicate discharge of contaminated groundwater from the Abbotsford aquifer (Berka *et al.*, 2001, Smith (pers comm.), 2003). In the Hatzic Valley it is reasonable to speculate that the opposite is true. We have established in previous sections that the water quality in AQ3 is quite good and that there are no significant seasonal fluctuations of most parameters measured including nitrate and conductivity (for which we also have stream data). There are, however, significant differences in nitrate levels as well as conductivity levels in the samples of stream water taken throughout the year. The nitrate levels in the stream were much lower in the summer than in the winter; it follows, therefore, that in the summer, the streams are receiving low nitrate groundwater discharge from the deep confined aquifer. The stream nitrate levels rise in the winter while the groundwater nitrate levels remain more constant (especially in the deeper wells in AQ3). In the winter the surface water is receiving much more input from rain and surface run-off which likely raises the levels of nitrate in the streams directly (rather than through groundwater recharge.)

A similar pattern can be seen when comparing conductivity values between groundwater samples and surface water samples. Again, the conductivity values of the groundwater samples didn't change dramatically between winter and summer. However, there were significant differences in conductivity in the streams between the seasons. In the surface water conductivity was highest in summer. This can be attributed in large part to the fact that there is less water in most streams in the summer and therefore dissolved ions will be more concentrated, giving higher readings. Conductivity of the groundwater samples was consistently higher than that of the surface water samples because as groundwater travels through the subsurface it tends to pick up dissolved ions. It would, therefore, be expected that if a majority of the stream flow were being provided by groundwater recharge, this stream water would have higher conductivity. This is consistent with the observations, the stream water had higher conductivity levels in the summer when more of the flow was being provided by direct groundwater recharge and

lower values in the winter when lower conductivity rainwater was diluting the flow and providing more of its volume.

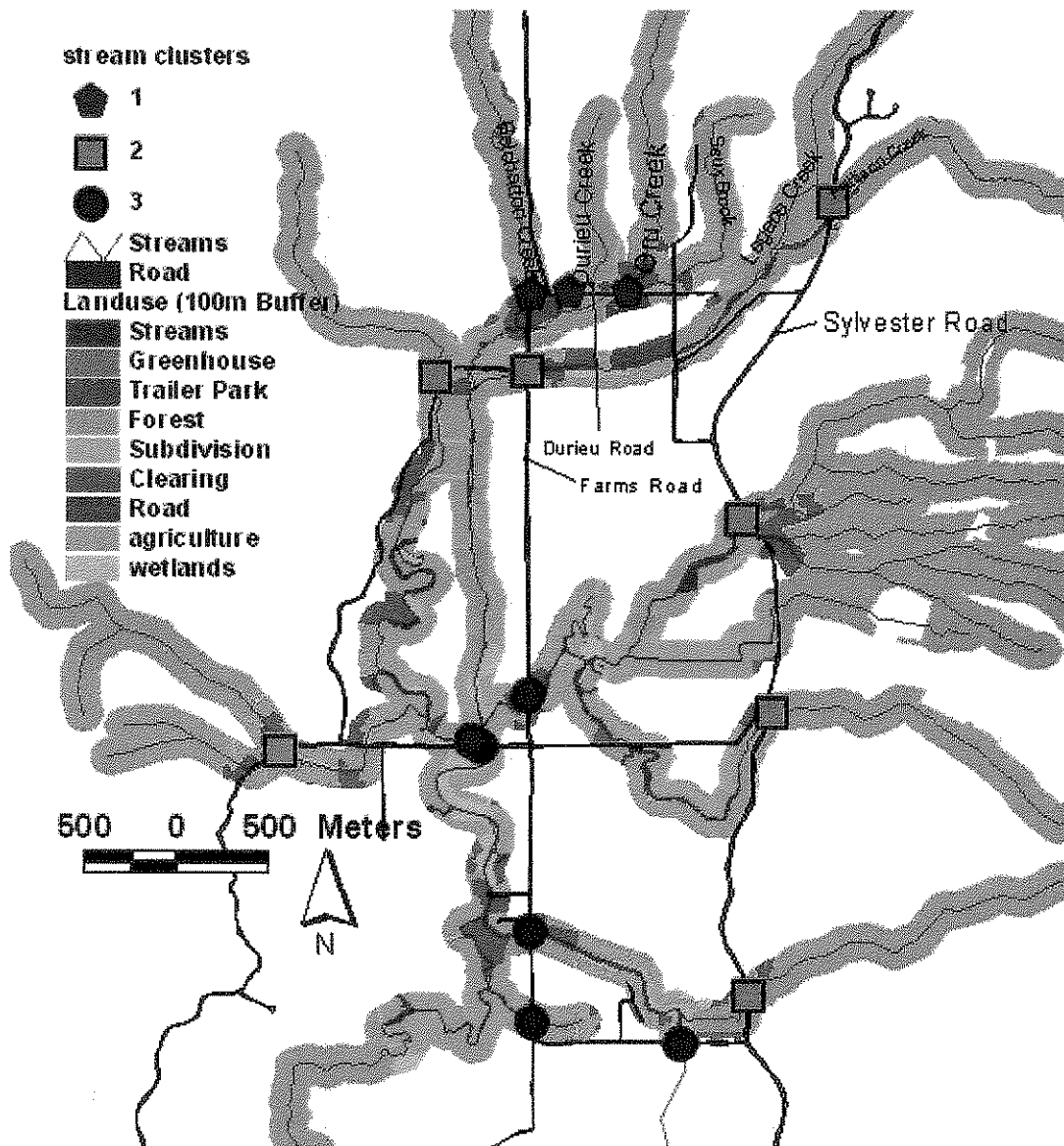


Figure 45. Clusters based on stream temperature (entire sampling period)

A final parameter that can indicate the presence of groundwater discharge is temperature. Streams that are strongly influenced by groundwater tend to have more stable temperatures and in particular may have cooler water in the summer than the surrounding areas and warmer water in the winter (Wernick *et al.*, 1998). A cluster analysis was performed using all the temperature data in order to see if the clustering of the temperature suggests any groundwater influence. The results (shown on figure 45) show three clusters. Cluster one includes station 8,9 and 10, cluster 2 stations 2,4,5,6,11,12,and 13, and the final cluster includes the remaining stations.

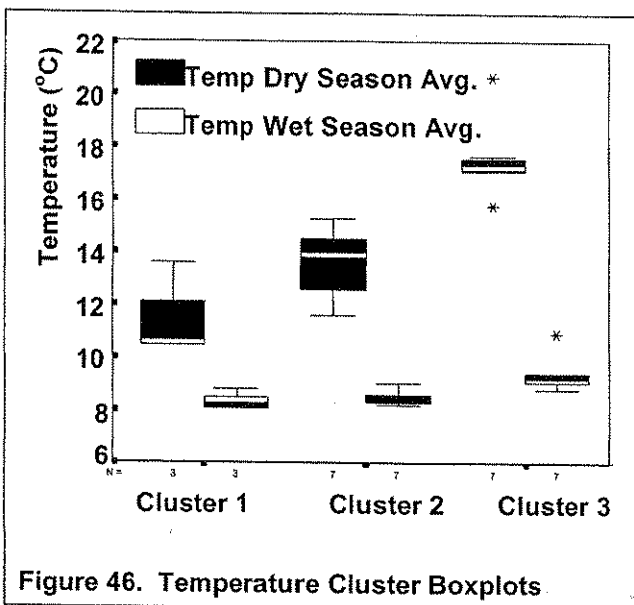


Figure 46. Temperature Cluster Boxplots

The existence of cluster one further confirms the hypothesis that groundwater is influencing stations 8, 9 and 10, at least for part of the year. In order to test strength of the clusters a Kruskal-Wallis test was run on all the temperature data using the clusters as groups. The results showed that there were significant differences between the temperatures of at least one of the clusters for most of the summer months (with the exception of data from July 24, when most stations had higher than normal temperatures). When the Mann-Whitney U test was used to determine which of the samples were different from each other it was

found that cluster 1 was significantly different than cluster 2 only in July, August, September and October, the time of year we expect these streams to be most dependent on ground water for recharge. The other clusters were different from each other at almost all times of the year. The differences between cluster 2 and 3 are likely related to differences in land cover, as are the differences between clusters 1 and 3.

4.7.1 Surface Water Impacts on Groundwater Quality

The influence of surface water on groundwater in the Hatzic Valley is difficult to determine because of the sporadic nature of high nitrate wells. It can be assumed that the wells with high nitrate that are not on Hatzic Island (i.e. are not impacted by septic systems – which is largely subsurface impact) may be under local influence of surface water. If any of these wells are not constructed properly it is likely that contaminated run-off may be entering these wells. In general, however, the stream data seem to suggest that the surface water does not impact the groundwater quality. The nitrate values measured in the streams were generally quite low, meaning that they would not be a source of nitrate to the streams.

In order to come to more definitive conclusions about the groundwater and stream water interactions more detailed hydrological investigations would have to be carried out. This monitoring could include procedures such as installation of seepage meters (Lee and Cherry, 1978), use of isotopes, more detailed temperature and conductivity profiling along the entire length of the stream (Oxtobee and Novakowski, 2002; Hinton *et al.*, 1993) or taking ICP measurements for the stream samples (Beckie, pers comm., 2003). However with the information at hand we can make educated speculation that the groundwater has a substantial influence on the flow of Belcharton, Durieu, Oru Creek and Seux Brook during the dry

season (especially between July and October) and that this influence is less evident during the wet season (November to March).

4.8 Survey Results and Discussion

Most of the households who supplied groundwater samples also completed a questionnaire (see appendix 5 for survey questions). Ninety-seven percent of those given a survey returned it. Not all surveys handed back were complete; therefore, “n” is variable for each question. The survey results will be presented as follows. First, the responses to specific questions are given, this is followed by a discussion of the relationships between the questions and the water quality parameters, regional variation in responses to specific questions are also examined, and the final section is a discussion the perceptions vs. the analytical reality.

4.8.1 General Responses

4.8.1a Water Quality Perception

The majority of residents in the Hatzic Valley (79%) perceive their water quality as being excellent or good. Table 19 outlines the residents’ water quality perceptions.

Table 19. Responses to "What is your perception of the water quality from your well?"					
	Excellent	Good	Moderate	Fair	Poor
Percentage	43%	36%	9%	7%	4%
Number	32	27	7	5	3

It is known that members of the public often base their perceptions of risk or of water quality on different metrics than ‘experts’ (Scherer, 1990). Figure 47 shows measures of “intuitive toxicology” (Kraus *et al.*, 1992) that people might use to discern if water quality is “good” or not. The figure shows the importance of these measures for residents of the Hatzic Valley.

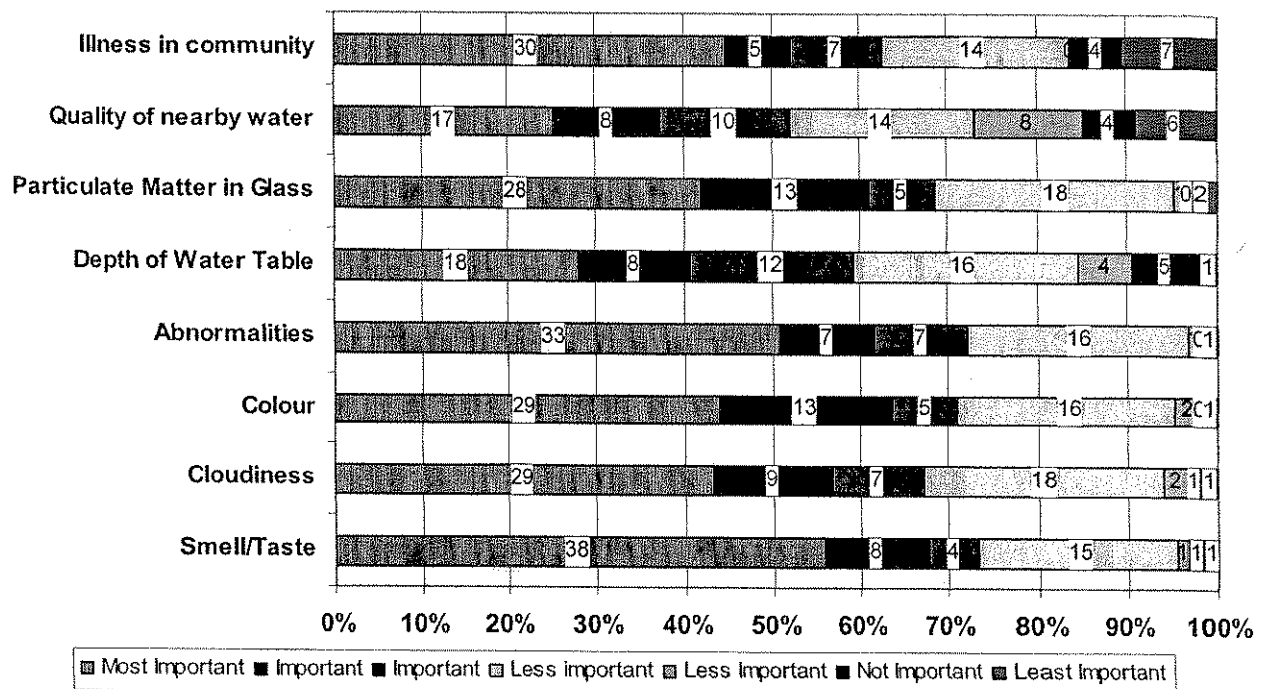


Figure 47. Responses to the question “How important are the following as a guide for indicating the quality of your water?”

People are much more likely to rely on tangible indicators of water quality to form their perceptions of quality, that is those parameters they can easily taste, smell or see. As figure 47 shows, smell and taste was an important indicator of water quality to just over 60% of respondents followed closely by visible abnormalities in the water. Many residents saw quality of nearby water and depth to the water table as less important.

4.8.1b Water Sources

Residents were asked several survey questions that pertained to their specific sources of water as well as more general questions about which land use activities could adversely affect their water sources and how water sources should best be managed. When asked, “do you think an increase in groundwater aquifer use is appropriate?” Seventy one percent of respondents felt they needed more information. This response highlights the lack of knowledge about the groundwater resource in the Hatzic Valley and the need for technical investigations to determine the extent of the resource.

A question regarding land use asked, “How important is each of the following activities in causing water quality problems?” The responses are presented in figure 48. In general, over 50% of respondents felt that chemicals from farming, manure from farming, industrial activity and fertilizer from farming were very important in causing water quality problems. Aggregate extraction was considered very important

by 47% of respondents and septic systems by only 45% of respondents.

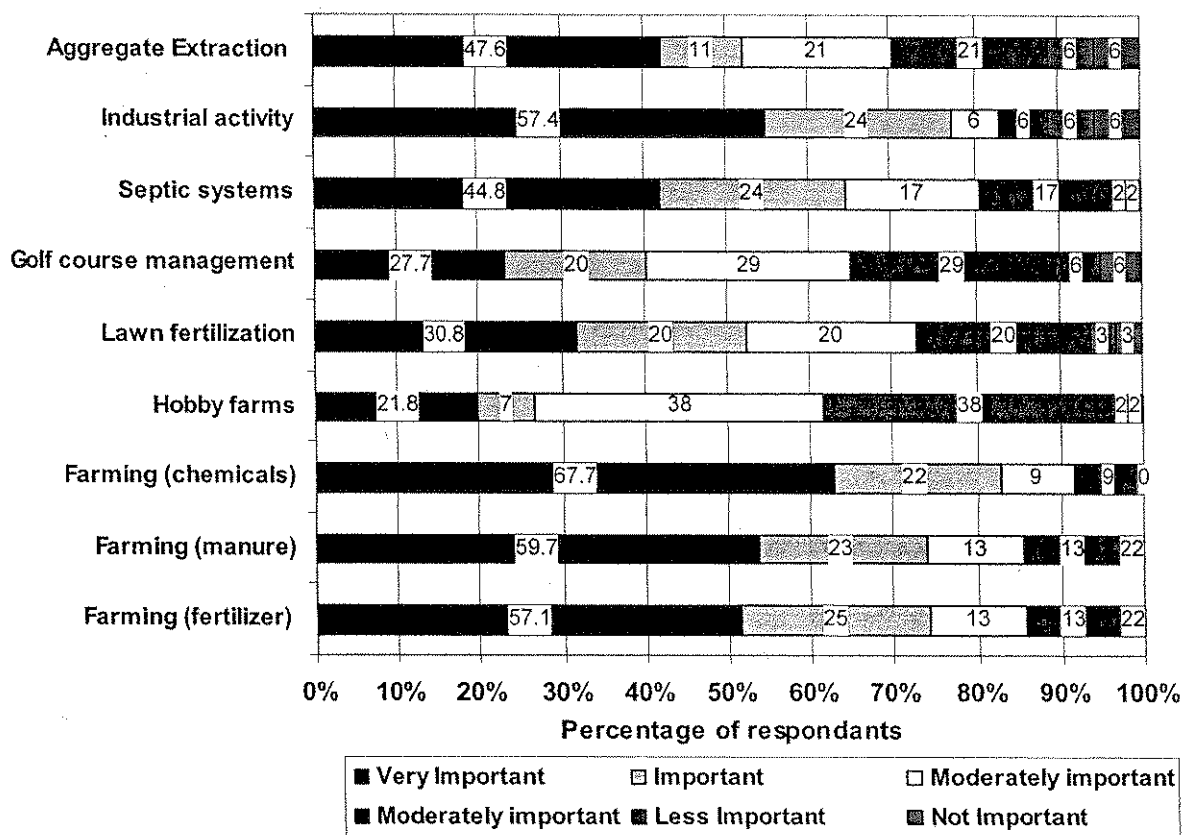


Figure 48. Response to the question “How important are these activities in causing water quality problems?”

Following the questions about the importance of certain activities in causing water quality problems participants were asked for opinions about the appropriateness of various management techniques for managing groundwater resources (shown in figure 49). People felt the most important strategy would be to limit industrial development, 58% felt this was very important. Restrictions on manure allocations and fertilizer applications were seen as being very appropriate strategies by 47% and 50% of respondents respectively. In addition to questions about specific strategies for managing groundwater, participants were asked if they favoured voluntary, regulatory or a combination of both strategies for managing groundwater resources. Sixty-four percent of respondents favoured a mixture of regulatory and voluntary initiatives.

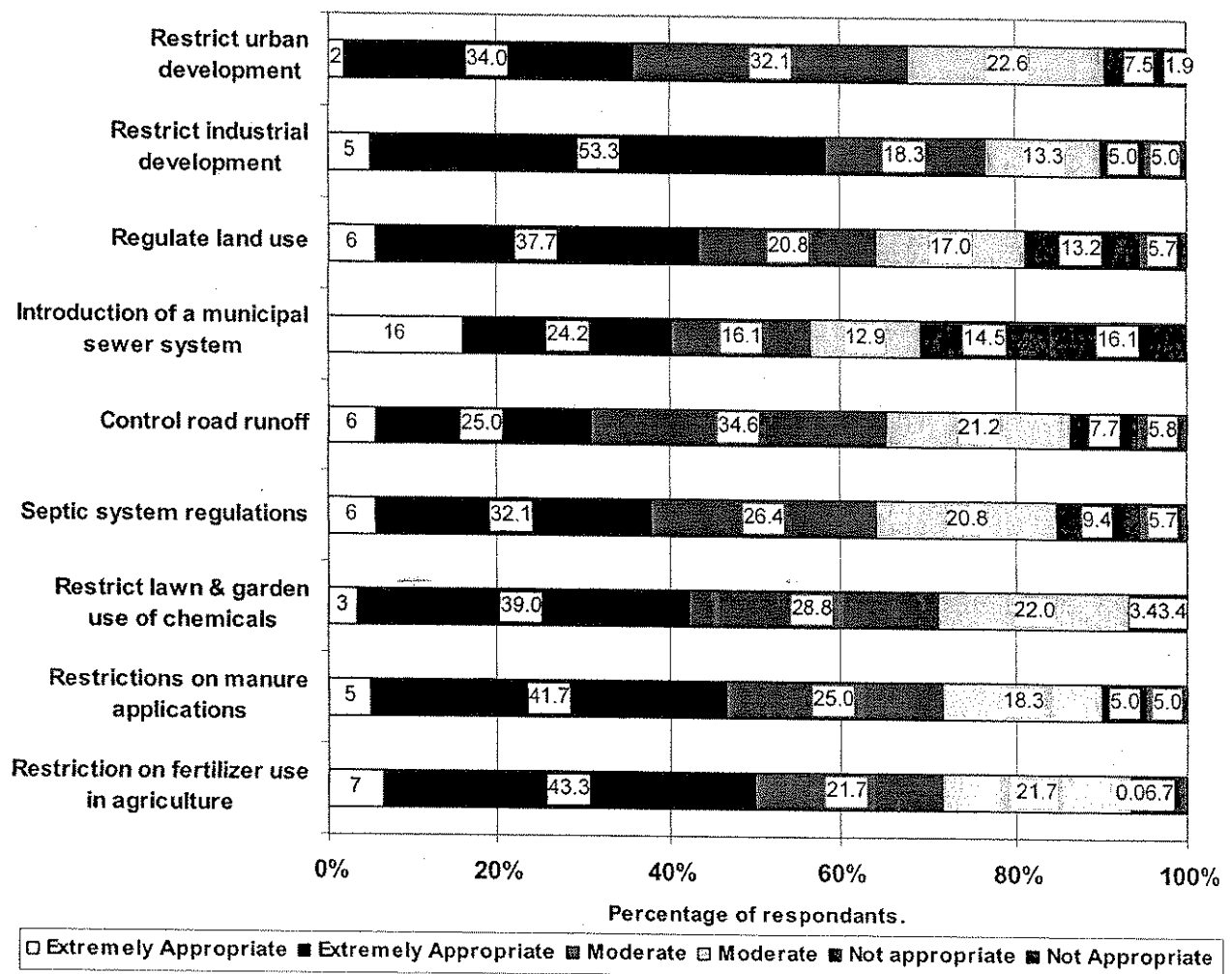


Figure 49. Responses to the questions "How appropriate do you think the following strategies are for managing groundwater resources"

A final question that related directly to knowledge or opinion of groundwater sources was intended to gauge knowledge about interactions between groundwater and stream water. Participants were asked, "To what extent do you think use of the groundwater aquifer affects the local rivers?" The breakdown of responses is found in table 20. In general most respondents were aware that groundwater and stream water interact with each other.

Table 20. Groundwater Impact on Local Rivers						
	Significant Impact		Some Impact		No Impact	
River Flow	n=17	27.4%	n=29	46.7%	n=16	25.8%
Water Quality	n=24	38.7%	n=22	35.5%	n=16	25.8%

4.8.1c Treatment

Several questions were asked about the treatment practices of well owners in the Hatzic watershed. Until recently there were no requirements for groundwater treatment anywhere in

British Columbia. However, the recently amended Drinking Water Protection Regulation requires that, "... drinking water from a water supply system must be disinfected if the water originates from (a) surface water, or (b) *ground water that, in the opinion of a drinking water officer, is at risk of containing pathogens*"(emphasis mine) (B.C. REG200/2003). This section of the regulation does not apply to the individual wells that supply water to most residents of the Hatzic Valley. According to the survey results very few residents of the Hatzic Valley treat their water. We asked questions about filtration and other treatment practices and found that although 86% of those surveyed drink the water from their wells most people in the valley do not filter their water or treat it in any other way. Thirty-two percent of respondents filter their water and only 7% percent treat their water in any other way. Additionally 15% of respondents always or often drink bottled water at home as opposed to 65% who never do. A remaining 20% sometimes drink bottled water at home.

4.8.1d Monitoring

When asked about monitoring, only 12 % of respondents were found to have tested their well once a year or more than once a year. Fourteen percent tested their water every 2 to 3 years. Forty percent said "other", which is assumed to mean less frequently than every three years. Six percent said they had tested their well once when drilled and 28% never tested their well. It is assumed, therefore, that 74% of participants test their wells very infrequently. Most community water systems are required to test their water much more frequently than once per year and of the respondents who sample their water more than once a year, one sells bottled water from their spring and the others are community water systems that serve multiple households and are likely regulated to do use.

Table 21. Frequency of Chemical and Biological Testing		
<i>Frequency</i>	<i>Number</i>	<i>Percent</i>
More than once a year	4	6%
Once a year	4	6%
Every 2 years	3	4%
Every 3 years	7	10%
Other	28	40%
Tested when drilled	4	6%
Never Tested	20	28%

4.8.2 Regional Variation in Survey Response

There was no correlation between perceptions of water quality and location; people living on AQ1 were just as likely as people living on AQ3 to feel their water quality was excellent or good. Despite similar perceptions of water quality there was a significant correlation ($r = 0.344$ at $\alpha 0.01$) between location and

whether the residents filtered their water or not; those living on AQ1 are more likely to filter their water than those living on the other aquifers (see table 22 for details).

Table 22. Cross-tab: Location vs. Filtration.				
		Do you filter your well water?		Total
		Yes	No	
Location	AQ1	13 (54%)	11	24
	AQ2	6 (31%)	12	19
	AQ3	5 (16%)	26	31
	Total	24	50	74

When looking at the measures of intuitive toxicology there was a significant correlation between location and the importance of smell and taste as a water quality indicator ($r = -0.371$ at $\alpha 0.01$). These factors were less important to people surveyed from AQ1 (47% rated it as most important) than from AQ2 (64%) or AQ3 (83%). Other factors such as visible abnormalities in the water, colour and cloudiness and the presence of particulate matter in the glass were also seen as being quite important indicators throughout the watershed but of these; cloudiness ($r = -0.249$), colour ($r = -0.285$), visible particulate matter in the glass (-0.277) and incidence of gastrointestinal illness in the community ($r = -0.247$) were also significantly correlated with location (all at $\alpha 0.05$). In all cases the indicators were more important to people who lived on AQ3 than to those living on AQ1. The importance of the depth to the water table as an indicator of water quality also had regional variation in the responses ($r = -0.326$, $\alpha 0.01$). Table 23 shows that depth to the water table is a more important indicator of water quality for residents of AQ3 than for those who live on AQ1. This is interesting because the residents of AQ1 have significantly shallower wells than the residents of AQ3. Perhaps residents of AQ1 place less importance on water table depth as an indicator of water quality because they have no choice but to have shallower wells.

Table 23. Cross-Tab: Location vs. depth to water table					
		How important is depth of water table as a guide for indicating the quality of your water?			Total
		Very Important	Somewhat Important	Not Important	
Aquifer	AQ1	8 (40%)	11	1	20
	AQ2	9 (60%)	3	3	15
	AQ3	21 (72%)	6	2	29
	Total	38	20	5	64

People from different parts of the aquifer placed different levels of importance on different land use activities. There was a significant positive correlation between aggregate extraction and location ($r = 0.0419$ at $\alpha 0.01$). This activity was seen as more important by residents in the north of the valley where, as mentioned in chapter 3, there is local controversy over the development of a quarry. Table 24 shows the breakdown of the responses to this question based on aquifer. Likely related to this is that industrial

activity was also seen as a bigger problem by people from AQ3 than from AQ1 or AQ2 (correlation coefficient 0.308 at α 0.05).

Table 24. Cross-tab: Location vs. aggregate extraction					
		How important is aggregate extraction in causing water quality problems?			Total
		Not important	Moderately Important	Extremely Important	
Location	AQ1	4	9	8 (38%)	21
	AQ2	3	4	7 (50%)	14
	AQ3	0	5	22 (81%)	27
	Total	7	18	37	62

4.8.2a Septic Systems

In rural areas one of the potential point sources of groundwater contamination is septic systems (Jaffe and DiNovo, 1987) and as discussed previously septic systems are the likely source of nitrate contamination on Hatzic Island. When working properly septic systems are effective at treating waste generated by individual homes, however service and proper siting are essential to maintain well functioning septic systems. Everyone surveyed had a private septic system with which to treat his or her household waste. However, opinions about how important septic systems are in causing water quality problems and the appropriateness of potential solutions show the greatest regional variation of all issues. The first regional difference was seen in the responses to the questions about how important septic systems were in causing water quality problems. The responses to this question were significantly correlated with location ($r = -0.304$ α 0.05). Residents of AQ1 thought that septic systems were a much more important factor in causing water quality problems than did the residents of the other two aquifers.

Table 25. Cross-tabs: Location vs. Importance of Septic Systems					
		How important are septic systems in causing water quality problems?			Total
		Not Important	Moderately Important	Extremely Important	
Location	AQ1	1	2	19 (86%)	22
	AQ2	6	4	8 (57%)	14
	AQ3	3	8	15 (57%)	26
	Total	6	14	24	62

When asked about which strategies were most appropriate for managing groundwater resources opinion on strategies that related to septic systems also differed between aquifers. There was a significant negative correlation between location and response to the question "how appropriate do you think the introduction of septic system monitoring and servicing regulations is for managing groundwater resources" ($r = -0.273$ at α 0.05). Slightly more residents from the south of the valley found this appropriate than those from the north. The question with the largest split in opinion was, "How

appropriate do you think the introduction of a municipal sewer system is for managing groundwater resources.” Sixty-eight percent of respondents from AQ1 felt this was a very appropriate strategy whereas 45% of respondents from AQ3 felt it was very inappropriate. The responses are presented in table 26. The responses for this question were significantly correlated with location ($r = -0.322$ at $\alpha 0.05$).

Table 26. Cross-tabs: Location vs. Sewer System Installation					
		Is the introduction of a municipal sewer system an appropriate strategy for managing groundwater resources?			Total
		Not Appropriate	Moderately Appropriate	Extremely Appropriate	
Location	AQ1	6	1	15 (68%)	22
	AQ2	3	5	4 (33%)	12
	AQ3	11 (45%)	8	5 (20%)	24
	Total	20	14	24	58

Some of the reasons for these discrepancies in response can perhaps be explained by the breakdown of the responses to the question “How close is your septic system to your well?” As with the previous questions related to septic systems there is a significant correlation between the responses to this question and location (correlation coefficient 0.291, $\alpha 0.05$). Sixty-one percent of those living on AQ1 reported their septic systems as being between 0 and 30 metres from their well as opposed to only 17% of residents of AQ2 and 25% of those living on AQ3. In contrast, 44% of people from AQ3 reported their septic system as being farther than 50 m from their well. Finally, residents were asked questions about how frequently they serviced their septic systems. Very few residents serviced their systems more frequently than every five years. The residents of AQ1 serviced their systems much more frequently than people living on the other aquifers ($r = 0.251$ $\alpha 0.05$). Eighty percent of those living on AQ1 service their septic systems between 1-5 years as opposed to only 37% of AQ2 residents and 55% of AQ3 residents who do the same. These results suggest that although the residents of AQ1 are more concerned about their septic systems being a possible cause of groundwater contamination because of the proximity to their wells to their septic systems than residents of the other aquifers they are also trying to minimize the risks of contamination from their septic systems by servicing them slightly more frequently. In AQ3, where septic systems are farther away from homes and wells there is less potential for contamination from these sources and therefore they cause less concern.

4.8.3 Other Correlations

As mentioned above, most of the residents of the Hatzic Valley perceive their water quality as being good or excellent. There is a positive correlation between people’s perception of their water quality and whether or not they drink their water ($r = 0.528$, $\alpha 0.01$). Those with good perception of their drinking water are also less likely to drink bottled water at home ($r = 0.397$ at $\alpha 0.01$), of the 8 people who rated their water quality as fair to poor, five (63%) always drink bottled water at home whereas 45 of the 59

people (76%) who perceive the quality of their water as excellent never drink bottled water at home. There is a small but significant positive correlation between water quality perception and those who have had chemical or bacterial exceedances in their well water ($r = 0.258$, $\alpha 0.05$); people are more likely to have a negative impression of their water quality if they have previously exceeded the water quality guidelines. There was no correlation between frequency of monitoring and perception of water quality nor was there any correlation between the perception of quality and whether people filter their water. Twenty people who felt they had excellent water quality filtered their water while 39 did not (as mentioned above incidence of filtration did relate to aquifer location – which is also not related to water quality perception). See table 27 for the numbers of people who filtered their water and those who do not compared with water quality perceptions.

Table 27. Cross-Tab: Water Quality Perception vs. Filtration				
		Do you Filter your well Water?		Total
		Yes	No	
What is your perception of your water quality? (grouped into 3 ranks)	Excellent-Good	20	39	59
	Moderate	1	6	7
	Fair-Poor	3	5	8
	Total	24	50	74

4.8.2a Water Quality Perception and Chemical Parameters

As mentioned previously, the majority of residents of the Hatzic Valley, regardless of the aquifer they live on, perceive their water quality as being excellent or good. The water quality analysis done for this study confirms these perceptions. Interestingly correlations between water quality perception and the chemical parameters measured showed that those who perceived their water quality as poor were more likely to have higher levels of iron ($r = 0.417$ at $\alpha 0.01$) or manganese ($r = 0.252$ at $\alpha 0.05$) in their water (see table 28). There was no correlation between nitrate levels and water quality perception. Of the people with nitrate levels above 3 mg/L only one participant ranked their groundwater quality less than good. Both of the well owners who had nitrate above the health standards perceived their water quality as excellent and remarked that they always drank their well water.

Table 28. Spearman's Correlation (r): Drinking Water Perception								
	NO ₃ -N	Cu	Fe	Mn	Do you Drink you well water?	Do you filter your well water?	Do you treat your well water another way	Perception of water quality
NO ₃ -N	1							
Cu	.216	1						
Fe	-.022	.111	1					
Mn	-.210	-.033	.553(**)	1				
Do you drink your well water?	-.049	-.124	.145	.206	1			
Do you filter your well water?	-.063	.080	-.088	-.031	.026	1		
Do you treat your well water another way?	.274(*)	-.010	-.070	.020	-.133	.368(**)	1	
Perception of water quality	-.161	-.032	.417(**)	.252(*)	.512(**)	-.044	-.314(**)	1

Spearman's rank correlation coefficient
 (**) = Significant at α 0.01
 (*) = Significant at α 0.05

Based on the results of chemical testing and the survey responses it is evident that the residents are basing their water quality perceptions largely on tangible (intuitive) indicators of water quality rather than on the results of chemical analysis. Nitrate, a parameter with negative health implications, is tasteless and odourless. Iron and manganese, on the other hand, are visible nuisance parameters in tap water when present at high enough concentrations, that is, their presence can be discerned without sending water samples to a laboratory for analysis. The basing of perceptions on tangible indicators of groundwater quality is not surprising as the survey revealed that most residents test their groundwater infrequently. Many water quality problems such as elevated levels of coliforms and other pathogens can also only be detected through laboratory analysis. By not testing well water more frequently and basing perception of water quality only on tangible indicators residents may be exposing themselves to potential health hazards.

5.0 Summary and Conclusions

The objectives of this project were to determine the quality of drinking water in the Hatzic Valley (with a focus on groundwater quality), investigate the links between groundwater, surface water and land use, to find out how local residents perceive their water quality and to compare the scientific results with those perceived by the residents. Field research was conducted in the Hatzic watershed in British Columbia's Lower Fraser Valley. Groundwater samples were taken from drinking water wells with the help of local residents. The water quality was determined for 75 wells that were sampled in July 2002 and again in March 2003. Surface water samples were collected at 19 stations on a semi-monthly basis between May 2002 and May 2003. A land use database was created using a GIS and the percentages of the four predominant land uses (forest, agriculture, rural residential and urban) were calculated within 50, 100 and 200 m radii of the wells sampled and within 100 m of the streams sampled. The perceptions and opinions of local residents were collected through a survey questionnaire that was collected at the same time as the water samples. Non-parametric statistical techniques were used to link the three types of data.

5.1 Summary

The results show that the groundwater quality is relatively good based on the parameters measured in this study. Of the 75 groundwater wells tested, only 2 (2.6%) had nitrate levels above the GCDWQ standard of 10 mg/L nitrate-N and 12 (16% - including the 2 mentioned above) had nitrate-N values above 3 mg/L (the level which is generally considered to be an indicator of land use impacts). Several other wells were above the GCDWQ for aesthetic objectives such as iron and manganese. These compounds are a nuisance in water, but they do not represent a direct threat to human health.

5.1.1 Differences between Aquifers

It was discovered early in the research that the study area encompassed three distinct aquifers. The results of significance testing showed that the chemistry of AQ1 (the southernmost aquifer) is significantly different based on Si, Ca, Mg, Sr, PO₄ and Na than that of AQ2 and AQ3. The difference in water quality between AQ2 and AQ3 is not as pronounced and it may be that these aquifers have similar substrates or that the water from AQ3 flows south towards AQ2 and that these two aquifers are part of a continuous flow system. In addition to the three main aquifers it was determined that four wells in the region tap into a deep regional aquifer system with highly saline water. These wells had abnormally high conductivity (up to two orders of magnitude higher than the majority of wells sampled) as well as high levels of many other parameters. Although these wells are located on AQ2 they have chemistry unique from the other shallower wells sampled on this aquifer. Another local anomaly, shallow wells on AQ3, likely tap into small perched aquifers that are dispersed among the thick clay/till aquitard that confines the main aquifer in this area.

5.1.2 Nitrate and Depth

There was a strong relationship between nitrate level and depth. The wells that had nitrate levels higher than 3 mg/L were all shallow wells, less than 12 m deep. The only wells with a change in nitrate level more than 1 mg/L between winter and summer were also less than 12 m deep. These two relationships highlight how important the depth of the wells is in determining nitrate levels. Shallower wells appear to be more prone to contamination from surface sources than deeper wells. No other parameters showed similar relationships with depth suggesting that the nitrate levels are related to human activity whereas the levels of other parameters are not.

5.1.3 Nitrate and Land Use.

Significant negative correlations were found between nitrate levels and the percentage of forest surrounding the wells and significant positive correlations were found between nitrate levels and the percentage of urban land surrounding the wells. A significant relationship between nitrate in groundwater and agriculture was not seen despite the fact that this relationship has been observed elsewhere in the Lower Fraser Valley. The likely source of nitrate in the urban areas is septic systems. On Hatzic Island, especially, the water table is high at some points in the year, which may impede the proper functioning of septic systems causing nitrate to leach into the groundwater. The results show that the wells at most risk of nitrate contamination are shallow wells (<12 m) in urban areas.

5.1.4 Surface Water Conditions.

The water quality in the streams appears good based on the parameters measured. Nitrate levels at all stations were below 3 mg/L throughout the sampling period. However, it should be kept in mind that the stream sampling was limited to a few nutrients and did not include metals or sediment sampling. For the parameters that were measured, the following trends were seen. As expected, temperature and conductivity were higher in summer than in winter. Both of these parameters tended to increase throughout the length of the watershed. Locally high levels of conductivity were seen in the upstream areas of some of the tributaries and diluted further downstream were also seen. Nitrate, on the other hand, increased in the winter (especially in November) and decreased in the summer. The highest stream nitrate levels were recorded at station 13; the levels decreased further downstream due to dilution from other tributaries.

5.1.5 Land use impacts on surface water quality

Significant relationships were seen between land use and 1) conductivity and 2) temperature. Stream temperature was lower when a greater percentage of the stream reach was forested and higher in the stream reaches with greater percentages of agricultural land. This relationship was repeated for conductivity. Because the headwaters of the streams are in granitic rocks and the lower reaches of the

stream flow through areas where parent material is predominantly sand and gravel, the higher conductivity that was seen in the downstream reaches is likely due to the change from forested land to agricultural activity rather than geological factors.

These results show that the land use in the Hatzic Valley influences the water quality in the streams that run through the valley. The impact of agriculture on nitrate levels was only seen locally whereas significant correlations between temperature and conductivity and amount of agricultural or forested land were seen throughout the watershed, suggesting that there are cumulative impacts from the changing land use, which is increasingly agricultural as one moves downstream.

5.1.6 Groundwater and Surface Water Interactions

Based on the information available about the stream water and groundwater it seems likely that the streams in the vicinity of Durieu Road (stations 8-10) are directly recharged by groundwater in the summer. The water at these stations is cooler in summer and has higher conductivity than that measured at surrounding stations, suggesting that groundwater accounts for a significant portion of base flow in these areas. Since the nitrate in the streams was lower in summer than in winter this suggests that groundwater does not contaminate streams in the Hatzic Valley as it does in other areas of the Lower Fraser Valley.

Throughout the valley, direct relationships between surface water and groundwater cannot be seen; however, since a strong relationship exists between levels of nitrate in groundwater and depths of wells it is assumed that land based sources of nitrate are impacting these shallow wells. Flooding is a problem in the Hatzic Valley and could cause negative impacts on groundwater if surface water is able to back-flow into wells during times of high water. In the area of Hatzic Island the water table is very high. It is likely that there is continuous interaction between lake water and groundwater in this area.

5.1.7 Perceptions

The majority of the residents of the Hatzic valley perceive their water quality to be good to excellent. Water quality testing revealed that in general, water quality through the valley could be classified as good to excellent meaning that most residents were not wrong in their perceptions. These perceptions were significantly correlated with levels of iron and manganese measured in the water. Those with poor opinion of their water quality were more likely to have high levels of these two elements. Iron and manganese are nuisance chemicals in water that produce unpleasant taste as well as staining of fixtures and laundry. Nitrate, which was not correlated with water quality perception, is tasteless and odourless. Since most residents test their drinking water infrequently it is, perhaps, not surprising that water quality

perceptions were partly based on a tangible parameter such as iron rather than on an invisible one like nitrate.

Regional differences were seen in many of the survey answers with residents from AQ3 placing greater emphasis on the importance on the various measures of “intuitive toxicology” than those who lived on AQ1. The residents of AQ1 (which includes Hatzic Island) were also far more concerned about the effects of septic systems on water quality than those who lived elsewhere. As water quality testing showed clear correlations between nitrate levels and percentage of urbanisation surrounding wells it seems that the concerns of those living on AQ1 are not unfounded. However the opinions of those living on AQ3 are also valid given that those living on AQ1 are more likely to have their septic systems located within 30 m of their wells than those who lived in other parts of the valley. Sixty-eight percent of those living in the south of the valley felt that the introduction of a municipal sewer system would be a very appropriate measure to safeguard water quality while 45% of those living on AQ3 felt this strategy was extremely inappropriate. Again, the differences in housing density in these two areas probably explain the differences in the responses making neither opinion invalid.

5.2 Recommendations

5.2.1 Hatzic Island

The majority of wells with high levels of nitrate were located in urban areas on Hatzic Island. Further testing of wells for nitrate and pathogens on the island is recommended to determine the extent of groundwater contamination in this area. If further sampling reveals widespread areas of nitrate contamination steps will need to be taken to try and alleviate the problem.

Local solutions should be attempted before in implementation of large new infrastructure in the area. Homeowners should ensure they are servicing their septic systems on a regular basis as well as ensuring that individual wells are properly constructed and sealed. If these preventive measures are not sufficient to improve groundwater quality the FVRD may have to consider alternate sources of drinking water or sewage treatment for the island. Some of the options that should be considered to improve the quality of drinking water on Hatzic Island include the following, development of centralized sewage collection, piping in treated drinking water from a nearby municipality, providing local residents with bottled water for domestic consumption, or installation of point of use treatment for residents with contaminated water. Many of these options will be much more expensive than the status quo and it is beyond the scope of this project to complete a full cost benefit analysis and offer a conclusive recommendation. In considering options to improve drinking water quality on Hatzic Island the following factors must be considered:

1. Will the quality of water improve?
2. Will there be impacts on the ecosystem (i.e. Hatzic Lake) from the action?
3. What is the initial and long term cost of the action?

It should be remembered that while the quality of water from several of the wells on Hatzic Island is of concern, it is relatively good compared to the water found in other aquifers in the Lower Fraser Valley where nitrate levels as high as 45 mg/l have been recorded (Carmichael et al., 1995)

5.2.2 Other Impacted Wells

All of the wells with high nitrate levels were shallower than 12 m. Although many of the high nitrate wells were concentrated in the urban areas in Hatzic Island others, (including the well with the highest nitrate value in summer) are located throughout the valley in areas with different land uses. Studies in other parts of the LFV have linked elevated nitrate with agricultural activities. Although agriculture does not appear to have a widespread impact on the groundwater quality in the Hatzic valley it is recommended that homeowners with shallow wells monitor their wells more frequently for nitrate and pathogens (total and fecal coliforms) regardless of the land-use surrounding their well. If agricultural activity in the valley intensifies in the future more widespread nitrate contamination may be seen. Special attention should be paid to shallow wells on AQ1 in the area just east of Hatzic Island, as this is where the second greatest concentration of wells with nitrate levels above 3 mg/L was seen. It may be appropriate to include this area in any long term plans for alternate drinking water delivery that are developed for Hatzic Island.

5.2.3 Other Factors Influencing Water Quality

Although not discussed in this project, it is known that the Hatzic Valley is prone to flooding and slope instability. These issues have been discussed at length in many government and consultant reports (these are summarized by Hogan (2001)). The instability and flooding will have implications for any future groundwater management options. Flooding is of special concern for groundwater quality as wells can become contaminated during periods of high water by direct surface water influence on the wells (flooding of the town's water supply was directly linked to the contamination in Walkerton). Any future actions to improve drinking water quality in the area will have to consider the impacts that flooding or landslides would have on the water quality.

5.3 Conclusions

The residents of the Hatzic Valley are lucky; their groundwater has not been highly impacted by human activity (land use) like some of the other aquifers in the Lower Fraser Valley. There are, however, localized areas that should be monitored to ensure they do not deteriorate further. Hatzic Island is the main area of concern. The density of septic systems and proximity of wells to septic systems in the subdivisions on the island are a cause for concern. Elevated nitrate levels were found in these areas and further monitoring is recommended to determine how widespread these problems are. Considering the high seasonal increase in population on Hatzic Island during the summer, steps should be taken to

consider a new source of drinking water for this area especially for those living in the subdivisions. All incidences of elevated nitrate are confined to wells less than 12 m deep; therefore these wells should be monitored closely at locations throughout the valley.

This project has provided the first set of water quality information that spans all three aquifers located in the Hatzic Watershed. It provides valuable base-line data that can help both residents and the regional district to better understand processes in the watershed that might negatively affect groundwater quality. Establishing this sort of information is particularly important for developing appropriate public policy with regards to future land use planning in the Hatzic Watershed.

References

- QuikChem Method No. 12-107-04-1-B Nitrate + Nitrite. Milwaukee, Lachat Instruments.
- Final Report: Panel Review of British Columbia's Drinking Water Protection Act (2002). Government of British Columbia.
- Drinking Water Protection Regulation (2003). B.C. Reg 200/2003. O.C. 508/2003.
- Water (2003). Government of Ontario: Queen's Printer for Ontario Accessed: November 20. Updated: November 13, 2003: www.ene.gov.on.ca/water.htm
- Allen, M., J. Clancy and E. Rice (2000). "The Plain, Hard Truth about Pathogen Monitoring." *Journal of the American Waterworks Association* 92 (9): 63-76
- Armstrong, J.E. (1980). *Surficial Geology Mission, British Columbia; NTS Map Sheet 92/I*, Geological Survey of Canada.
- Auditor General of British Columbia (1999). *Protecting Drinking-Water Sources: 1998/1999: Report 5: Office of the Auditor General of British Columbia*. Victoria, British Columbia: Office of the Auditor General.
- AWWA Organisms in Water Committee (1987). "Committee Report: Microbiological Considerations for Drinking Water Regulation Revisions." *Journal of the American Waterworks Association* 79 (5): 81-84
- Baker, D. (1990). "Groundwater quality assessment through cooperative private well testing: An Ohio example." *Journal of Soil and Water Conservation* 45: 230-235
- Benidickson, J. (2002). "Water Supply and Sewage Infrastructure in Ontario, 1880-1990s: Legal and Institutional Aspects of Public Health and Environmental History." *Walkerton Inquiry Commissioned Paper 1*
- Berka, C., H. Schreier and K. Hall (2001). "Linking Water Quality with Agricultural Intensification in a Rural Watershed." *Water, Air and Soil Pollution* 127: 389-401
- Borchardt, M., P. Bertz, S. Spencer and D. Battigelli (2003). "Incidence of Enteric Viruses in Groundwater from Household Wells in Wisconsin." *Applied and Environmental Microbiology* 69 (2): 1172-1180
- Brandling-Bennett, A.D. (1998). The Water Challenge. in: *Providing Safe Drinking Water in Small Systems; Technology, Operations and Economics*.(ed.) J Cortruvo, G Craun and N Hearne. Washington, D.C., Lewis Publishers.
- Burkart, M.R. and J.D. Stoner (2002). "Nitrate in aquifers beneath agricultural systems." *Water Science & Technology* 45 (9)
- Cameron, K. (1998). *Kenworthy Creek Community Watershed: Coastal Watershed Assessment Level 1*. Mission, BC, (Forest Technician, District of Mission).
- Carmichael, V., M. Wei and L. Ringham (1995). *Fraser Valley Groundwater Monitoring Program: Final Report*, Ministry of Environment Lands and Parks and Agriculture, Fish and Food.
- Cey, E., D. Rudolph, G. Parkin and R. Aravena (1998). "Quantifying groundwater discharge to a small perennial stream in southern Ontario, Canada." *Journal of Hydrology* 210: 21-37
- Christensen, R. and B. Parfitt (2003). *Watered Down: A Report on Waterborne Disease in British Columbia*, Sierra Legal Defence Fund.

- Coote, D.R. and L.J.G. (eds.) (2000). *The health of our water: toward sustainable agriculture in Canada*. Publication; 2020/E. Ottawa, Research Branch Agriculture and Agri-Food Canada.
- Craun, G., P. Berger and R. Calderon (1997). "Coliform Bacteria and Waterborne Disease Outbreaks." *Journal of the American Waterworks Association* 89 (3): 96-105
- Craun, G. and R. Calderon (2001). "Waterborne Disease Outbreaks Caused by Distribution System Deficiencies." *Journal of the American Waterworks Association* 93 (9): 64-75
- Dakin, A. (1994). Groundwater Resources of the Basins, Lowlands and Plains. in: *Groundwater Resources of British Columbia*.(ed.) AW Atwater, B.C Environment and Environment Canada.
- DeLoe, R.C., S.E. DiGiantomasso and R.D. Kreutzweiser (2002). "Local Capacity for Groundwater Protection in Ontario." *Environmental Management* 29 (2): 217-233
- deVilliers, M. (1999). *Water*. Toronto, Stoddart Publishing.
- Diamond, D. (1995). *QuikChem Method 10-115-01-1-A Orthophosphate in Waters*. Milwaukee, Lachat Instruments.
- Drinnan, W. (1975). *A Brief Review of the Water Quality of Hatzic Lake with Respect to Future Land-Use Planning*. Victoria, BC, Province of British Columbia: Environmental Water Investigation Branch.
- Environment Canada (2003a). *Quickfacts Environment Canada* Accessed: Sept 10. Updated: 2003-04-03: http://www.ec.gc.ca/water/en/e_quickfacts.htm
- Environment Canada (2003b). *Almost nine million Canadians depend on groundwater* Environment Canada Accessed: September 10. Updated: 2001-03-29: www.ec.gc.ca/water/en/nature/grdwtr/e_sixmil.htm
- Eyre, B.D. and P. Pepperell (1999). "A spatially intensive approach to water quality monitoring in the Rous River catchment, NSW, Australia." *Journal of Environmental Management* 56 (2): 97-118
- Federal-Provincial Subcommittee on Drinking Water (2003). *Summary of Guidelines for Canadian Drinking Water Quality* Accessed: February 3rd, 2004. Updated: <http://www.hc-sc.gc.ca/hecs-sesc/water/pdf/summary.pdf>
- Follet, R.F., (ed). (1989). *Nitrogen Management and Ground Water Protection*. The Netherlands, Elsevier.
- Gilliam, J.W., D.L. Osmond and R.O. Evans (1997). *Selected Agricultural Best Management Practices to Control Nitrogen in the Neuse River Basin: North Carolina Agricultural Research Service Technical Bulletin 311* North Carolina State University Accessed: Updated: http://www.soil.ncsu.edu/lockers/Gilliam_J/BMPs/
- Goss, M.J., D.A.J. Barry and D.L. Rudolph (1998). "Contamination in Ontario Farmstead Domestic Wells and its Association with Agriculture: 1. Results from drinking water wells." *Journal of Contaminant Hydrology* 32: 267-293
- Haas, C. (1999). "Benefits of Using a Disinfectant Residual." *Journal of the American Waterworks Association* 91 (1): 65-69
- Halstead, E.C. (1986). *Ground water supply -- Fraser Lowland, British Columbia*, NHRI Paper N0. 26.
- Harman, J., J.E. McLellan, D.L. Rudolph, D.J. Heagle, C. Piller and S.E. Denhoed (2000). *A Proposed Framework for Managing the Impact of Agriculture on Groundwater: A report prepared for the Sierra-ALERT Coalition for Submission to Part 2 of the Walkerton Inquiry*, Sierra- ALERT.

- Health Canada - Health Protection Branch (1978-1995). *Foodborne and Waterborne Disease in Canada*. - Food-borne and water-borne disease in Canada 1974-1979. Ottawa, Health Protection Branch, Health and Welfare Canada.
- Hillel, S. (1998). Stabilized Formulation of Hydrogen Peroxide with Silver: a Secondary Disinfectant. in: *Providing Safe Drinking Water in Small Systems: Technology, Operations and Economics*.(ed.) J Cortruvo, G Craun and N Hearne. Washington, D.C., Lewis Publishers.
- Hinton, M., S. Schiff and M. English (1993). "Physical properties governing groundwater flow in a glacial till catchment." *Journal of Hydrology* 142: 229-249
- Hogan, M. (2001). *Literature Review: Hatzic Prairie Watershed*. Prepared for FVRD by Mike Hogan; UCFV Practicum Student.
- Hudak, P. (1999). "Chloride and Nitrate Distributions in the Hickory Aquifer, Central Texas, USA." *Environmental International* 25 (4): 393-401
- Jaffe, M. and F. DiNovo (1987). *Local Groundwater Protection*. Washington, American Planning Association.
- Jaques, D. and H. Rohde (2001). *Rural Municipality of Mount Hope # 279: Water Well Inventory and Microbiological Activity Assessment*. Regina, Saskatchewan, Prairie Farm Rehabilitation Administrator: Earth Sciences Unit.
- Kirmeyer, G.J., M. Friedman, K. Martel, P. Noran and D. Smith (2001). "Practical Guidelines for Maintaining Distribution System Water Quality." *Journal of the American Waterworks Association* 93 (7): 62
- Kraus, N., T. Malfors and P. Slovic (1992). "Intuitive Toxicology: Expert and Lay Judgements of Chemical Risks." *Risk Analysis* 12 (2): 215-232
- Kreye, R. and M. Wei (1994). *A Proposed Aquifer Classification System for Groundwater Management in British Columbia*, Province of British Columbia, Ministry of Environment Lands and Parks, Water Management Division, Groundwater Section, Hydrology Branch.
- Lee, D. and J. Cherry (1978). "A Field Exercise on Groundwater Flow Using Seepage Meters and Mini-piezometers." *Journal of Geological Education* 27: 6-10
- Legault, T. (2000). *Microbiological Activity and the Deterioration of Water Well Environments on the Canadian Prairies* Prairie Farm Rehabilitation Administration, Earth Sciences Unit. Accessed: August 20, 2003. Updated: www.agr.gc.ca/pfra/water/swwi/ian2000t.pdf
- Leitch, R. (2000). "Balancing Act: Small Community Water Supplier Mulls Affordable Corrosion Control with Pleasing Aesthetics." *Water Engineering and Management* 147 (9)
- Lichtenberg, E. and T. M. Penn (2003). "Prevention versus Treatment Under Precautionary Regulation: A Case Study of Groundwater Contamination Under Uncertainty." *American Journal of Agricultural Economics* 85 (1): 44-58
- Liebscher, H., B. Hii and D. McNaughton (1992). *Nitrates and Pesticides in the Abbotsford Aquifer: Southwestern British Columbia*, Environment Canada.
- Lippy, E. and S. Waltrip (1984). "Waterborne Disease Outbreaks -- 1946-1980: A Thirty-Five-Year Perspective." *Journal of the American Waterworks Association*: 60-67
- Luttmerding, H.A. (1980a). *Soils of the Langley-Vancouver Map Area: report No. 15 British Columbia Soil Survey: Volume 1 Soil Map Mosaics and Legend, Lower Fraser Valley (Scale 1:25 000)*. Kelowna, Province of British Columbia, Ministry of Environment, Assessment and Planning Division.

- Luttmerding, H.A. (1980b). *Soils of the Langley-Vancouver Map Area: report No. 15 British Columbia Soil Survey: Volume 2 Soil Maps and Legend, Southern Sunshine Coast and Southern Coast Mountains (Scale 1:50 000)*. Kelowna, Province of British Columbia, Ministry of Environment, Assessment and Planning Division.
- McGarrigle, M., J. Bowman, K. Clabby, J. Lucey, P. Cunningham, M. MacCarthaigh, M. Keegan, B. Cantrell, M. Lehane, C. Clenaghan and P. Toner (2002). Chapter 5: The Water Quality of Groundwaters. in: *Water Quality in Ireland (1998-2000)*, Environmental Protection Agency (of Ireland).
- Méranger, J.C., K.S. Subramanian and C. Chalifoux (1979). "A National Survey for Cadmium, Chromium, Copper, Lead, Zinc, Calcium, and Magnesium in Canadian Drinking Water Supplies." *Environmental Science and Technology* 13 (6): 707-711
- Muhammetoğlu, H., A. Muhammetoğlu and S. Soyupak (2002). "Vulnerability of Groundwater to Pollution from Agricultural Diffuse Sources: a case study." *Water Science and Technology* 45 (9)
- Murphy, E. (1992). "Nitrate in drinking water wells in Burlington and Mercer Counties, New Jersey." *Journal of Soil and Water Conservation* 47 (2): 183-187
- Nolan, B.T. and J.D. Stoner (2000). "Nutrients in Groundwaters of the Conterminous United States, 1992-1995." *Environmental Science and Technology* 34 (7): 1156-1165
- O'Connor, D. (2002a). *Report of the Walkerton Inquiry, Part 1: The Events of May 2000 and Related Issues*. Toronto, Ministry of the Attorney General of Ontario; Queen's Printer.
- O'Connor, D. (2002b). *Report of the Walkerton Inquiry, Part 2: A Strategy for Safe Drinking Water*. Toronto, Ministry of the Attorney General of Ontario; Queen's Printer for Ontario.
- Oxtobee, J. and K. Novakowski (2002). "A Field Investigation of Groundwater/Surface Water Interaction in a Fractured Bedrock Environment." *Journal of Hydrology* 269: 169-193
- Pacific Hydrology Consultants Ltd. (2003). *Hydrogeological Impact Evaluation Concerning the Relocation of the Quarry at 13361 Stave Lake Road In Mission, B.C. - an update of PHCL report of June 21, 1994*.
- Piteau Associates (1994). *Review Comments Relating to Groundwater Supplies and Hydrogeological Impacts: Prepared for John Conroy and Residents of Upper Hatzic/McConnel Creek Area: Mission British Columbia*.
- Postel, S., G.C. Daily and P.R. Erlich (1996). "Human Appropriation of Renewable Fresh Water." *Science* 271: 785-787
- Prokopy, W. (1992). *QuikChem Method 10-107-06-2-A. Ammonia in surface water, drinking water and wastewater*. Milwaukee, Lachat Instruments.
- Provincial Health Officer. British Columbia. (2001). *A report on the health of British Columbians; Provincial Health Officer's Annual Report 2000: Drinking Water Quality in British Columbia: the Public Health Perspective*. Victoria, B.C., Ministry of Health Planning.
- Reid, D., A. Edwards, D. Cooper, E. Wilson and B. Megrew (2002). "The Quality of Drinking Water from Private Water Supplies in Aberdeenshire, UK." *Water Research* 37: 245-254
- Reynolds, K. (2003). "Coliform Bacteria: A Failed Indicator of Water Quality?" *Water Conditioning and Purification Magazine* 45 (9). online access (January 6, 2004) at <http://www.wcp.net/column.cfm?T=T&ID=2349>

- Rudolph, D.L., D.A.J. Barry and M.J. Goss (1998). "Contamination in Ontario farmstead domestic wells and its association with agriculture: 2. Results from multilevel monitoring well installations." *Journal of Contaminant Hydrology* 32 (3-4): 295-311
- Rutter, M., G. Nichols, A. Swan and J. DeLouvois (2000). "A Survey of the Microbiological Quality of Private Water Supplies in England." *Epidemiology and Infection* 124: 417-425
- Scherer, C. (1990). "Communicating Water Quality Risk." *Journal of Soil and Water Conservation* 45 (2): 189-200
- Schreiber, J.D., R.A. Rebich and C.M. Cooper (2001). "Dynamics of Diffuse Pollution for US Southern Watersheds." *Water Research* 35 (10): 2534-2542
- Schreier, H., K. Hall, L. Elliott, J. Addah and K. Li (2003). *Groundwater and Surface Water Issues in Agassiz, BC*. By: Institute for Resources, Environment and Sustainability for the District of Kent & Agassiz, BC: Multimedia Report.
- Schreier, H., P. Scales, K. Hall, B. Wernick, W. Tamagi, A. Kenney, W. Thompson, S. Brown and L.M. Lavkulich (1996). *A Groundwater Quality Assessment in the Hopington Aquifer*, The Corporation of the Township of Langley (Engineering Division) and Fraser River Action Plan: Environment Canada and Department of Fisheries and Oceans.
- Siegel, S. (1956). *Nonparametric Statistics for the Behavioral Sciences*. New York, McGraw-Hill Book Company.
- StatSoft (2002). *Electronic Statistics Textbook* StatSoft Accessed: Jul y 11th. Updated: <http://www.statsoft.com/textbook/stathome.html>
- Summers, R. and J. FitzGibbon (2003). *Groundwater Protection Through Water Well Regulation, A Review of Provincial Regulations Across Canada*. Canadian Water Resources Association 56th Annual Conference: Water Stewardship: How Are We Managing?, Vancouver, British Columbia.
- Tuthill, A., D.B. Meikle and M. Alavanja (1998). "Coliform Bacteria and Nitrate Contamination of Wells in Major Soils in Frederick, Maryland." *Journal of Environmental Health* 60 (8)
- VanDerKooij, D., J.H.M. VanLieverloo, J. Schellart and P. Hiemstra (1999). "Maintaining Quality Without A Disinfectant Residual." *Journal of the American Waterworks Association* 91 (1): 55-64
- Wernick, B.G., K.E. Cook and H. Schreier (1998). "Land Use and Streamwater Nitrate-N Dynamics in an Urban-Rural Fringe Watershed." *Journal of the American Water Resources Association* 34 (3): 639-650
- Wetzel, R. (2001). *Limnology; Lake and River Ecosystems (3rd Ed.)*, Academic Press.
- Wong, B. (2004) *Procedure for testing watershed / surface water* Unpublished, British Columbia Centre for Disease Control. Vancouver, B.C.
- Yanggen, D. and S. Born (1990). "Protecting groundwater quality by managing local land use." *Journal of Soil and Water Conservation* 45 (2): 207-210
- Zar, J. (1984). *Biostatistical Analysis (2nd Ed.)*. Englewood Cliffs, N.J., Prentice-Hall.
- Zebarth, B., B. Hii, H. Liebscher, K. Chipperfield, J. Paul, G. Grove and S. Szeto (1998). "Agricultural Land Use Practices and Nitrate Contamination in the Abbotsford Aquifer, British Columbia, Canada." *Agriculture, Ecosystems and Environment* 69: 99-112

Appendixes

Appendix 1 – Initial Contact Letter

UBC-FVRD Groundwater Study looking for volunteer well-owners.

The Institute for Resources and Environment at the University of British Columbia in collaboration with the Fraser Valley Regional District is carrying out a groundwater study in the Hatzic watershed to determine the quality of the groundwater and the linkages between land use, groundwater and stream-water. We plan to select some 100 wells for water quality analysis and we will test the well-water in late July 2002 and in February 2003 (The anticipated July sampling date is Monday, July 29th). Participation in the study is on a voluntary and confidential basis; it will give well owners an opportunity to get their water tested in the UBC laboratories at no cost, and they will be provided with a report on the general status of the drinking water in the watershed at the end of the study.

The aims of the project are to examine the chemical composition of the water, identify potential sources of contamination, study the direction of groundwater movement and propose options to maintain or improve the water quality conditions. The project will be carried out with the help of volunteers and students and we need participating well owners that fit our sampling design in relation to well depth, spatial distribution, well age, and capacity of the well.

Those willing to participate should contact Bill Walsh at the North Fraser Community Futures Office, indicate that they are calling regarding the Hatzic Groundwater Study and leave their name and contact number (tel. or email) and their mailing address, as well as information on the well depth and the approximate age of the well.

We will contact you in mid July, at which time we will provide you with water sampling bottles and instructions on how, and when to collect the water from your tap. Volunteers will help in the distribution and collection of the water samples and you will be informed of the results within one month of the sample analysis.

Your participation and cooperation in this study is much appreciated.

If you are willing to participate in the study please contact Bill Walsh at (604) 826-6252 ex 120 or e-mail Simone Magwood at magwood@interchange.ubc.ca

If you have any questions do not hesitate to contact:

Simone Magwood
MSc. Candidate
Institute for Resources and Environment
University of British Columbia
Vancouver, B.C. V6T 1Z3
Tel: 604-435-0442
Email:
magwood@interchange.ubc.ca

Bill Walsh
Watershed Stewardship
Coordinator
North Fraser Valley Area
Community Futures Development Corporation
32286 Fletcher Avenue
Mission, B.C. V2V 5T1
Tel: (604) 826-6252 ex 210

Graham Daneluz
Planner I - Long Range
Fraser Valley Regional District
8430 Cessna Drive, Chilliwack,
BC V2P 7K4
Tel: 1-800-528-0061 or 604 702-5000
Fax: 604 792-9684

Appendix 2 – News Release

NEWS RELEASE

FOR IMMEDIATE RELEASE
04 JULY 2002

Participants Required for UBC-FVRD Groundwater Study

BC is rapidly waking up to the fact that water is a precious resource that must be protected.

One of the leaders in innovative water research, the Institute for Resources and Environment at UBC, is sponsoring a groundwater study in the Hatzic watershed, in collaboration with the Fraser Valley Regional District.

The study goals are to determine the quality of the groundwater, and the linkages between land use, groundwater and stream-water. The plan is to select some 100 wells within the Hatzic watershed for water quality analysis. Testing will commence in late July. Participation in the study is on a voluntary and confidential basis. All participants who are selected will receive free testing of their water in the UBC labs, and will receive a final report.

The project will examine the chemical composition of the water, identify potential sources of contamination, study the direction of groundwater movement and propose options to maintain or improve the water quality conditions. The project will be carried out with the help of volunteers and students. As the aim of the study is to sample wells that represent different areas, depths, age and capacity of the wells, it is recommended that you sign up early to ensure your well gets tested.

To participate contact Bill Walsh of North Fraser Community Futures at 604-826-6252, ext. 120. Leave your name, contact number, mailing address, well depth and approximate age of your well.

For more information on the study itself, contact Simone Magwood at magwood@interchange.ubc.ca.

Appendix 3 – Instruction Letter

Hatzic Watershed Groundwater Survey

July 24, 2002

Thank you for participating in the groundwater survey. The sampling of your well is scheduled for **Monday, July 29, 2002**. On Monday morning July 29, 2002 between **7 and 9 am** we would like you to let your tap run for 5 minutes and then fill the bottle. Put your name and address on the bottle and a volunteer will pick up the bottle between 9 and 11 a.m. If you are not at home during that time period please leave the bottle on your front step (or inform us of an alternate location). Make sure the water stays cool (**do not put it into the sun**). Enclosed with the bottle is a questionnaire, which we would like you to fill out and attach to the bottle or mail to the UBC address below.

You will be informed by mail of the result of the analysis in August. We will examine the nitrate, ammonia, phosphate, and salt content in the first set of samples and will do a follow up survey on selective wells for microbial contamination. We plan to conduct a second survey in February and hope you are willing to continue to collaborate with us at that time. If you have any questions do not hesitate to contact us.

We would like to thank you for your collaboration.

Simone Magwood
MSc. Candidate
Institute for Resources and Environment
University of British Columbia
Vancouver, B.C. V6T 1Z3
Tel: 604-822-9245
Email: magwood@interchange.ubc.ca

Bill Walsh
Watershed Stewardship Coordinator
North Fraser Valley Area
Community Futures Development Corporation
32286 Fletcher Ave.
Mission, B.C. V2V 5T1
(604) 826-622 ex 210

Appendix 4 – Report Back Letter

«Owner»
«Number» «Owner_Address»
«City»
«Postal_Code»

April 13, 2004

Results of the July 2002 Well Water Survey

Dear Participant

Thank you for participating in the well water survey. We appreciate your time and effort.

The following results were obtained for the recent well water analysis:

«Nitrate_ppm_N» mg/L of Nitrate-N «Conductivity_micro_MHO»umhos/cm Conductivity (salt content)
--

Nitrate-N: Values greater than 10 mg/L are considered a health concern. 10 mg/L is the National Health Standard. Water with Nitrate-N levels between 7 and 9.9 mg/L is of concern and is likely impacted by different land use activities (fertilizers, manure, or septic system effluent). Levels below 3 mg/L are of little concern and considered unpolluted water.

Conductivity: Water with less than 100 umhos/cm is considered to be “soft” water with low salt content. Water with greater than 500 umhos/cm is considered to be “hard” water with relatively high salt content. These measurements are not a health concern but they give us an idea about the source of water, the geological formation and the land use influence.

Additional tests will be done on selective metals but the data will not be available until the February survey is completed.

We hope to do a **follow-up analysis in February** when the groundwater table is low, and we hope you will once again participate. We will contact you closer to the time.

Sincerely yours,

Simone Magwood
IRE-UBC
604.822.9245

Bill Walsh
Stewardship Coordinator
Community Futures Development Corporation of North Fraser
604.826.6252

Appendix 5 Survey



Institute for Resources and Environment
The University of British Columbia
Vancouver, B.C.

GROUNDWATER SURVEY

UBC and the Fraser Valley Regional District are collaborating on a comprehensive groundwater study and we would appreciate your collaboration in filling in this questionnaire. The completion of this questionnaire is voluntary and your response will remain confidential, but your input would significantly improve our understanding of water quality in the area.

Please answer by placing an X in the appropriate box or by filling in the space.

1. How many years have you been using your well?

	Years
--	-------

1a. How many people does your well serve?

	People
--	--------

2. How deep is your well?

	Feet
--	------

or

	Metres
--	--------

3. Do you drink your well-water?

YES	
-----	--

NO	
----	--

SOMETIMES	
-----------	--

4. Do you filter your well-water?

YES	
-----	--

NO	
----	--

If YES, what kind of filter do you use? _____

5. Do you treat your water in any other way?

YES	
-----	--

NO	
----	--

If YES, how do you treat your water? _____

6. Do you drink bottled water at home?

ALWAYS	
--------	--

OFTEN	
-------	--

SOMETIMES		NEVER	
-----------	--	-------	--

7. Does your well provide sufficient water throughout the year?

YES	
-----	--

NO	
----	--

8. Are you engaged in: (Please place an X in the boxes that best represent the amount of activity)

Occupation	Full-time	Part-time	Never
Farming / Agriculture			
Other professional service			

9. What is your perception of the water quality from your well?

EXCELLENT	
-----------	--

GOOD	
------	--

MODERATE	
----------	--

FAIR	
------	--

POOR	
------	--

10. Do you think an increase in groundwater aquifer use is appropriate?

YES	
-----	--

LIMITED USE ONLY	
------------------	--

NEED MORE INFO	
----------------	--

NO	
----	--

11. How important is each of the following **activities** in causing water quality problems?
(Please circle the number that best represents the importance of each activity)

	STRATEGY	Extremely important		Moderately important		Not at all important	
11a	Farming (fertilizer use)	5	4	3	2	1	0
11b	Farming (manure use)	5	4	3	2	1	0
11c	Farming (chemicals)	5	4	3	2	1	0
11d	Hobby farms	5	4	3	2	1	0
11e	Lawn fertilization	5	4	3	2	1	0
11f	Golf course management	5	4	3	2	1	0
11g	Septic systems	5	4	3	2	1	0
11h	Industrial activity	5	4	3	2	1	0
11i	Aggregate Extraction	5	4	3	2	1	0
11j	Other	5	4	3	2	1	0

12. To what extent do you think use of the groundwater aquifer affects the **local rivers**?

River flow	Significant impact		Some impact		No impact	
Water quality	Significant impact		Some impact		No impact	

13. What type of **management** approach do you favour?

Voluntary		Regulation		A Combination	
-----------	--	------------	--	---------------	--

14. How appropriate do you think the following **strategies** are for managing groundwater resources?
(Please circle the number that best represents the importance of each activity)

	STRATEGY	Extremely appropriate		Moderate		Not appropriate	
14a	Restriction on fertilizer use in agriculture	5	4	3	2	1	0
14b	Restrictions on manure applications	5	4	3	2	1	0
14c	Restrict lawn & garden use of chemicals	5	4	3	2	1	0
14d	Introduce septic system monitoring & servicing regulations	5	4	3	2	1	0
14e	Control road runoff	5	4	3	2	1	0
14f	Introduction of a municipal sewer system	5	4	3	2	1	0
14g	Regulate land use	5	4	3	2	1	0
14h	Restrict industrial development	5	4	3	2	1	0
14i	Restrict urban development	5	4	3	2	1	0
	Other	5	4	3	2	1	0

15. What type of **land use** activity occurs within 100 m of your well?

16. Have you had any **problems** with your well?

17. How often do you **test** your well? (Please Check the Appropriate Box)

	Once a Year	Every 2 Years	Every 3 Years	Other
Bacteria				
Chemical				

18. Have you had any chemical and bacterial **exceedances** in your well water. If YES, explain

--	--	--	--

19. Do you have a septic system? If YES, How close is your septic system to your well (in metres)

--	--	--	--	--	--

20. When was your **septic system** installed?

--	--

21. How often do you service your system? (Please circle the correct response)

Once/ Year	Once/2 years	Once/3 Years
Once/ 5 Years	Once/10 years	Never

22. How likely is it that you or someone in your family will suffer the effects of:

		Highly likely		Likely		Very Unlikely	
22a	Natural Disasters such as flooding or earthquakes	5	4	3	2	1	0
22b	Air Quality in the Region	5	4	3	2	1	0
22c	Pesticide Residue in local air, water or soil	5	4	3	2	1	0
22d	Downstream Effects of Industrial Pollution	5	4	3	2	1	0
22e	Fecal Coliform in Drinking Water	5	4	3	2	1	0

23. How much control do you see yourself as having over any risks posed by the following:

		No Control		Some Control		Much Control	
23a	Natural Disasters such as flooding or earthquakes	5	4	3	2	1	0
23b	Air Quality in the Region	5	4	3	2	1	0
23c	Pesticide Residue in local air, water or soil	5	4	3	2	1	0
23d	Downstream Effects of Industrial Pollution	5	4	3	2	1	0
23e	Fecal Coliform in Drinking Water	5	4	3	2	1	0

24. How important are the following as a guide for indicating the quality of your water?:

		Not at all Important			Very Important			
24a	Smell/ Taste	7	6	5	4	3	2	1
24b	Cloudiness	7	6	5	4	3	2	1
24c	Colour	7	6	5	4	3	2	1
24d	Visible Abnormalities (e.g., change in colour)	7	6	5	4	3	2	1
24e	Depth of Water Table	7	6	5	4	3	2	1
24f	Amount of visible particulate matter in a glass of water	7	6	5	4	3	2	1
24g	Local Newspaper reports on the quality of nearby bodies of water	7	6	5	4	3	2	1
24h	Multiple incidents of gastrointestinal illness in the community	7	6	5	4	3	2	1

Circle the answer that you feel is most correct:

25. If you are exposed to even the smallest amount of a water-borne pathogen such as *E-coli* or *Giardia*, you are likely to suffer adverse health effects .

Strongly Agree	Agree	Disagree	Strongly Disagree
----------------	-------	----------	-------------------

26. Your health will not be negatively affected by pesticides unless you are exposed to a lot of the chemical over a long period of time.

Agree	Disagree
-------	----------

27. Most water quality risks can be eliminated by a common household filter.

Agree	Disagree
-------	----------

28. People are unnecessarily frightened about very small amounts of contaminants found in groundwater

Agree	Disagree
-------	----------

29. On the whole, the risks to human health posed by water quality problems are far greater than the risks posed to the local fish, flora and fauna.

Agree	Disagree
-------	----------

30.. In order to arrive at a sustainable use of the groundwater resources ...

A. What do you think you could do as an individual?

B. What should the municipality do to improve the situation?

C. What actions are needed by the provincial and federal governments?

Thank you for your cooperation,

We will tabulate the results and provide you with a summary before the next water quality survey.

Sincerely,

Simone Magwood

MSc. Candidate

Institute for Resources and Environment

University of British Columbia

#48E - 2206 East Mall

Vancouver, B.C. V6T 1Z3

magwood@interchange.ubc.ca

Appendix 6 – Results of Blind Duplicates

Sample #	Conductivity uS/cm	pH	ppm PO ₄	ppm NH ₃ -N	ppm NO ₃ -N	Boron	Calcium
Well 47	109	7.44	0.115	0.025	0.138	0.014389	12.7265
	101	7.42	0.403	0.051	0.141	0.013002	12.8138
Well 41	180	8.40	0.445	0.039	0.005	0.076946	15.2703
	258	8.26	0.512	0.052	0.005	0.088161	15.0911
	Potassium	Magnesium	Manganese	Sodium	Silicon	Strontium	Zinc
Well 47	0.846126	2.64969		2.28885	6.96607	0.030732	
	0.877814	2.66057		2.03754	6.9664	0.030511	
Well 41	1.82421	3.86545	0.030937	9.45733	7.46018	0.043704	0.50827
	1.85232	3.84832	0.030718	9.57943	7.4068	0.043773	0.487846

Appendix 7. Soil and Surficial Geology Codes

Soil Texture Codes Used in the GIS (from Luttmerring, 1980)			
Texture		Drainage	
1	Fine	1	Poor to very poor
2	Moderately fine to medium	2	Poor / Imperfect
3	Medium	3	Moderately Well
4	Medium to moderately coarse	4	Moderately Well to Well
5	Coarse	5	Well to Rapid

Parent Material Categories	
1	Glaciomarine Deposits
2	Well decomposed organic material over floodplain deposits
3	Medium textured eolian deposits over moderately coarse textured glacial till
4	Laterally accreted floodplain deposits over
5	Laterally accreted floodplain deposits over sand.
6	Local stream deposits
7	Eolian deposits over gravely glacial outwash

Surficial Geology Codes Used in GIS (from Armstrong, 1980)		
0	Peat	
1	Sandy loam and clay loam	
2	Stony silt to Loamy Clay	Sandy Till
3	Sandy Loam and Loamy Sand	
4	Sand and Rubble	Gravel and Rubble
4	Gravel and Sand	Gravel, sand and rubble
5	Bedrock	

Appendix 8 – Groundwater Sampling Data

Extra Wells Sampled (Winter Sampling) near Well 19

Well Number	Depth (m)	Conductivity (µS/cm)	pH	Ammonia (mg/L)	Nitrate-N (mg/L)	Aluminium (mg/L)	Boron(mg/L)	Barium (mg/L)	Calcium (mg/L)
81	Not known	130	6.22	0.059	3.141	0.050	0.0199	0.0100	12.330
82	Not-known	140	6.56	0.050	1.860	0.050	0.0100	0.0100	12.785
83	Not-known	159	6.59	0.060	0.969	0.050	0.0122	0.0146	14.791

Well Number	Copper (mg/L)	Iron (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Manganese (mg/L)	Sodium (mg/L)	Silicon (mg/L)	Strontium (mg/L)	Zinc (mg/L)
81	0.0500	0.0500	0.5000	6.416	0.0050	1.4163	8.9860	0.0589	0.0100
82	0.0500	0.0500	0.5000	6.4188	0.0050	1.9239	11.3192	0.0651	0.0975
83	0.0828	0.0500	0.5000	7.6378	0.0117	3.8325	11.6850	0.0771	0.0100

Well Number	%For50	%Rur50	%Ag50	%Urb50	%For100	%Rur100	%Ag100	%Urb100
81	0.0	77.4	7.8	0.0	0.0	42.0	25.2	0.0
82	0.0	70.5	20.6	0.0	0.0	36.3	35.7	0.0
83	0.0	55.7	43.8	0.0	0.0	23.8	71.8	0.0

Well Number	%For200	%Rur200	%Ag200	%Urb200	Drainage Code	Texture code	Geology Code	Surficial Texture	Parent Material
81	5.1	20.7	31.8	0.0	1	2	1	3	4
82	2.7	17.8	43.6	0.0	4	3	1	3	4
83	0.0	8.0	89.4	0.0	1	2	1	3	4

Well Number	Aquifer Number	Depth (m)	Conductivity (µS/cm)		pH		Orthophosphate (mg/L)		Ammonia (mg/L)		Nitrate-N (mg/L)	
			Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
1	1	9.4488	219	160	6.16	6.19		0.429	0.05	0.05	3.008	1.003
2	1	9.14	92	100	5.90	5.82		0.381	0.05	0.05	0.05	0.115
3	1	24.38	not-tested	240	not-tested	7.01		0.466	not-tested	0.321	not-tested	0.05
4	1	6.71	129	100	6.37	6.33		0.405	0.05	0.05	1.064	0.679
5	1	7.01	129	130	6.44	6.38		0.341	0.05	0.05	3.075	4.828
6	1	6.10	185	180	6.28	6.30		0.397	0.05	0.05	4.933	5.286
7	1	18.29	92	100	6.15	6.18		0.367	0.05	0.05	0.274	0.274
8	1	8.53	93	120	6.48	6.29		0.385	0.05	0.05	0.956	0.674
9	1	0.00	169	170	6.22	6.15		0.458	0.05	0.05	0.287	0.235
10	1	7.62	154	160	6.13	6.14		0.366	0.05	0.05	2.381	1.983
11	1	0.00	275	200	6.11	6.16		0.521	0.05	0.05	11.962	4.538
12	1	7.62	162	180	6.30	6.30		0.542	0.05	0.05	3.369	4.705
14	1	6.10	67	110	6.66	6.40		0.239	0.053	0.05	0.498	0.357
15	1	0.00	199	230	6.53	6.58		0.267	0.05	0.05	2.168	3.284
16	1	9.14	173	130	6.39	6.40		0.258	0.05	0.05	5.307	0.579
17	1	6.10	157	170	6.32	6.49		0.331	0.05	0.05	0.05	0.05
18	1	5.18	141	150	6.59	6.58		0.298	0.05	0.05	0.647	0.586
19	1	4.27	235	250	6.33	6.28		0.276	0.061	0.05	7.499	10.129
20	1	9.14	132	150	6.40	6.39		0.283	0.05	0.05	2.462	2.443
21	1	0.00	168	150	6.28	6.28		0.307	0.05	0.05	0.787	0.559
22	1	9.14	not-tested	160	not-tested	6.17		0.300	not-tested	0.05	not-tested	2.517
23	1	9.14	130	130	6.18	6.14		0.270	0.05	0.05	0.422	0.240
24	1	6.10	153	150	6.43	6.36		0.284	0.05	0.05	1.674	1.236
25	1	7.62	390	410	6.88	6.95		0.162	0.188	0.05	0.05	0.05
26	2	91.44	3290	3200	7.92	7.92		0.186	0.05	0.663	0.05	0.05
27	2	0.00	77	100	6.51	6.46		0.05	0.05	0.05	0.461	0.949
28	2	10.06	84	130	6.49	6.38		0.053	0.05	0.05	0.513	1.029
29	2	3.66	70	70	6.34	7.21		0.052	0.05	0.05	0.812	0.339
30	2	22.36	not-tested	140	not-tested	7.04		0.116	not-tested	0.05	not-tested	0.398
31	2	9.45	103	100	6.08	6.18		0.05	0.067	0.05	1.557	0.823
32	2	5.49	55	50	6.05	6.06		0.052	0.05	0.05	0.372	0.077
33	2	3.66	51	50	6.49	6.46		0.055	0.05	0.05	0.586	0.239
34	2	0.00	47	60	6.27	6.20		0.057	0.05	0.05	1.012	0.324
35	2	12.19	120	90	6.31	6.35		0.05	0.063	0.05	0.587	0.287
36	2	76.20	130	130	7.78	7.66		0.087	0.056	0.05	0.073	0.071
37	2	19.51	155	130	7.06	7.08		0.107	0.05	0.05	1.015	0.425
38	2	137.16	194	270	9.03	6.63		0.109	0.05	0.05	0.05	0.05
39	2	5.18	68	70	5.80	5.89		0.057	0.05	0.05	1.004	0.794

Well Number	Aquifer Number	Depth (m)	Conductivity (µS/cm)		pH		Orthophosphate (mg/L)		Ammonia (mg/L)		Nitrate-N (mg/L)	
			Winter	Summer	Winter	Summer	Summer	Summer	Winter	Summer	Winter	Summer
40	2	60.96	610	550	8.40	8.35	0.249	0.061	0.099	0.05	0.05	0.05
41	2	79.25	180	170	8.40	8.10	0.123	0.05	0.05	0.05	0.05	0.05
42	2	60.96	1030	1000	8.21	8.07	0.126	0.062	0.076	0.05	0.05	0.05
43	3	5.49	104	90	5.85	5.88	0.05	0.05	0.05	0.05	3.447	3.141
44	3	56.39	59	60	6.42	6.41	0.053	0.05	0.05	0.05	0.283	0.274
45	3	19.20	340	330	7.91	7.85	0.190	0.085	0.105	0.05	0.05	0.05
46	3	52.12	95	90	7.21	7.21	0.069	0.05	0.05	0.05	0.284	0.284
47	3	0.00	109	110	7.44	7.44	0.082	0.05	0.051	0.05	0.141	0.134
48	3	0.00	25	50	6.67	6.95	0.05	0.05	0.05	0.05	0.452	0.368
49	3	7.62	not-tested	110	not-tested	6.60	0.070	0.05	not-tested	0.05	not-tested	0.462
50	3	41.76	116	120	8.14	7.92	0.075	0.05	0.05	0.05	0.05	0.05
51	3	56.39	106	100	7.38	7.49	0.078	0.05	0.05	0.05	0.060	0.051
52	3	5.49	37	30	7.27	7.38	0.05	0.05	0.05	0.05	0.216	0.184
53	3	5.49	161	180	6.66	7.05	0.118	0.05	0.05	0.05	2.609	1.863
54	3	30.48	170	160	8.32	8.20	0.124	0.05	0.055	0.05	0.05	0.05
55	3	36.58	141	160	8.23	8.22	0.133	0.05	0.05	0.05	0.05	0.05
56	3	56.39	201	60	7.32	6.27	0.065	0.05	0.053	0.05	0.309	0.581
57	3	67.06	53	50	6.16	6.22	0.05	0.05	0.05	0.05	0.567	0.625
58	3	7.62	123	130	6.35	6.63	0.066	0.05	0.05	0.05	4.061	2.784
59	2	13.72	54	60	6.59	6.56	0.05	0.05	0.053	0.05	0.391	0.508
60	3	54.86	44	50	6.12	6.11	0.05	0.05	0.05	0.05	0.728	1.168
61	3	28.96	47	60	6.23	6.53	0.05	0.05	0.054	0.05	0.605	0.322
62	3	0.00	17	30	6.22	6.41	0.05	0.05	0.05	0.05	0.179	0.126
63	3	43.89	57	60	6.03	6.22	0.05	0.05	0.05	0.05	0.711	0.591
64	3	24.38	52	60	5.85	6.07	0.05	0.05	0.052	0.05	0.544	0.638
65	3	18.29	34	40	5.99	6.10	0.05	0.05	0.059	0.05	0.427	0.303
66	3	24.38	32	50	6.07	6.00	0.05	0.05	0.05	0.05	0.243	0.239
67	3	36.58	44	50	6.00	6.00	0.05	0.05	0.05	0.05	0.714	0.574
68	3	32.92	35	50	6.27	6.17	0.05	0.05	0.083	0.05	0.352	0.570
69	3	30.48	33	40	6.21	6.32	0.05	0.05	0.052	0.05	0.418	0.343
70	3	12.80	34	40	6.07	6.02	0.05	0.05	0.086	0.05	0.496	0.369
71	3	128.63	134	150	8.41	8.24	0.063	0.05	0.061	0.05	0.05	0.05
73	3	19.81	66	70	6.18	6.31	0.051	0.05	0.05	0.05	0.237	0.184
74	3	6.10	44	50	5.73	5.83	0.05	0.05	0.05	0.05	0.814	0.707
75	2	11.58	231	240	7.81	7.65	0.296	0.988	0.826	0.05	0.05	0.05
76	3	2.74	33	50	6.36	6.49	0.074	0.059	0.075	0.05	0.05	0.05
77	2	0.00	3100	3100	8.05	8.07	0.292	0.124	0.154	0.249	0.249	0.236
79	2	0.91	141	100	6.05	6.68	0.067	0.05	0.054	0.05	6.111	0.901

Well Number	Aluminium (mg/L)		Boron(mg/L)		Barium (mg/L)		Calcium (mg/L)		Copper (mg/L)		Iron (mg/L)		Potassium (mg/L)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
1			0.0166	0.1	0.0162	19.093	17.1042	0.05	0.0346	0.05	0.05	0.2	0.5833	0.5558
2	0.05		0.01	0.1	0.01	9.291	11.9723	0.1454	0.1163	0.05	0.05	0.2	0.8393	0.9205
3	not-tested	0.1	not-tested		not-tested	not-tested	36.3294	not-tested	0.025	not-tested	not-tested	0.2498	not-tested	1.8484
4	0.05	0.1	0.0287	0.1	0.0136	11.908	11.0115	0.05	0.025	0.05	0.05	0.2	0.6785	0.6882
5	0.05	0.1	0.0110	0.1	0.01	11.706	14.6530	0.05	0.1783	0.05	0.05	0.2	0.5	0.2523
6	0.05	0.1	0.0454	0.1	0.0144	16.131	16.1514	0.05	0.0460	0.05	0.05	0.2	0.5	0.4593
7	0.05	0.1	0.01	0.1	0.01	10.089	10.8840	0.05	0.025	0.05	0.05	0.2	0.6950	0.7292
8	0.05	0.1	0.0116	0.1	0.01	10.246	13.5828	0.0857	0.025	0.05	0.05	0.2	0.5	0.8107
9	0.05	0.1	0.01	0.1	0.01	16.956	18.1892	1.3882	0.5348	0.05	0.05	0.2	0.5	0.2657
10	0.05	0.1	0.0352	0.1	0.01	14.902	15.7194	0.05	0.025	0.05	0.05	0.2	0.6754	0.7360
11	0.05	0.1	0.0576	0.1	0.0234	15.603	13.4970	0.05	0.025	0.05	0.05	0.2	0.8394	0.6773
12	0.05	0.1	0.0399	0.1	0.0146	11.651	14.7344	0.05	0.0664	0.05	0.05	0.2	0.5	0.4611
14	0.05	0.1	0.0110	0.1	0.01	5.685	10.3113	0.0641	0.0447	0.0542	0.0542	0.2	0.5	0.4872
15	0.05	0.1	0.0163	0.1	0.0332	23.838	29.9904	0.05	0.025	0.0894	0.0894	0.2	5.1350	7.1459
16	0.05	0.1	0.0136	0.1	0.0315	15.614	12.7727	0.0914	0.0833	0.05	0.05	0.2	1.7337	1.6744
17	0.05	0.1	0.0195	0.1	0.01	0.128	0.5	0.05	0.025	0.05	0.05	0.2	0.5	0.1389
18	0.05	0.1	0.0147	0.1	0.01	13.858	16.0966	0.05	0.025	0.0518	0.0518	0.2	0.5	0.3784
19	0.05	0.1	0.0119	0.1	0.0162	19.106	22.7780	0.05	0.0724	0.05	0.05	0.2	0.5	0.3403
20	0.05	0.1	0.0116	0.1	0.01	11.686	13.4597	0.1841	0.1698	0.05	0.05	0.2	0.5	0.2917
21	0.05	0.1	0.0175	0.1	0.01	17.148	17.0423	0.0534	0.0376	2.1748	0.5840	0.5	0.5	0.3010
22	not-tested	0.1	not-tested	0.1	not-tested	not-tested	15.9074	not-tested	0.0546	not-tested	not-tested	0.2	not-tested	0.2568
23	0.05	0.1	0.0103	0.1	0.0116	11.957	12.5883	0.05	0.0635	0.05	0.05	0.2	0.5	0.2939
24	0.05	0.1	0.0171	0.1	0.0131	15.549	15.4982	0.0982	0.1254	0.05	0.05	0.2	0.5884	0.6212
25	0.05	0.1	0.01	0.1	0.0167	20.370	21.2070	0.05	0.025	0.3204	0.3204	0.2	0.6150	0.6186
26	0.05	0.465058	0.4436	0.1	0.0393	200.195	183.7600	0.1724	0.0565	0.8440	0.8440	0.4150	16.8919	18.7202
27	0.05	0.1	0.0223	0.1	0.01	7.913	11.2363	0.05	0.025	0.05	0.05	0.2	0.5	0.5484
28	0.05	0.1	0.0173	0.1	0.01	9.395	15.3154	0.05	0.025	0.1104	0.1104	0.2	0.5223	0.6506
29	0.05	0.1	0.0473	0.1	0.01	8.138	7.8171	0.2475	0.025	0.0868	0.0868	0.2	0.5	0.4159
30	not-tested	0.1	not-tested	0.1	not-tested	not-tested	7.9970	not-tested	0.025	not-tested	not-tested	0.2	not-tested	1.4119
31	0.05	0.1	0.0672	0.1	0.01	10.083	9.3580	0.0603	0.1195	0.0904	0.0904	0.2	0.7336	0.7010
32	0.05	0.1	0.0358	0.1	0.01	4.992	4.3738	0.1045	0.1429	0.05	0.05	0.2	0.5	0.1953
33	0.05	0.1	0.01	0.1	0.01	6.395	5.9797	0.05	0.025	0.05	0.05	0.2	0.5	0.2182
34	0.05	0.1	0.0212	0.1	0.01	4.724	6.3959	0.1457	0.1879	0.05	0.05	0.2	0.5	0.1
35	0.05	0.1	0.1746	0.1	0.01	6.121	4.8655	0.05	0.025	0.1461	0.1461	0.2423	0.5030	0.4120
36	0.05	0.1	0.1562	0.1	0.01	17.389	17.3370	0.05	0.025	0.05	0.05	0.2	0.6812	0.7050
37	0.05	0.1	0.0200	0.1	0.01	17.313	15.7640	0.05	0.0779	0.05	0.05	0.2	1.1136	1.0907
38	0.05	3.70366	3.3658	0.1	0.01	1.585	1.9144	0.05	0.025	0.05	0.05	0.2	0.8857	0.2569
39	0.05	0.1	0.0160	0.1	0.01	6.512	6.2763	0.05	0.025	0.05	0.05	0.2	1.8521	1.9902

Well Number	Aluminium (mg/L)		Boron (mg/L)		Barium (mg/L)		Calcium (mg/L)		Copper (mg/L)		Iron (mg/L)		Potassium (mg/L)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
40	0.05	0.1598	0.138485	0.01	15.245	14.1860	0.05	0.025	0.05	0.025	0.05	0.2	3.9491	3.9920
41	0.05	0.0769	0.1	0.01	15.270	15.9458	0.05	0.025	0.05	0.025	0.05	0.2	1.8242	1.9746
42	0.05	0.0814	0.1	0.0334	47.475	54.3970	0.05	0.025	0.05	0.025	0.05	0.2	4.6105	5.0650
43	0.05	0.01	0.1	0.0520	6.852	7.5518	0.05	0.1073	0.05	0.1073	0.05	0.2	0.5	4.5708
44	0.05	0.01	0.1	0.01	5.201	6.3886	0.05	0.2044	0.05	0.2044	0.2932	0.2	0.5	0.3199
45	0.05	0.0141	0.1	0.0106	43.811	51.0559	0.05	0.0322	0.05	0.0322	0.05	0.2	2.8193	3.0026
46	0.05	0.0122	0.1	0.01	10.330	11.6396	0.05	0.025	0.05	0.025	0.05	0.2	0.6394	0.6626
47	0.05	0.0130	0.1	0.01	12.814	14.7258	0.05	0.025	0.05	0.025	0.05	0.2	0.8778	0.9047
48	0.05	0.01	0.1	0.01	1.925	4.1960	0.05	0.025	0.05	0.025	0.05	0.2	0.5	0.1
49	not-tested	not-tested	0.1	not-tested	not-tested	14.5965	not-tested	0.1973	not-tested	0.1973	not-tested	0.2	not-tested	0.6164
50	0.05	0.0127	0.1	0.01	14.154	16.1469	0.05	0.025	0.05	0.025	0.05	0.2	0.9619	1.0117
51	0.05	0.0141	0.1	0.01	11.800	13.3432	0.05	0.025	0.05	0.025	0.05	0.2	0.9692	1.0393
52	0.05	0.01	0.1	0.01	4.205	4.9109	0.05	0.025	0.05	0.025	0.05	0.2	0.5	0.2929
53	0.05	0.01	0.1	0.01	19.014	24.3708	0.1347	0.7079	0.05	0.025	0.05	0.2	1.0845	1.6042
54	0.05	0.0216	0.1	0.01	14.082	15.9518	0.05	0.025	0.05	0.025	0.05	0.2	1.7859	1.8461
55	0.05	0.0164	0.1	0.01	14.008	15.6697	0.05	0.025	0.05	0.025	0.05	0.2	1.5841	1.7226
56	0.05	0.0679	0.1	0.01	7.660	7.8715	0.05	0.025	0.05	0.025	0.1089	0.6064	2.1359	0.3399
57	0.05	0.01	0.1	0.01	5.414	6.0102	0.05	0.0295	0.05	0.0295	0.05	0.2	0.5	0.2661
58	0.05	0.01	0.1	0.0142	14.017	21.2033	0.3918	0.2528	0.05	0.025	0.05	0.2	0.5	0.4579
59	0.05	0.0147	0.1	0.01	5.570	7.3684	0.0658	0.0512	0.05	0.0512	0.05	0.2	0.5	0.3602
60	0.05	0.01	0.1	0.01	4.638	6.1033	0.05	0.025	0.05	0.025	0.05	0.2	0.5	0.3480
61	0.05	0.01	0.1	0.01	3.526	4.1468	0.05	0.025	0.05	0.025	0.4268	0.4548	0.5	0.3679
62	0.05651	0.01	0.1	0.01	1.050	1.4244	0.05	0.0400	0.05	0.0400	0.05	0.2	0.5	0.5
63	0.05	0.01	0.1	0.01	6.561	6.7867	0.05	0.0267	0.05	0.0267	0.4773	0.5360	0.5	0.2395
64	0.05	0.01	0.1	0.01	4.934	5.6863	0.05	0.0615	0.05	0.0615	0.2921	0.2	0.5	0.3514
65	0.05	0.0113	0.1	0.01	3.663	3.7710	0.05	0.025	0.05	0.025	0.05	0.2	0.5	0.1948
66	0.05	0.0150	0.1	0.01	3.348	5.5673	0.0590	0.0571	0.05	0.0571	0.05	0.2	0.5	0.1844
67	0.05	0.01	0.1	0.01	4.526	5.1587	0.05	0.0366	0.05	0.0366	0.05	0.2	0.5	0.2462
68	0.05	0.01	0.1	0.01	3.926	5.8868	0.05	0.025	0.05	0.025	0.05	0.2	0.5	0.2237
69	0.05	0.01	0.1	0.01	3.610	3.9162	0.1672	0.1505	0.05	0.1505	0.05	0.2	0.5	0.1769
70	0.05	0.0175	0.1	0.01	3.324	3.3131	0.7072	0.5064	0.0927	0.5064	0.0927	0.2	0.5	0.1668
71	0.05	0.0175	0.1	0.01	12.103	13.7597	0.05	0.025	0.05	0.025	0.05	0.2	0.5274	0.5471
73	0.05	0.0101	0.1	0.01	7.144	8.8236	0.05	0.0704	0.05	0.0704	0.1237	0.2	0.5	0.2817
74	0.05	0.0132	0.1	0.01	4.385	5.2274	0.05	0.025	0.05	0.025	0.4570	1.0668	0.5	0.2882
75	0.05	0.0499	0.1	0.01	22.330	26.3532	0.05	0.025	0.05	0.025	1.4696	1.1547	2.3357	2.4835
76	0.05	0.01	0.1	0.01	2.858	6.4499	0.05	0.025	0.05	0.025	0.05	0.2	0.5	0.1711
77	0.05	1.7775	1.97975	0.0145	36.230	40.0727	0.05	0.025	0.05	0.025	0.05	0.2	12.9222	14.0015
79	0.076069	0.0178	0.1	0.0511	12.649	9.9243	0.05	0.0300	0.05	0.0300	0.05	0.2	7.1830	0.9917

Well Number	Magnesium (mg/L)		Manganese (mg/L)		Sodium (mg/L)		Silicon (mg/L)		Strontium (mg/L)		Zinc (mg/L)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
1	10.7010	9.5274	0.005	0.05	3.2136	3.5743	14.5075	14.3982	0.0887	0.081033	0.0101	0.2
2	3.0022	3.7805	0.005	0.05	2.2906	3.0866	12.0199	12.2801	0.0542	0.07386	0.0215	0.2
3	not-tested	9.9937	not-tested	0.7179	not-tested	10.0029	not-tested	14.4809	not-tested	0.13993	not-tested	0.2
4	4.6554	4.2937	0.005	0.05	5.5479	6.2771	12.7045	13.2196	0.0723	0.072058	0.0141	0.2
5	4.8511	5.9489	0.005	0.05	4.2340	5.3603	9.6225	10.3551	0.0662	0.089826	0.0872	0.2
6	6.6671	6.4983	0.005	0.05	9.4758	11.6345	12.1082	12.6103	0.0943	0.101241	0.01	0.2
7	3.3624	3.6368	0.005	0.05	2.3773	3.1194	11.3969	12.1650	0.0469	0.055687	0.0194	0.2
8	4.6079	5.0981	0.005	0.05	3.3689	4.0414	11.0038	11.9996	0.0534	0.077149	0.01	0.2
9	8.6335	9.2778	0.005	0.05	2.8850	3.7459	13.4697	13.9891	0.0777	0.087911	0.0158	0.2
10	6.3147	6.5464	0.0134	0.05	5.4131	6.3213	10.3088	11.3983	0.0818	0.090212	0.01	0.2
11	10.5726	9.1716	0.005	0.05	23.0823	14.5522	19.6757	17.3494	0.0723	0.064566	0.0330	0.2
12	7.4932	9.3259	0.005	0.05	8.7606	10.1263	16.9395	16.8722	0.0518	0.069122	0.0150	0.2
14	3.1341	5.7854	0.005	0.05	1.2475	2.9826	8.9493	10.4187	0.0204	0.044713	0.2196	0.2
15	7.4441	7.9949	0.0449	0.05	1.9625	3.0035	11.2178	11.3980	0.1090	0.14253	0.0346	0.2
16	7.8017	6.7297	0.0522	0.0545	4.1874	3.8484	10.3294	11.0145	0.0966	0.084221	0.01	0.2
17	0.0910	0.025	0.005	0.05	36.4937	46.6409	13.0828	13.6272	0.0020	0.025	0.01	0.2
18	7.6611	8.5972	0.0176	0.05	2.9554	4.2782	12.5846	13.0347	0.0603	0.075895	0.4905	0.338275
19	13.8021	15.6578	0.0051	0.05	3.5097	4.2997	10.3213	11.0675	0.1018	0.120852	0.2156	0.2
20	6.9795	8.0090	0.005	0.05	2.5901	4.1417	11.2936	11.8662	0.0600	0.07534	0.01	0.2
21	8.8362	8.9418	0.0264	0.05	2.8297	3.7897	13.0239	13.9295	0.0843	0.089032	0.0134	0.2
22	not-tested	6.7979	not-tested	0.05	not-tested	7.8417	not-tested	12.4058	not-tested	0.094541	not-tested	0.2
23	5.8112	6.0044	0.0933	0.1127	4.4420	5.7352	10.8850	11.5183	0.0697	0.079431	0.0143	0.2
24	6.0212	5.9887	0.005	0.05	6.2245	7.9919	10.5604	11.2428	0.0968	0.103425	0.0264	0.2
25	18.6850	24.6269	0.2105	0.2613	27.4218	31.8017	19.2160	19.1252	0.0659	0.076082	0.4444	0.398781
26	28.5807	31.3770	0.2655	0.2749	422.1250	497.2510	11.4689	13.1705	0.8019	0.849843	0.0495	0.2
27	1.3035	1.8777	0.005	0.05	2.6648	4.5091	5.4594	6.3378	0.0211	0.036334	0.01	0.2
28	1.5141	2.4744	0.005	0.05	2.7968	4.9589	5.7783	6.6933	0.0271	0.05216	0.0204	0.2
29	0.8762	1.2605	0.005	0.05	2.0867	2.6432	4.7456	5.7635	0.0202	0.026602	0.1097	0.2
30	not-tested	1.5523	not-tested	0.05	not-tested	19.0647	not-tested	7.2114	not-tested	0.033408	not-tested	0.2
31	1.2514	1.1822	0.0123	0.05	5.2623	6.2361	5.4052	5.6134	0.0273	0.029076	0.0196	0.2
32	1.0000	1.0350	0.005	0.05	2.2402	3.9950	4.5173	6.3421	0.0249	0.028353	0.0336	0.2
33	0.8790	0.8175	0.005	0.05	0.7347	1.6167	6.2175	6.5074	0.0071	0.025	0.01	0.2
34	0.8780	0.9819	0.005	0.05	1.1806	2.4524	4.8868	6.2654	0.0148	0.022959	0.01	0.2
35	1.1101	0.8702	0.0365	0.05	11.8864	11.5021	5.5238	5.3241	0.0181	0.025	1.9534	1.11205
36	3.0979	3.5436	0.005	0.05	3.6480	4.9214	7.4330	8.4885	0.0226	0.027923	0.01	0.2
37	5.7891	5.2520	0.005	0.05	4.3612	5.4344	10.4274	11.1911	0.0497	0.049549	0.01	0.2
38	0.2096	0.3196	0.005	0.05	43.3531	56.0303	11.2124	12.5575	0.0040	0.025	0.01	0.2
39	1.2366	1.1954	0.005	0.05	1.6666	2.4756	6.2636	6.2501	0.0933	0.101195	0.01	0.2

Well Number	Magnesium (mg/L)		Manganese (mg/L)		Sodium (mg/L)		Silicon (mg/L)		Strontium (mg/L)		Zinc (mg/L)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
40	9.5657	8.9196	0.0341	0.05	87.7515	99.5555	7.5473	8.0344	0.0885	0.086167	0.01	0.2
41	3.8655	4.0369	0.0309	0.05	9.4573	11.6736	7.4602	8.1492	0.0437	0.05571	0.5083	0.2
42	14.0783	16.7296	0.0864	0.0981	121.0770	137.6110	7.1866	8.0998	0.2020	0.252677	0.01	0.2
43	1.7975	2.0945	0.005	0.05	2.3528	3.5802	4.2602	4.6386	0.0568	0.077935	0.01	0.2
44	0.7631	0.9452	0.0403	0.05	1.1834	2.3506	5.2632	6.1738	0.0245	0.036387	3.3377	2.83896
45	11.7912	13.8644	0.3521	0.05	6.5273	8.5551	13.6343	14.8776	0.1578	0.192252	0.01	0.2
46	1.9490	2.2836	0.005	0.05	2.2000	3.6628	6.8745	7.6417	0.0243	0.034016	0.01	0.2
47	2.6606	3.1561	0.005	0.05	2.0375	3.4918	6.9664	7.7855	0.0305	0.041484	0.01	0.2
48	0.2784	0.5342	0.005	0.05	0.2500	1.3856	2.3448	3.6827	0.0031	0.025	0.01	0.2
49	not-tested	2.3127	not-tested	0.05	not-tested	4.0541	not-tested	7.3990	not-tested	0.083678	not-tested	0.2
50	2.7400	3.2137	0.0770	0.0865	1.7853	3.1990	6.6774	7.3438	0.0287	0.039374	0.0155	0.2
51	2.6140	3.0476	0.005	0.05	2.2387	3.7751	6.5313	7.1413	0.0254	0.035176	0.01	0.2
52	0.5486	0.6375	0.005	0.05	0.2500	1.4083	3.6356	4.0209	0.0072	0.025	0.01	0.2
53	4.4700	6.6693	0.005	0.05	4.1536	6.3076	9.7111	11.5429	0.1050	0.122516	0.0564	0.2
54	3.7018	4.3504	0.0261	0.05	11.5674	14.2297	7.0370	7.8952	0.0428	0.055521	0.01	0.2
55	2.9806	3.4197	0.0104	0.05	8.0421	10.5919	7.1566	7.9401	0.0409	0.054282	0.01	0.2
56	1.8638	1.1475	0.005	0.05	27.4045	2.8069	8.2714	6.5540	0.0300	0.030115	0.01	0.2
57	0.7477	0.8316	0.005	0.05	0.8704	1.9826	4.9096	5.2875	0.0170	0.025	0.01	0.2
58	1.7734	2.1907	0.0052	0.05	2.9163	4.9317	4.8443	6.9851	0.0675	0.093318	0.0530	0.2
59	0.8898	1.1555	0.005	0.05	0.8845	2.1478	4.2477	4.8319	0.0149	0.02587	0.01	0.2
60	0.5610	0.7397	0.005	0.05	0.5347	1.8458	4.5127	4.9533	0.0138	0.025	0.0106	0.2
61	0.4115	0.4867	0.0374	0.0590	0.5196	1.6390	3.4325	3.6169	0.0103	0.025	2.8968	6.67657
62	0.1999	0.2596	0.005	0.05	0.2500	1.2005	1.8131	2.5166	0.0020	0.008875	0.01	0.2
63	0.8594	1.0766	0.0236	0.05	0.8763	1.9866	5.0962	5.3070	0.0214	0.027396	0.01	0.2
64	0.7178	0.8216	0.0070	0.05	1.1379	2.4220	4.3923	4.9558	0.0242	0.033062	0.01	0.2
65	0.4131	0.4215	0.005	0.05	0.2500	1.1970	3.0906	3.0968	0.0102	0.025	0.0326	0.2
66	0.3264	0.5111	0.005	0.05	0.2500	1.4030	3.1906	4.0141	0.0084	0.025	0.01	0.2
67	0.5093	0.6450	0.0056	0.05	0.4806	1.7171	4.1248	4.6310	0.0128	0.025	0.01	0.2
68	0.5032	0.7376	0.0242	0.05	0.3031	1.7519	3.9093	4.6537	0.0096	0.020338	0.01	0.2
69	0.4797	0.5205	0.005	0.05	0.2500	1.2997	3.8163	3.9238	0.0074	0.025	0.0140	0.2
70	0.3230	0.3268	0.0167	0.05	0.2500	0.05	2.7531	2.7981	0.0078	0.025	0.01	0.2
71	0.5986	0.6922	0.005	0.05	11.2957	14.9502	4.8639	5.2806	0.0226	0.031754	0.01	0.2
73	1.0760	1.3199	0.1230	0.1565	1.1135	2.4491	4.5683	5.0036	0.0217	0.034213	0.01	0.2
74	0.3646	0.4763	0.0091	0.05	0.4577	2.0862	3.4708	3.9991	0.0133	0.025	0.01	0.2
75	6.7611	7.8843	0.1863	0.2135	12.1038	16.0526	11.0286	12.0970	0.0739	0.095122	0.01	0.2
76	0.3106	0.4279	0.3106	0.05	0.5793	2.4530	4.4645	6.2247	0.0149	0.030519	0.1472	0.2
77	21.8342	25.7771	0.0692	0.05	573.9310	588.9150	7.0721	8.2643	0.2805	0.338554	0.01	0.2
79	2.7572	1.6204	0.005	0.05	2.0155	5.1068	5.8601	6.3053	0.0376	0.036044	0.01	0.2

Well Number	50 m Buffer			100 m Buffer			200 m Buffer			Drainage Code	Texture code	Geology Code	Surficial Texture	Parent Material			
	% For	% Rur	% Ag	% Urb	% For	% Rur	% Ag	% Urb	% For						% Rur	% Ag	% Urb
1	0.0	80.3	4.5	0.0	0.0	55.1	12.2	0.0	0.0	31.5	14.3	0.0	4	3	1	3	4
2	26.2	0.0	73.8	0.0	43.0	0.0	40.0	0.0	32.7	0.0	30.3	0.0	4	3	1	3	4
3	0.0	0.0	0.0	59.5	2.1	0.0	0.0	46.0	1.5	0.0	0.0	43.3	4	3	1	3	4
4	0.0	48.4	39.9	0.0	0.0	27.7	43.1	0.0	0.0	17.2	37.6	3.9	4	3	1	3	4
5	0.0	1.9	17.0	151.5	0.0	6.2	17.2	75.6	0.0	20.2	23.2	34.8	4	3	1	3	4
6	0.0	5.2	0.0	94.8	0.0	13.7	10.4	69.7	0.0	16.7	17.9	35.9	4	3	1	3	4
7	0.0	58.2	0.0	22.8	0.0	17.4	0.0	49.0	1.5	8.0	3.8	45.3	4	3	1	3	4
8	0.0	0.0	26.1	67.3	0.0	5.1	44.7	44.2	7.8	21.5	34.3	32.8	4	3	1	3	4
9	73.4	0.0	10.6	0.0	47.4	0.0	19.9	0.0	20.9	9.0	28.8	0.0	4	3	1	3	4
10	0.0	1.9	17.0	9.6	16.1	11.0	21.7	50.8	13.0	12.8	36.1	36.1	4	3	1	3	4
11	0.0	7.5	0.0	49.0	0.0	18.5	0.0	34.0	4.7	13.9	2.5	28.5	5	5	1	3	4
12	0.0	5.4	0.0	69.7	2.2	21.8	0.0	38.2	8.2	13.4	7.4	26.7	5	5	1	3	4
14	0.0	51.8	37.4	0.0	0.0	21.0	71.4	0.0	0.0	6.6	88.9	0.0	4	3	1	3	4
15	0.0	59.2	0.0	0.0	0.0	20.7	32.0	0.0	0.0	7.7	47.9	0.0	1	1	1	3	5
16	0.0	60.3	39.7	0.0	0.0	31.4	63.7	0.0	0.0	0.0	83.4	12.1	4	3	1	3	4
17	0.0	58.1	31.7	0.0	0.0	22.6	45.7	0.0	4.5	8.8	41.8	0.0	4	3	1	3	4
18	0.0	0.0	94.0	0.0	0.0	0.0	95.2	0.0	0.0	9.5	85.5	0.0	4	3	1	3	4
19	0.0	93.7	4.0	0.0	0.0	49.3	28.0	0.0	0.0	0.0	0.0	0.0	4	3	1	3	4
20	0.0	67.0	33.0	0.0	0.0	19.7	74.9	0.0	1.7	14.2	65.7	0.9	1	2	1	3	4
21	0.0	60.9	39.1	0.0	0.0	24.1	74.5	0.0	0.0	12.7	74.6	5.1	1	2	1	3	4
22	0.0	0.0	14.5	76.4	3.2	0.0	34.6	56.3	6.8	9.5	48.2	15.1	1	2	1	3	4
23	0.0	95.9	0.0	0.0	0.0	51.0	25.2	0.0	0.0	19.8	60.9	0.0	4	3	1	3	4
24	0.0	45.5	54.5	0.0	0.0	21.4	78.6	0.0	0.0	12.5	69.9	0.0	1	2	1	3	4
25	0.0	71.7	0.0	0.0	0.0	33.8	14.1	0.0	0.0	21.2	41.4	0.0	1	2	1	3	4
26	0.0	29.7	45.0	0.0	0.0	20.6	65.3	0.0	0.0	22.4	68.7	0.0	1	3	1	3	6
27	0.0	45.0	42.4	0.0	0.2	47.5	43.5	0.0	13.2	25.7	56.6	0.0	2	2	5	1	6
28	0.0	68.3	21.2	0.0	1.4	47.5	30.5	0.0	16.4	19.8	49.0	0.0	2	3	5	4	6
29	65.7	0.0	1.4	0.0	63.4	0.0	7.6	0.0	51.2	0.1	26.5	0.0	5	5	5	4	5
30	0.0	86.0	2.0	0.0	0.0	74.3	17.0	0.0	1.3	63.9	30.4	0.0	5	5	5	4	5
31	0.0	99.9	0.0	0.0	0.4	76.1	14.7	0.0	7.2	50.9	30.0	1.8	5	5	5	4	5
32	100.0	0.0	0.0	0.0	76.1	4.8	12.6	0.0	58.0	12.4	25.7	0.0	3	2	2	2	1
33	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	91.5	0.0	8.4	0.0	5	5	3	5	5
34	5.0	82.7	12.3	0.0	24.5	64.1	11.4	0.0	33.6	46.6	16.3	0.0	2	3	2	2	6
35	0.0	0.0	100.0	0.0	1.1	8.0	86.7	0.0	18.8	20.9	53.4	0.0	5	5	5	4	5
36	57.0	43.0	0.0	0.0	41.3	58.7	0.0	0.0	53.1	45.8	0.0	0.0	5	3	4	4	7
37	1.6	98.4	0.0	0.0	32.8	67.2	0.0	0.0	65.4	33.8	0.0	0.0	5	3	4	4	7
38	56.2	40.6	0.0	0.0	42.5	51.8	0.0	0.0	42.9	52.9	0.0	0.0	4	3	4	3	3
39	0.1	99.9	0.0	0.0	37.7	62.3	0.0	0.0	46.2	52.0	0.0	0.0	4	3	4	4	3