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PHE Report:
Water System Assessment

Site of Inspection:	Stewart Community Water System (CWS)
Date of Inspection:	9 Jul 2012
Report Sent to:	Maureen Tarrant, Chief Administrative Officer; cao@districtofstewart.ca Chad McKay, Director of Public Works; operations@districtofstewart.com
Report Copied to:	Azreer Gill, EHO; Shane Wadden EHO
Report Prepared by:	Dave Tamblyn, PHE
Date of Report:	17 February 2015

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Recommendations

The following recommendations flow from the water system assessment documented in the present report. These are not regulatory requirements, unless encoded as conditions in a permit or incorporated into an order issued by a drinking water officer. They are intended to promote the provision of safe drinking water for human consumption and domestic purposes by the owner, District of Stewart, to the users, people and businesses connected to the community water system.

Component	Recommendation
1. Demand	(a) Investigate why water consumption is so high. (b) Provide detailed water meter records for each well and any summary reports to Northern Health for review. (c) Ensure water service is off and lines are empty at unoccupied properties. (d) Consider hiring a specialist contractor to carry out an acoustic water loss survey. (e) Educate residents about the value of water and best practices for winterising – shut off the main valve on the water line and drain or blow out the interior plumbing if a residence is not going to be heated over the winter months..
2. Source	(a) Submit **Schedule 2** form to Ministry of Environment for all 3 wells. Attempt to locate better documentation on the well sources – original construction logs, any consulting reports or pumping tests – and scan or send copy to Northern Health. (b) Resample all 3 wells for Northern Health list of standard chemical parameters. (c) Review preliminary GUDI/GARP screening evaluations. Correct any misinformation. Report well depth, depth to top of screen, static water level, steady pumping water level, time to reach steady pumping water level, pump discharge. Follow up analyses should include microscopic particulate analysis (MPA) or equivalent.
3. Treatment	(a) If the GUDI/GARP screening is confirmed, and primary disinfection becomes mandatory, then the District should conduct a study on treatment options.
4. Distribution	(a) Review and correct information in the distribution system risk assessment form in Appendix. (b) Please explain why fewer samples were submitted in 2014. (c) Report maximum, minimum, and typical water pressures at various locations (well, high points, low points). (d) Prepare an updated map showing mains, valves, and fire hydrants all together.
5. Storage	(a) Investigate the feasibility of building a reservoir to provide equalisation storage, emergency storage and fire storage.
6. ERP	(a) Investigate making the backup genset for Well 3 operate automatically based on a pressure switch.
7. Reporting	(a) Update the website to make water sampling data available to residents, and to provide contact information in case they have questions.
8. Planning	(a) Assess the need for primary and secondary disinfection as a top priority, followed by assessing the feasibility of storage.

Introduction

Stewart BC is a small town on the west coast, 180 km north of Prince Rupert. Travel time is 3 hours from the Junction of Hwy 16 (Yellowhead) and Hwy 37 (Dease Lake) near Kitwanga, east of Terrace. The community water system (CWS) is owned and operated by the District of Stewart. It serves potable water to 270 active connections (650 total) (DoS, 2014). The population served averages about 520, with a peak of 1000 in the summer and a low of 300 in the winter. (The townsite was built for a population of 4000.) The CWS is classified as WS1A (301 to 10,000 connections) under the BC *Drinking Water Protection Act*, though it must be one of the smallest WS1As in all the province. It could be lowered to a WS2, if requested.

The CWS was last inspected by a public health engineer (PHE) by Michael Wu in Aug 2005. The present inspection was triggered by an Environmental Health Officer (EHO) request and 5 year inspection frequency for CWSs. The scope of the inspection covers the physical water system, and some operational details, but not management systems. The Chief Administrative Officer is Maureen Tarrant and Director of Public Works is Chad McKay.

Location

Stewart BC is set at the mouth of the Bear River, at the end of the Portland Canal, in a narrow, scenic mountain valley. From the Kitwanga junction on Hwy 16, it is 159 km north on Hwy 37 to Meziadin Junction, then 61 km west along Hwy 37A. The climate in Stewart is mild, considering its latitude of almost 56° N. Stewart has a coastal rainforest climate, with about 1,870 mm annual precipitation, and an average temperature of 6°C (**Figure 3**). Stewart is Canada's most northerly ice-free port.

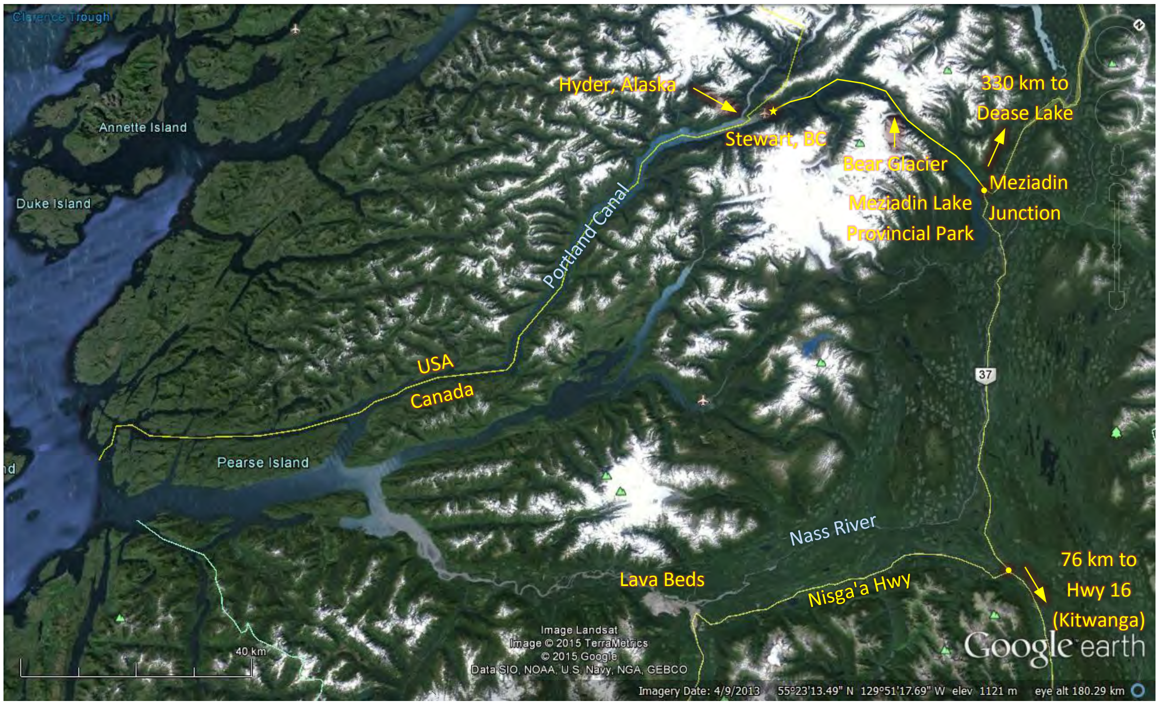


Figure 1. Regional Location.

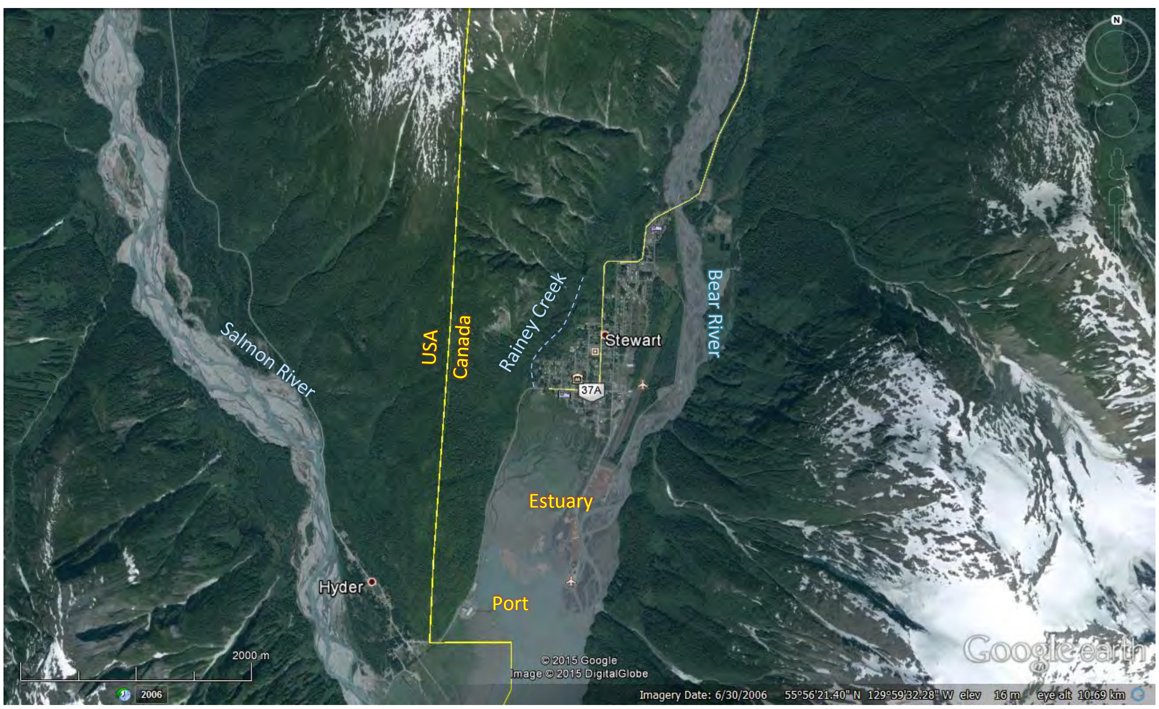


Figure 2. Local Setting.

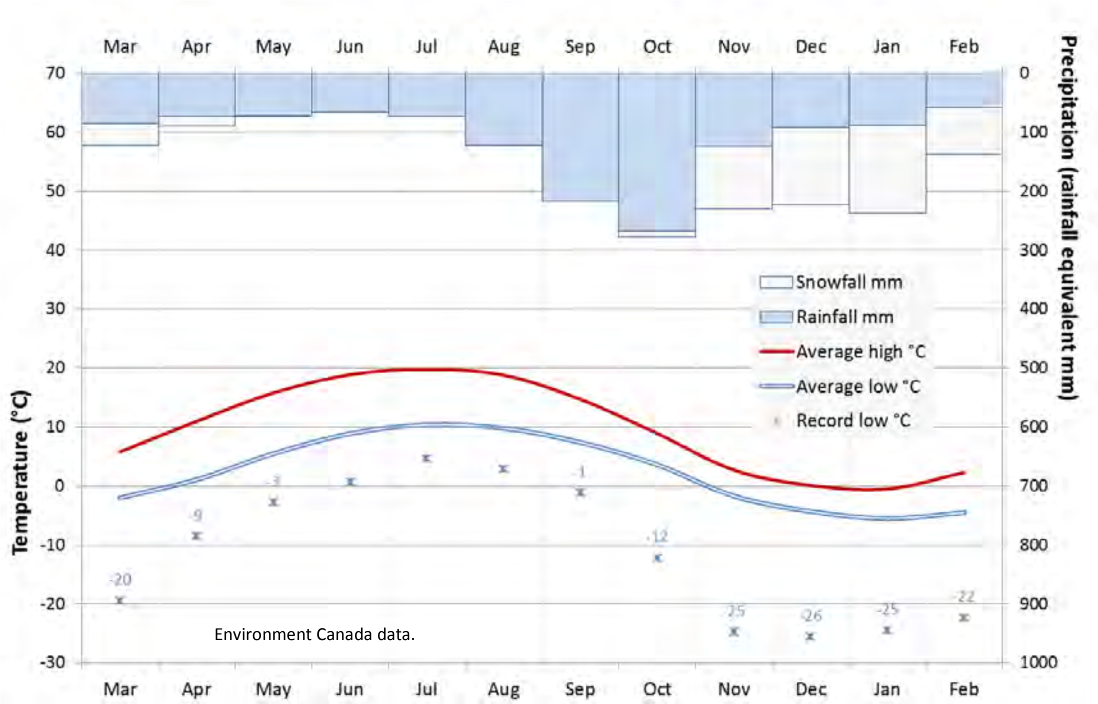


Figure 3. Stewart climate.

Background

The townsite is very flat, falling from an elevation of at the bridge coming into town to 1st Ave beside the airport at an average grade of 0.5%. There is also a high water table throughout much of the town, and some buried infrastructure, including water mains, is submerged some or all of the time. The water system is comprised of 3 independent well sources, each with its own submersible pump, and a distribution system. There is no treatment and no storage reservoirs. The bacteriological sampling history has been excellent. There have been no waterworks construction permits issued in the last decade, as the town is not expanding. There are no major industrial land uses near the wells, and the major municipal contaminant sources near the wells are on the other (east) side of the Bear River (**Figure 5**).

Water demand

There is very little industry in Stewart, so almost all water is for residential use. There is adequate rainfall in summer, and temperatures are cool, so lawn watering isn't as significant as in BC interior communities. Nonetheless, as reported in the last PHE report (Wu, 2005), consumption remains very high. The average demand (production) of 1,377 m^3/d (**Table 1**) for 500 people amounts to 2,754 L/day per person. **Figure 4** compares actual production (average day demand ADD) with the maximum day demand (MDD) from the design guidelines for small water systems published by the Ministry of Forests, Lands and Natural Resource Operations (FLNRO, 2012). I recommend the FLNRO guidelines as the best estimate of maximum day demand (MDD), since they include an up-to-date irrigation model, based on climate zone, lot area and land use, as well as the current AWWA watermain leakage model. Residential demand is based on population served. The FLNRO model is quite generous in its allowances for irrigation (49% of MDD) and leaks (24% of MDD). Water consumption for Stewart should not exceed 500 m^3/d (1000 L/pers/day).

Ordinarily, MDD might be expected to be 2 to 3 times higher than ADD. In the case of Stewart CWS, however, the ADD (1477 m^3/d) is 3 times higher than the MDD *predicted* by the FLNRO guidelines (462 m^3/d) – *about 7.5 times higher than expected*. Badry (1996) reports an even higher MDD (2180 m^3/d), and Watson (2001) reports similar high ADD values (**Figure 4**).

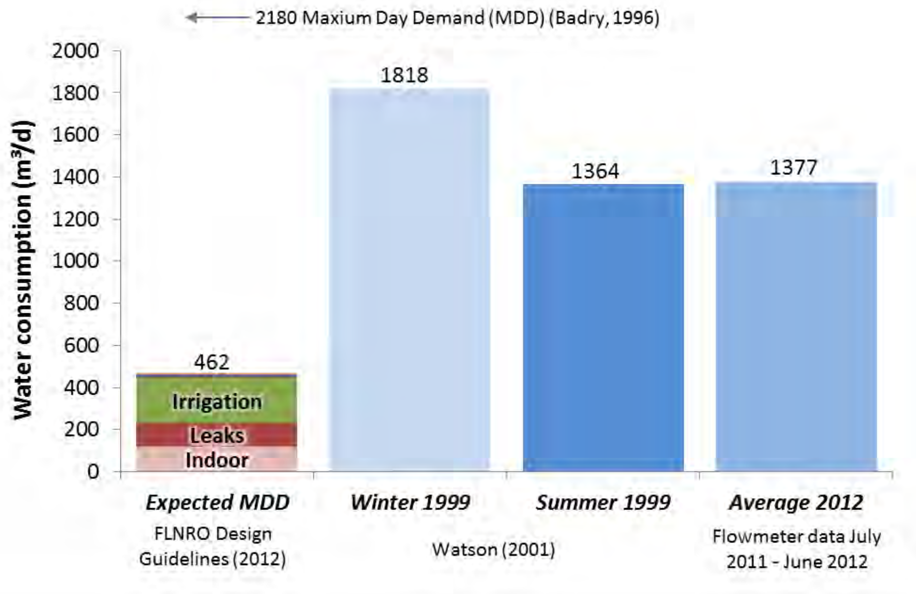


Figure 4. Expected and Actual Water Demand.

Why is Stewart's water consumption 5 to 10 times higher than expected? Anecdotal reports suggest that some residents leave the water running throughout the winter. Residents may not consider water valuable and worth conserving because (i) there are no residential water meters installed, (ii) the District reportedly does not have any specific charge for water, and (iii) it rains frequently (at least 75 mm month). Another possible explanation for the very high water consumption is leaking mains. It is common that municipal water systems will lose 10% to 25% of their product due to leakage and unaccounted water usage (FLNRO includes 24% leakage), but Stewart's losses could be much higher.

Since Well 2 provides almost all the water, any miscalibration in its flowmeter could distort the whole picture of water use, although Watson (2001, 2002) reported similar flows when a different well was lead. ***Investigate why water consumption is so high. Provide detailed water meter records for each well and any summary reports to Northern Health for review. Ensure water service is off and lines are empty at unoccupied properties. Consider hiring a specialist contractor to carry out an acoustic water loss survey. Educate residents about the value of water and best practices for winterising – shut off the main valve on the water line and drain or blow out the interior plumbing if a residence is not going to be heated over the winter months.***

Figure 5. Community Water System Overview.

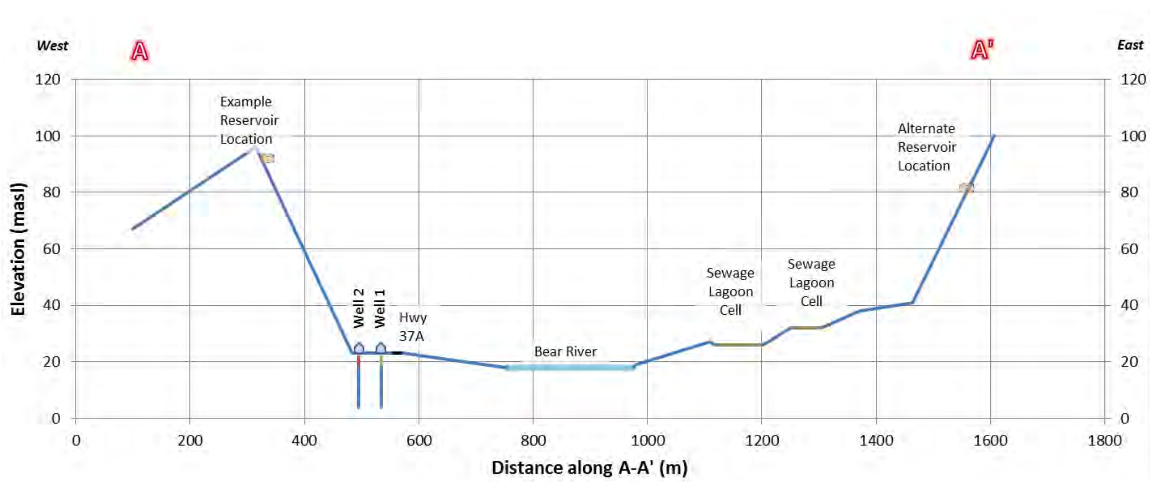
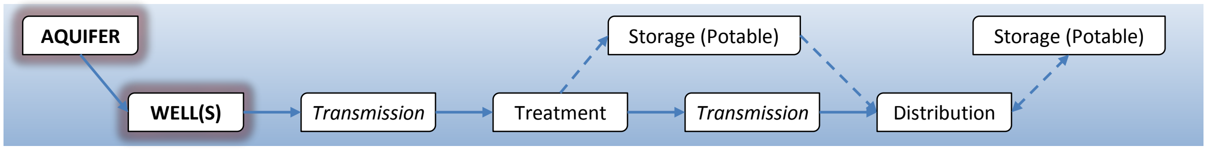


Figure 6. Cross Section along A-A' (approximate)

Water Sources



The source aquifer is shallow, unconfined, and unconsolidated (sand and gravel). This aquifer has not been mapped or classified by the BC Ministry of Environment, but based on my review of the commissioning report (Badry, 1996), I suggest it is:

- highly productive
- highly vulnerable, and
- not restricted by development capacity
  ∴ suggested classification is **IIIA (12).**

I have included an unofficial aquifer classification worksheet in the **Appendix**. Recharge to the wells is expected to be meteoric (precipitation) given the abundant precipitation, granular surface sediments, and cold climate. Areal recharge might be in the range of 20 to 60% of precipitation (In the case of wells 1 and 2, recharge is enhanced by the Bear River to the north, and for well 3, runoff from the rock outcrop (mountain) immediately to the west. Well logs are not available for Wells 1 or 2. Well 3 log is included in the **Appendix**. The commissioning report for Well 3 (Badry, 1996) found that the *aquifer transmissivity* was very high at 3,350 to 29,700 m²/day, and that the *hydraulic conductivity* of the sand and gravel in the aquifer was at least 160 m/d.

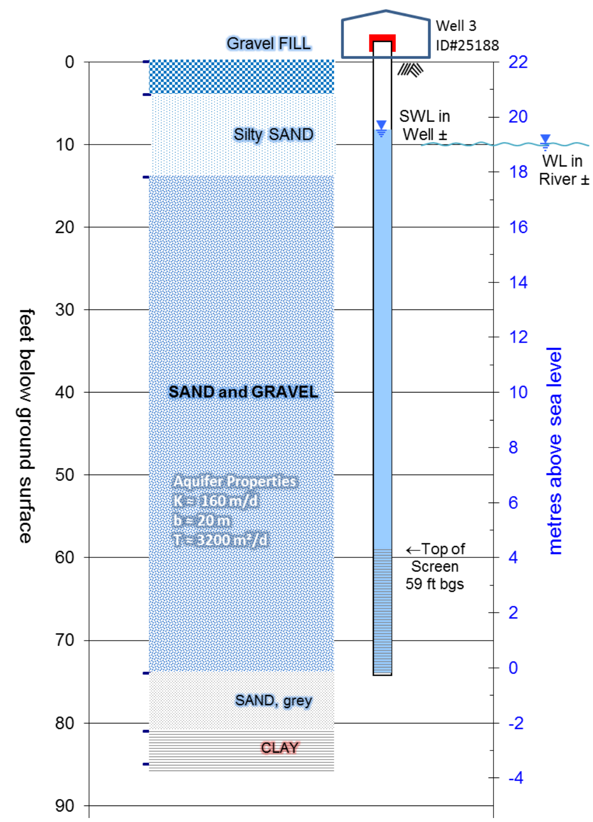


Figure 7. Aquifer Stratigraphy (Badry, 1996)

Well 1

Badry (1996) reported a well capacity of 800 gpm, and *specific capacity* of 920 m²/day for Well 1 (aka *P1*) in 1991, immediately following a rehabilitation, as its yield had declined to only 300 gpm. Well 1 is prone to declining performance over time, which is why it is no longer the lead pump, and which led to drilling Well 3 in 1996. Well 1 is currently throttled back to avoid excessive drawdown. The reported depth of Well 1 is 76 ft, with a 15 ft screen believed to run between 45 and 60 ft bgs.

If the aquifer is approximately *homogeneous* (not varying significantly from place to place), the wellhead protection area (WHPA) proposed by Badry (1996) for Well 3 will be approximately applicable to Well 1. This is shown in grey on **Figure 5** – note that it intersects the river, indicating that the *capture zone* for Well 1 may draw in water from the river. Surface water in all parts of BC contains pathogens dangerous to human health, so the *Drinking Water Protection Act* requires disinfection for all wells that are partially supplied by surface water (aka GUDI).

Well 2

No performance data is available for Well 2 (aka *P2*), but it has not yet been subject to progressive failure like Well 1. Well 2 produces almost 97% of Stewart's water (**Table 1**), despite having the smallest diameter and least pump power. The reported depth of Well 2 is 60 ft bgs, with a 20 ft screen assumed to run from 40 to 60 ft bgs. Again, if the aquifer is approximately *homogeneous*, the WHPA for Well 3 should be approximately applicable to Well 2. As shown in grey on **Figure 5**, it also intersects the river, indicating that the capture zone for Well 2 may draw in some river water, putting it *at risk of containing pathogens*.

Well 3

Badry (1996) reported a very high well capacity, in excess of 1500 gpm, and *specific capacity* of 4200 m^2/day for Well 3 (aka *P3*). She suggested a wellhead protection area (WHPA) of 280m long × 120m wide, as illustrated on **Figure 5**. Although Well 3 is far from the Bear River, there is a small tributary to Rainey Creek about 50 m northwest, so surface water influence (GUDI) cannot be ruled out. Well 3 has excellent documentation (Badry, 1996) including a 24h pumping test and 2h recovery test. The well depth is 74 feet, and the well screen runs from 59 to 74 ft bgs. The estimated hydraulic conductivity of the coarse sand and gravel is at least 160 m/d (**Figure 7**).

Table 1. Water source inventory (2011-12 data)

Source Name	Stewart Well 1	Stewart Well 2	Stewart Well 3
Well ID Plate	#25186	#25187	#25188
Classification	Shallow Well	Shallow Well	Deep Well
Well Depth (m)	19.7	18.3	22.6
Water Depth (m)	2.8	2.8	2.0
Well Diameter (m)	0.3	0.2	0.3
Pump (hp)	50 (throttled)	30	50
Status	Standby (Lag)	Primary (Lead)	Standby
Activation	Pressure switch	Pressure switch	Manual
Backup Power	No	No	Diesel genset
In WELLS Database?	No	No	Maybe
GUDI/GARP screening	probably at risk	possibly at risk	unlikely at risk
Annual Volume (m^3)	14,806 (2.9%)	485,395 (96.6%)	2,357 (0.5%)
Average Day Demand	1,377 m^3/day	(253 gpm)	
Rated Well Capacity	4,360 m^3/d (800 gpm)	4,360? m^3/d (800? gpm)	8,720 m^3/d (1,600 gpm)

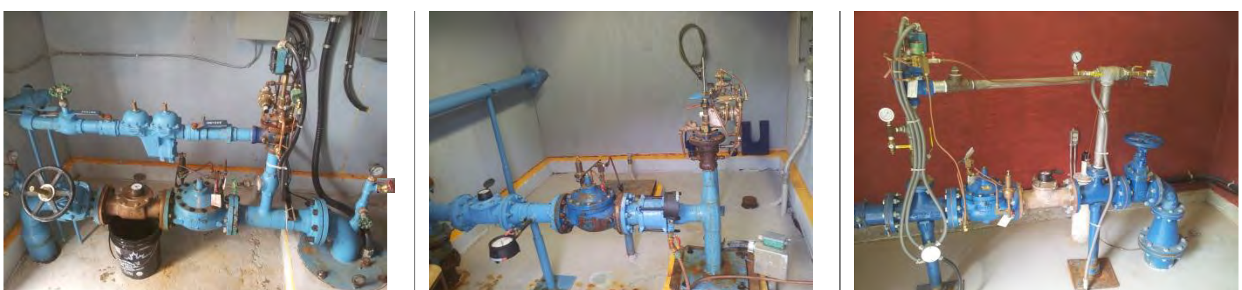
All wells are metered. Production averages about 1400 m^3/d (250 gpm), with Well 2 providing almost 97% by volume. In the past, Well 1 was the lead, and Well 2 was lag.

Operating scheme is lead/lag, with Well 2 as lead, Well 1 as lag, and Well 3 as emergency backup. The well pumps are electric. Only Well 3 has a diesel genset for backup power. Wells 1 and 2 are activated by pressure switch. Pump houses are clean, but equipment is not labelled. Well 2 has an external sampling tap. The well ID plates are on the doors to the pump houses, but the wells are not registered in the WELLS database, which is a legal requirement under the Ground Water Protection Regulation.

Submit Schedule 2 form to Ministry of Environment for all 3 wells*. *If better documentation on the wells 1 and 2 can be found – construction date, soil stratigraphy, original construction logs, any consulting reports – please scan and send a copy to Northern Health.

Figure 8. Wells 1 and 2 at north entrance to Stewart.

Figure 9. Well 3 at the north end of Brightwell St.



Well 1, lag, 50 hp throttled | Well 2, lead, 30 hp | Well 3, backup, 50 hp with genset

Figure 10. Pump house layouts.

Raw Water Quality

The raw water quality in Stewart is excellent. Below, I summarise existing information on bacteriological and physical/chemical water quality.

Bacteriological Parameters

Wells and distribution points are sampled approximately monthly for total coliforms and *E. coli*. Any detectable level of coliforms or *E. coli* is unsatisfactory. **Table 2** presents sampling data on file with Northern Health. Most often, we look at the average rate of unacceptable samples (or the median). It is surprising to most people that a well with no positive samples can nonetheless have a probability of unsatisfactory samples greater than zero. This arises because we are taking samples at discrete points in time, not continuously. Each sampling event is treated as a statistically independent trial, and if the actual rate of unacceptable samples is low (1% to 5%), we shouldn't *expect* to find any detectable coliforms in the first few samples. Thus, the data for wells 1 and 3 are provisional, because the number of samples is low (n<30).

Table 2. Bacteriological sampling results (1997 - 2014)

Sample Location	unsatisfactory / total samples	median	90% Confidence Interval ($p_{5\%}$ … $p_{95\%}$)
Well 1	0 / 7	3 %	(0. % … 23 %)
Well 2	1 / 112	1 %	(0.2 % … 3 %)
Well 3	0 / 6	4 %	(0. % … 26 %)
Distribution	1 / 427	0.3%	(<0.1 % … 1 %)
Overall	**2 / 552**	**0.4%**	(0.1 % … 1 %)

The bacteriological quality of water in the distribution system is discussed later (p15).

Chemical Parameters

The raw water quality from all 3 wells in Stewart appears outstanding. User satisfaction is high, based on few reported complaints.

Figure 11 below plots the *highest* chemical concentrations measured in the 2008 Metals Scan, relative to their guideline[1]. All parameters tested were acceptable (below the guideline), with one exception. The level of manganese in Well 3 (backup) is slightly above the aesthetic objective (AO) set by Health Canada on the basis of black staining and bitter metallic taste. Since this well is currently a backup, for emergency use, the level of manganese poses no concern.

[1] For example, Iron in Well 1 is about 16%. The AO guideline for Iron is 300 µg/L, so 16% is 0.16×300 = 48 µg/L.

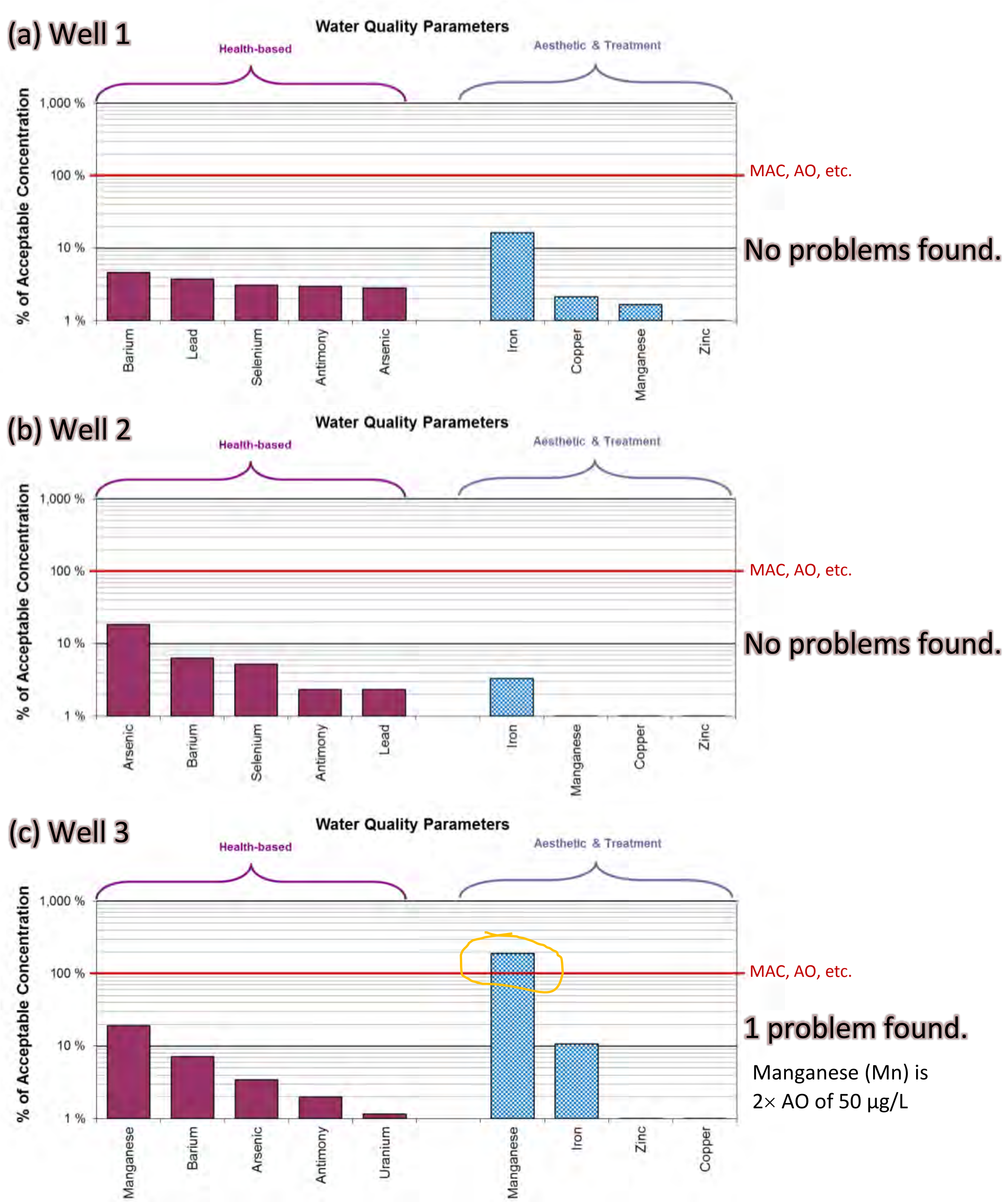


Figure 11. Highest health and aesthetic parameters – (a) Well 1 , (b) Well 2, (c) Well 3

Tables of all 2008 chemical data (metals) are included in the **Appendix**.

Although only 1 problem was found in the Metals Scan Project (2008), many treatment parameters and potential contaminants were not included. **All wells missing:** Alkalinity, Ammonia, Chloride, Colour, Conductivity, Fluoride , Hardness, Langelier Saturation Index, Manganese, Nitrate, Nitrite, Odour, Organic Nitrogen, pH, Phosphorus, Potassium, Sodium, Sulphate, TDS, TOC, Turbidity. These other

parameters are important to any consideration of treatment, and the next chemical sample is overdue.
→ ***Resample all 3 wells for Northern Health list of standard chemical parameters*.**

Groundwater at risk of containing pathogens (GARP)

Under the BC *Drinking Water Protection Act*, all groundwater that is "at risk of containing pathogens" in the opinion of the drinking water officer (Health Authority), must be disinfected. Northern Health is in the process of assessing all groundwater sources on regulated water systems to see if disinfection is indicated. This assessment considers risk factors associated with: (i) aquifer type and setting, (ii) well location, (iii) well construction, and (iv) water quality results. A *Stage 1 screening checklist* is the first step in assessment, and in many cases the only step required. I completed the three screenings myself (separate documents) based on the best (limited) information available, and each should be reviewed and discussed with District of Stewart staff.

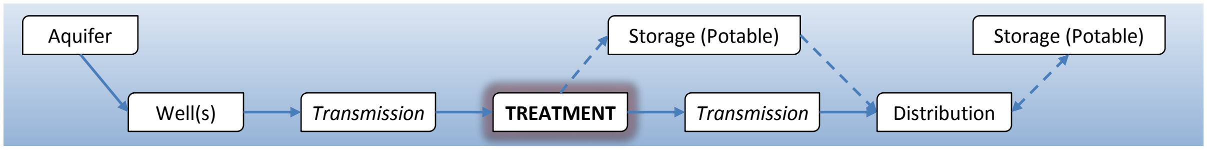
The results of the screening are preliminary, in particular for Wells 1 and 2, because no well construction logs were available to confirm lithology, well intake depth, or static/pumping water level. Initial results suggest:

Well 1: Probably at risk → requires disinfection
Well 2: Possibly at risk → requires disinfection
Well 3: Likely low risk → does not require disinfection.

Given the sparse information for Wells 1 and 2, a more direct measure of surface water influence would be beneficial. The microscopic particulate analysis (MPA) tests the biological make-up of a water source by microscopic examination (bright field and fluorescence). The primary indicators of surface water influence include *protozoa*: *Giardia*, *Coccidia* (*Crypto*); *algae*: diatoms and other, *animals*: insects, larvae, rotifers; and certain plant debris. Secondary indicators include pollen, nematodes (worms), crustacea, amoeba, ciliates/flagellates. Each MPA analysis costs approximately $1000.

Review preliminary GUDI/GARP screening evaluations. Correct any misinformation. Report well depth, depth to top of screen, static water level, steady pumping water level, time required to reach steady pumping water level, pump discharge. Follow up analyses should include microscopic particulate analysis (MPA) or equivalent.

Water Treatment



Water treatment comprises processes such as filtration, disinfection, and conditioning to improve the physical, bacteriological, and chemical water quality of the raw water, making it potable. Potable water is safe to drink and fit for domestic purposes without further treatment.

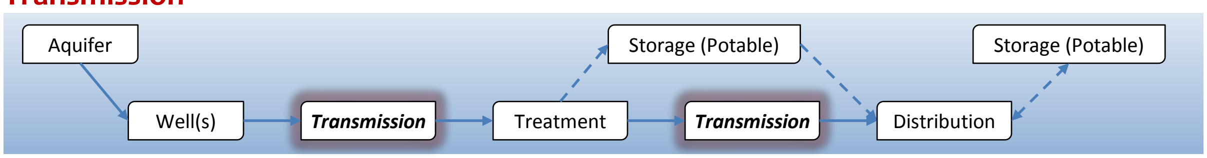
There is no water treatment at present in the Stewart CWS. Northern Health does not have sufficient chemical data on file to assess whether this is appropriate. Regarding bacteriological treatment (filtration, disinfection), our preliminary screening suggests that Wells 1 and 2 may be at risk of containing pathogens. In this case, primary disinfection will be mandatory. Numerous technologies are available to disinfect groundwater at risk of containing pathogens, briefly:

Table 3. Typical Small Municipality Treatment Technologies for Microbiological Treatment of Groundwater.

Technology	Typical Spec	Virus	Bacteria	Cysts	Turbidity
	treatment objective	*4-log ↓*	*8-log ↓*	*3-log ↓*	*1NTU*
granular filtration	50 to 5 micron				✓
microfiltration	0.1 to 1 micron			✓	✓
ultrafiltration	0.01 micron		✓	✓	✓
UV	40 mJ/cm²	✓	✓	✓	
ozonation (high)	48 min·mg/L	✓	✓	✓	
ozonation (low)	1 min·mg/L	✓	✓		
chlorination	12 min·mg/L	✓	✓		

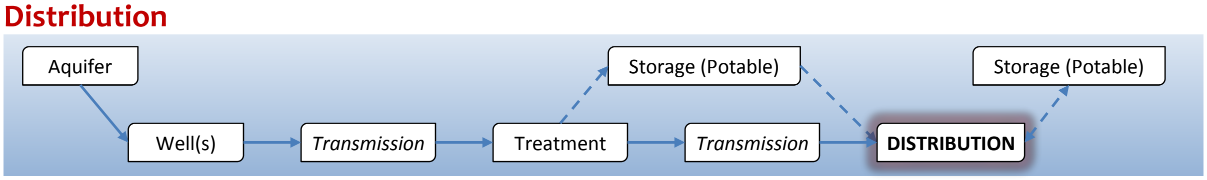
If the GUDI/GARP screening is confirmed, and primary disinfection becomes mandatory, then the District should conduct a study on treatment options. Staged implementation of full treatment is often possible for municipal systems.

Transmission



Transmission refers to conveying water, by pipeline or aqueduct, from the source to the treatment plant, and from the treatment plant to the distribution system. There is essentially no transmission component in the Stewart CWS. Wells pump directly into the distribution system.

Distribution



Distribution is the network of pipes, pumps, and storage facilities used to deliver drinking water to residential and business customers. The Stewart CWS distribution system comprises and unknown length of mains (estimated roughly as approx. 16 km) serving 270 active connections (650 total) and an average population of 520 persons. A map of the distribution system is attached as a separate document. Most mains are only 100mmø, which seems adequate for the existing population, but could be problematic if the town grows. There are also 150mmø and 200mmø mains. Fire hydrants (40) and valves are located throughout the town. Flushing is carried out annually by the Fire Department. There seem to be opportunities for looping to reduce stagnant zones. When the power goes off, pressure is lost until Well 3 can be manually restarted.

The water system dates back to the 1960s, so the age of most mains should be about 50 years old. There are no meters. Industrial use is minimal. There are no check valves (backflow prevention). Mains material unknown – could be DI, PVC, or AC based on age. Watermain repairs are required 3 to 4 times per year. No leak survey has been carried out, so no loss % is available, though there is reason to believe it could be very high. There is currently no residual disinfectant (eg, free chlorine) in the distribution system.

As shown in **Table 2**, bacteriological sampling results in the distribution system are spectacularly good – 1 unsatisfactory out of 427 samples over 19 years. This suggests a crude rate of unsatisfactory samples of 0.3% (90% confidence interval <0.1% to 1.0%) – well below the nominal 2% failure rate contemplated in provincial guidelines. No aesthetic water quality issues have been reported. Operator vigilance is good, but the number of samples submitted has declined recently. System documentation is tolerable, with outdated maps of watermains, hydrants and valves. Source well information is poor.

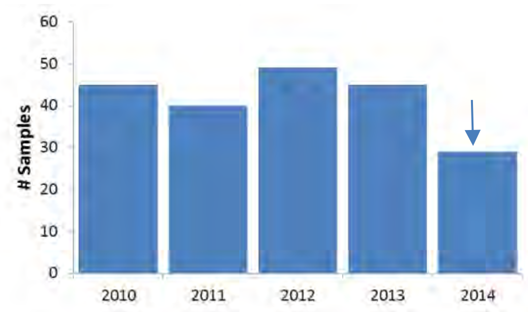
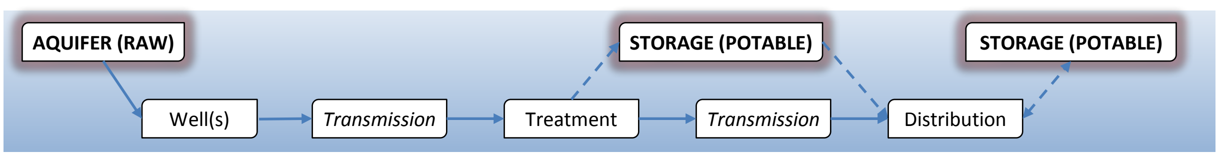


Figure 12. Sample submission statistics.

A *Distribution System Risk Assessment* was completed (**Appendix**), and should be reviewed by the operator. ***Review and correct information in the distribution system risk assessment form in Appendix. Please explain why fewer samples were submitted in 2014. Report maximum, minimum, and typical water pressures at various locations (well, high points, low points). Prepare an updated map showing mains, valves, and fire hydrants all together.***

Storage



Water storage includes raw water stored in open or closed reservoirs, tanks, ponds, or aquifers prior to treatment, as well as treated (potable) water stored in closed containers. Storage is used to equalise supply and demand of water over time, for emergency supply, and for fire flow. Elevated storage also buffers pressure changes in the distribution system.

Raw Storage

The Lower Bear River Aquifer is 20m thick, and covers at least 2.5 km^2 (**Appendix**). The volume of water stored is estimated at 12.5 million m^3. This provides about 25 years storage at current demand. Natural recharge due to precipitation is estimated at 750 mm/year, which is 3.7 × current demand. Raw water storage is therefore more than adequate.

Potable Storage

The Stewart CWS currently provides no potable water storage. This lack of storage is a significant health and fire risk, since the system loses pressure if the power is interrupted, as pointed out in previous PHE reports (Watson 1999-2002, Wu 2005). If a reservoir is built, is should be located up the walls of the valley to provide gravity-fed pressure. The elevation should not exceed approximately 70 m above the water distribution pipes in order to avoid excessive pressures. Example locations for a reservoir are shown on **Figure 6**. The western valley wall either north or south of town may be attractive because it avoids crossing the Bear River. Locating elevated storage at the opposite side of town from the pumping station helps equalise pressures in the distribution system. If a reservoir is contemplated, the FLNRO criteria (**Appendix**) suggest it should be sized for approximately 400 m^3.[2] ***Investigate the feasibility of building a reservoir to provide equalisation storage, emergency storage and fire storage.***

Contingency and Emergency Response Plan

The Contingency and Emergency Response Plan (ERP) for the Stewart CWS was not reviewed for the present report. When I talked with the operator in 2012, we discussed (i) adding a small chlorinator (chemical dosing pump and tank containing sodium hypochlorite bleach) in each pumping station and (ii) adding an onsite bacteriological testing facility, using the enzyme-substrate liquid-broth medium (Colilert). I forwarded a quote (approx. $6-7k + taxes) from a randomly selected Alberta vendor for a Colilert system. Remote-control metering pumps cost about $2000 for pump and carboy; manually adjustable metering pumps cost under $1000. Using 12% NaOCl, the Stewart CWS would need to pump about 1.8 L/h to achieve a 1 ppm concentration at estimated current peak hourly demand.

If a reservoir is not feasible at this time, it may be useful to ***investigate making the backup genset for Well 3 activate automatically based on a pressure switch***. This would prevent the system depressurizing and allowing ambient groundwater to seep in, contaminating the water mains.

Reporting

The *Drinking Water Protection Regulation* requires each water supplier to prepare and make public an annual report of the results of the monitoring. An annual report for 2013 was submitted to Northern Health in May 2014. It was quite sparse, but covered the basics. It is not clear if it was made available to interested residents. The district's website districtofstewart.com did not seem to have any information on public works, including the water system. ***Update the website to make water sampling data available to residents, and to provide contact information in case they have questions.***

Water System Planning

The District should begin planning for upgrades to the water system. It is aging, and may soon require significant capital investment. ***Assess the need for primary and secondary disinfection as a top priority, followed by assessing the feasibility of storage.***

Respectfully submitted,

Public Health Engineer
Prince George
17 February 2015

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[2] Note that Watson (2002) suggested a much smaller reservoir, 18 m^3. This would provide continuity of pressure for 15 to 20 minutes at current usage, barely enough time for a backup well to be put in service.

References

Badry, A. (1996). *Completion Report, District of Stewart, 1996 Water System Upgrade: Installation and Capacity Testing of Well P3-96 Located Northwest of the Intersection of 14th Avenue and Brightwell Street in Stewart, BC.* 10 September 1996. Pacific Hydrology Consultants Ltd. Project Number S727101. 52 p. Available at: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=36842.

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APPENDIX

Design Guidelines for Water Quantity

Table 4. Water Quantity Guidelines

Design Guidelines for Rural Residential Community Water Systems (MFLNRO, 2012)				
Water System:	**Stewart CWS**			
Date:	**16-Feb-2015**			
Number of Connections	Nc	300		
Lot area	LA	528	m²	
mains length	Lm	16	km	
total length of service lines	Lc	6	km	
average system pressure	WP	50	m H2O	
Occupancy Class	OC	single / duplex		
Water Metering?	WM	unmetered		
Personal water consumption	PWC	0.23	m³/d·capita	
Climate Zone	CZ	Northern/Coastal	see map -->	
Green Area (Irrigation)	GA	7.92	ha	
Occupancy Rate	OR	1.75	persons/connection	**
Population	P	525	persons	
Max Day Peaking Factor	PF.1	2.5		
Max Hour Peaking Factor	PF.2	3.8		
Irrigation rate	IR	28	m³/d·ha	
Maximum Day Calculations				
Indoor water consumption	IWC	121	m³/d	26%
Water loss allowance	WLA	108	m³/d	23%	35 % mains
Irrigation demand	ID	222	m³/d	48%	42 % connections
Non-residential	ICI	12	m³/d	3%	22 % service lines
Fire Flow				
Fire Protection?	FP	Yes		
Fire Class	FC	B		
Fire Flow	FF	174	m³/h	
Fire Storage	FS	218	m³	
Water Demand Summary		m³/d	m³/h	USgpm
Average day demand	ADD	185	8	34
Maximum day demand	***MDD***	***462***	***19***	***85***
Peak Hour Demand	PHD	703	29	129
Storage				
Balancing	BS	116	m³	(25% of MDD)
Fire	FS	218	m³	(48 L/s for 1.25 h)
Emergency	ES	83	m³	(25% of BS+FS)
Total Storage Required	***TS***	***417***	***m³***	
Average Residence Time	RT	54	h	=TS/ADD
		2.3	d	

** occupancy is about ½ the provincial standard rate

Well 3 Log

DISTRICT OF STEWART WELL P3-96

Location: Northwest of the intersection of 14th Avenue and Brightwell Street in Stewart, B.C.

Date of installation: June 1996.

Drilling contractor: Interior Water Wells Ltd.

Driller's litholog:

0.0 - 1.2 m (0 - 4 ft)	gravel backfill
1.2 - 5.5 m (4 - 18 ft)	*sand,* silty
5.5 - 8.5 m (18 - 28 ft)	*sand and gravel,* compact
8.5 - 22.6 m (28 - 74 ft)	*sand and gravel,* coarse
22.6 - 24.7 m (74 - 81 ft)	*sand,* grey
24.7 - 26.5 m (81 - 87 ft)	*clay,* grey.

Diameter: 300 mm (12").

Completed well depth: 22.6 m (74 ft).

Well Completion:

District of Stewart Well P3-96 is completed with a 5.5 m (18 ft) long assembly of 300 mm (12") nominal diameter well screen as follows:

at top at 17.1 m (56 ft)	K-type packer
0.6 m (2 ft) of	zero-wind stainless steel screen (riser pipe)
4.6 m (15 ft) of	6.35 mm (0.250") slot screen
at bottom at 22.6 m (74 ft)	bail bottom.

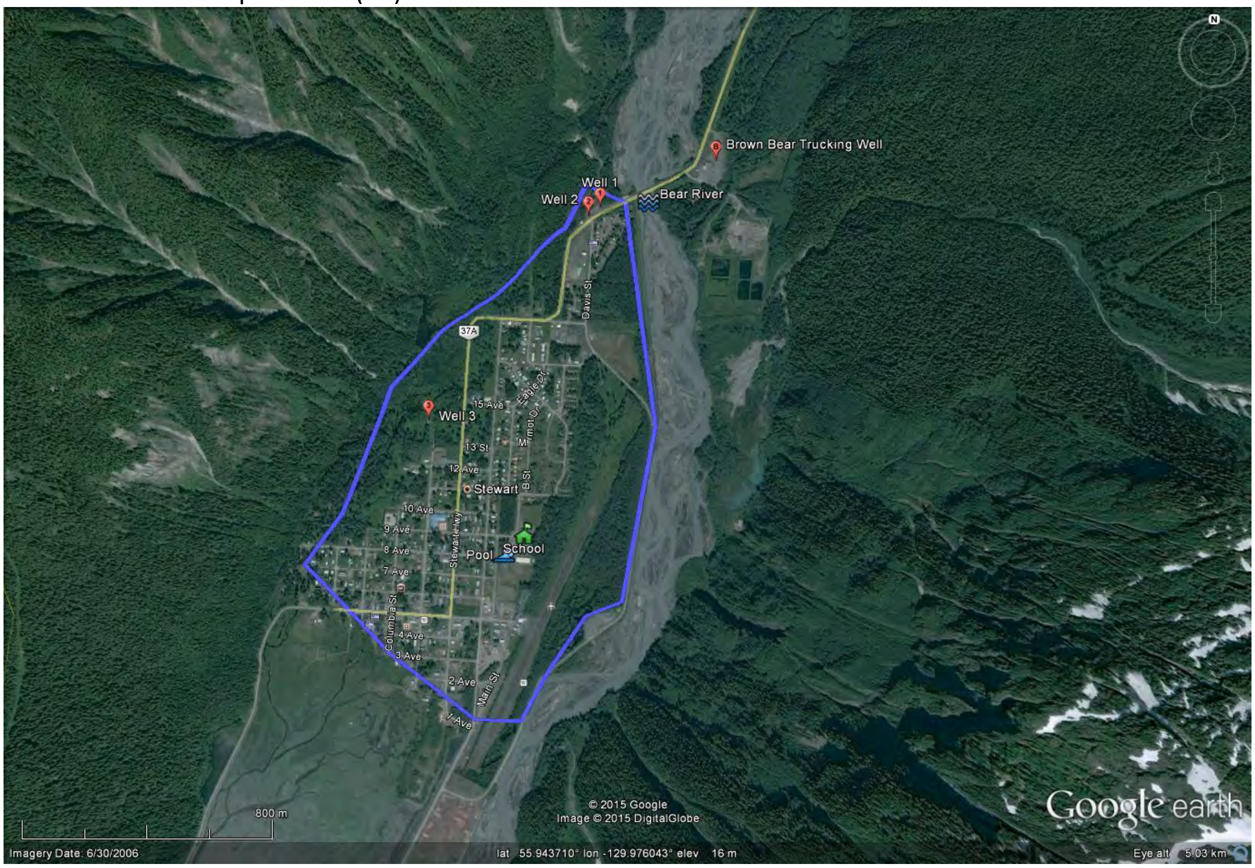
Static water level: 2.79 m (9.15 ft) below the well casing on June 20, 1996 prior to the start of the pumping test.

Well performance: During well capacity testing in June 1996, when pumping at a final constant rate of 65.6 *l*ps (1039 USgpm), maximum drawdown was 1.34 m (4.40 ft), giving a specific capacity of 48.95 *l*ps/m (236 USgpm/ft).

Well capacity: Rated according to standard procedure, the *theoretical* capacity of District of Stewart Well P3-96 is several times the pumping rate of 65.6 *l*ps (1039 USgpm) which utilized only about 9% of the total available drawdown in the well. Future pumping should not exceed 94.65 *l*ps (1500 USgpm) without first testing the well at a higher rate to confirm well performance. The *practical* capacity of Well 3-96 is controlled by the size of pumping that can be installed in a 300 mm diameter well casing.

Aquifer Classification Worksheet

Lower Bear River Aquifer: IIIA(12)



2.2 km N-S × 1.2 km E-W → Area 2.5 km²
thickness ≈ 20 m, porosity 25% (assumed) → Vw = 12.5×10^{6} m³
recharge ≈ 0.4 × 1870 mm/a = 750 mm/a (based only on aquifer area – additional recharge at base of mountains and from Bear River).

3 municipal wells:
Stewart CWS Well 1: 60 ft deep
Stewart CWS Well 2: 60 ft deep
Stewart CWS Well 3: 74 ft deep

0 … 4 ft	GRAVEL BACKFILL
4 … 18 ft	SAND, SILTY
18 … 28 ft	SAND AND GRAVEL, COMPACT
28 … 74 ft	SAND AND GRAVEL, COARSE
74 … 81 ft	SAND, GREY
81 … 87 ft	CLAY, GREY

24h pumping test, 2h recovery → T>3200 m²/d; Q>1500 gpm

Brown Bear Trucking Well

0 ... 18 ft	SAND - OLD WOOD (ROTTEN) gravel
18 ... 45 ft	SAND, SILT gravel
45 ... 60 ft	GRAVEL sand

Aquifer Classification

Development: **III**

Level of Development	Interpretation
Heavy **I**	• Demand for water is high relative to water availability. • Additional development* of this aquifer should be carefully assessed.
Moderate **II**	• Demand is moderate relative to water availability. • Additional development* of this aquifer should be given careful consideration.
Light ***III***	• Demand is light relative to water availability. • Additional development* should not be a problem, provided productivity can meet the demand.

Vulnerability: **A**

Vulnerability	Interpretation
High ***A***	• Highly vulnerable to contamination from surface sources, **a** aquifers have little natural protection against contamination introduced at the ground surface. • Existing land uses or future additional developments, which may introduce a contaminant to the land surface, should initiate measures to protect against introducing contaminants. • **a** aquifers should be given first priority for the implementation of quality protection measures.
Moderate **B**	• Moderately vulnerable to contamination from surface sources, **B** aquifers have limited natural protection against contamination introduced at the ground surface. Degree of natural protection may vary across an aquifer. • Existing land uses or future additional developments, that could introduce a contaminant to the land surface, should initiate measures to protect against introducing contaminants. • **B** aquifers should be given priority over **C** aquifers when it comes to implementing quality protection measures.
Low **C**	• Generally not considered very vulnerable to contamination from surface sources, **C** aquifers are more protected against contamination introduced at the ground surface. • **C** aquifers have the lowest vulnerability rating and are the least likely to become contaminated. • a rating of **C** does not imply that all **C** aquifers are immune to contamination. All aquifers are vulnerable to contamination to a certain degree, especially if there are "windows" exposing the underlying aquifer or if the land-use activity breaks through the overlying confining layer.

	Point Value				
Criteria	**0**	**1**	**2**	**3**	**Rationale**
Productivity	N/A*	<5 gpm	5 - 50 gpm	***> 50 gpm***	abundance of the resource
Vulnerability	N/A	Low: deep, confined	Moderate: semi-confined	***High: shallow, unconfined***	potential for water quality degradation
Aquifer Area	N/A	***< 5 km²***	5–25 km²	> 25 km²	regionality of the resource
Demand for Water	N/A	<4 well/km²	4-20 well/km²	***>20 well/km²***	level of reliance on the resource for supply
Type of Water Use	N/A	non-drinking water	***drinking water***	multiple/ drinking water	variability/diversity of the resource for supply
Quality Concerns	***unknown/none***	isolated	local	regional	actual documented concerns
Quantity Concerns	***unknown/none***	isolated	local	regional	actual documented concerns

Ranking

Productivity: Q > 1000 gpm 3
Vulnerability: unconfined, sand, static water level 9 ft 3
Aquifer Area: 2 km² (likely extends up the valley, but townsite is only 2 km²) 1
Demand for Water: 20 domestic wells/km² × 2.5 persons/well = 50 persons/km²
Stewart: population served = 520 persons / 2 km² = 260 persons/km² >> 50 → high demand........ 3
Type of Water Use: 99% domestic use 2
Quality Concerns: none 0
Quantity Concerns: none 0
Total 12

DRAFT Classification: **IIIA (12)**

Prepared by Dave Tamblyn, PEng.
11 February 2015

References

Badry, A. (1996). *Completion Report, District of Stewart, 1996 Water System Upgrade: Installation and Capacity Testing of Well P3-96 Located Northwest of the Intersection of 14th Avenue and Brightwell Street in Stewart, BC.* 10 September 1996. Pacific Hydrology Consultants Ltd. Project Number S727101. Available at: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=36842.

Berardinucci, J., & Ronneseth, K. (2002). *Guide to using the BC aquifer classification maps for the protection and management of groundwater resources*. Ministry of Water, Land, and Air Protection, Victoria, BC.

GUDI/GARP Screening

The 3 page screening form for each well is available as a separate document. At the time of writing, these have not been finalised because of uncertain information. These can be updated as new information becomes available. All wells are within 150 m of the high water mark of adjacent surface water bodies (Bear River for Wells 1 and 2, and Rainey Creek for Well 3).

As all are in unconfined aquifers, it would be good to have more direct evidence to refute the possibility of surface water influence. An MPA analysis is recommended. These cost about $1000 each, and involve microscopic examination of the filter contents. If undertaken, it would be good to ensure that the well has pumped long enough to potentially draw in surface water. Butler (1990) provides guidance on portion of the aquifer that is contributing 95% of the flow to the pumping well, the inner and outer radii of this ring can be defined as follows:

$$r_{inner} = \sqrt{0.1Tt/S}\ ;\ r_{outer} = \sqrt{14.8Tt/S} \approx 12 \cdot r_{inner} \qquad [1]$$

where:

T = transmissivity, $[L^2/T] \approx 3200\ m^2/d$ (Badry 1996)
S = storativity, dimensionless = S_Y for unconfined aquifer ≈ 0.2
t = duration of pumpage, [T]

We can set r_{inner} = distance from pumping well to surface water, and solve for duration (t) in **[1]**. This yields very long pumping durations, so to compromise, we may set r_{inner} = distance/4, which means r_{outer} = 3 × distance. This results in more manageable pumping durations (**Table 5**).

Table 5. Recommended (minimum) pumping durations prior to sample collection for MPA analysis.

	Well 1	Well 2	Well 3
distance (m)	110	180	40
r_{inner} (m)	28	45	10
r_{outer} (m)	330	540	120
t (days)	0.5	1.3	0.06
***t* (hours)**	**11**	**30**	**2**

That is, sample collection for MPA analysis (or equivalent, GUDI/GARP assessment) after pumping:

- 11 hours for Well 1,
- 30 hours for Well 2, and
- 2 hours for Well 3.

Reference:

Butler, J. J. (1990). The role of pumping tests in site characterization: Some theoretical considerations. *Groundwater*, 28(3), 394-402.

Water Quality

Table 6. Well 1 (2008 Metals Scan data).

Parameter	Units	Result		Guideline	Interpretation
Health Parameters					
Turbidity	NTU	-?-	~	1.	Missing - required
Fluoride	mg/L	-?-		1.5	Missing - required
Nitrate	mg/L	-?-		10.	Missing - required
Nitrite	mg/L	-?-		1.	Missing - required
Antimony	mg/L	0.000 18		*0.006*	ok
Arsenic	mg/L	0.000 28		*0.01*	ok
Barium	mg/L	0.046 5		*1.*	ok
Boron	mg/L	< 0.05		*5.*	ok
Cadmium	mg/L	0.000 007		*0.005*	ok
Chromium	mg/L	< 0.000 1		*0.05*	ok
Lead	mg/L	0.000 374		*0.01*	ok
Manganese	mg/L	0.000 83		*0.5*	ok
Selenium	mg/L	0.000 31		*0.01*	ok
Sodium	mg/L	-?-		*800.*	Missing - required
Uranium	mg/L	0.000 023		*0.02*	ok
Aesthetic Parameters					
Odour	—	-?-		inoffensive	Missing - required field test
Colour	TCU	-?-		15.	Missing - required
Conductivity	µS/cm	-?-	~	800.	Missing - required - see TDS
TDS	mg/L	-?-	~	500.	Missing - required
Chloride	mg/L	-?-		250.	Missing - required
Sulphate	mg/L	-?-		500.	Missing - required
Hardness	mg/L	-?-	~	250.	Missing - required
Calcium	mg/L	18.9	~	*100.*	ok - see Hardness
Magnesium	mg/L	1.27	~	*30.*	ok - see Hardness
Copper	mg/L	0.010 7		*0.5*	ok
Iron	mg/L	0.049		*0.3*	ok
Manganese	mg/L	0.000 83		*0.05*	ok
Phosphorus	mg/L	-?-		0.1	Missing - required
Potassium	mg/L	-?-		400.	Missing - required
Sodium	mg/L	-?-		200.	Missing - required
Zinc	mg/L	0.012		*5.*	ok
Treatment Parameters					
pH	—	-?-		6.5 to 8.5	Core parameter - sample Missing - required.
Alkalinity	mg/L	-?-	~	30 to 500	Core parameter - sample Missing - required.
Langelier Saturation Index	—	-?-		-2 to +2	Missing - required
Ammonia	mg/L	-?-	~	1.5	Missing - required
Organic Nitrogen	mg/L	-?-	~	0.5	Missing - required
TOC	mg/L	-?-		2.5	Missing - required
UVT	—	-?-	~	80%	Optional

Table 7. Well 2 (2008 Metals Scan data).

Parameter	Units	Result		Guideline	Interpretation
Health Parameters					
Turbidity	NTU	-?-	~	1.	Missing - required
Fluoride	mg/L	-?-		1.5	Missing - required
Nitrate	mg/L	-?-		10.	Missing - required
Nitrite	mg/L	-?-		1.	Missing - required
Antimony	mg/L	0.000 14		*0.006*	ok
Arsenic	mg/L	0.001 84		*0.01*	ok
Barium	mg/L	0.063		*1.*	ok
Boron	mg/L	< 0.05		*5.*	ok
Cadmium	mg/L	< 0.000 005		*0.005*	ok
Chromium	mg/L	< 0.000 1		*0.05*	ok
Lead	mg/L	0.000 231		*0.01*	ok
Manganese	mg/L	0.000 22		*0.5*	ok
Selenium	mg/L	0.000 52		*0.01*	ok
Sodium	mg/L	-?-		*800.*	Missing - required
Uranium	mg/L	0.000 056		*0.02*	ok
Aesthetic Parameters					
Odour	—	-?-		inoffensive	Missing - required field test
Colour	TCU	-?-		15.	Missing - required
Conductivity	µS/cm	-?-	~	800.	Missing - required - see TDS
TDS	mg/L	-?-	~	500.	Missing - required
Chloride	mg/L	-?-		250.	Missing - required
Sulphate	mg/L	-?-		500.	Missing - required
Hardness	mg/L	-?-	~	250.	Missing - required
Calcium	mg/L	22.9	~	*100.*	ok - see Hardness
Magnesium	mg/L	1.66	~	*30.*	ok - see Hardness
Copper	mg/L	0.000 45		*0.5*	ok
Iron	mg/L	0.01		*0.3*	ok
Manganese	mg/L	0.000 22		*0.05*	ok
Phosphorus	mg/L	-?-		0.1	Missing - required
Potassium	mg/L	-?-		400.	Missing - required
Sodium	mg/L	-?-		200.	Missing - required
Zinc	mg/L	0.001 2		*5.*	ok
Treatment Parameters					
pH	—	-?-		6.5 to 8.5	Core parameter - sample Missing - required.
Alkalinity	mg/L	-?-	~	30 to 500	Core parameter - sample Missing - required.
Langelier Saturation Index	—	-?-		-2 to +2	Missing - required
Ammonia	mg/L	-?-	~	1.5	Missing - required
Organic Nitrogen	mg/L	-?-	~	0.5	Missing - required
TOC	mg/L	-?-		2.5	Missing - required
UVT	—	-?-	~	80%	Optional

Table 8. Well 3 (2008 Metals Scan data).

Parameter	Units	Result		Guideline	Interpretation
Health Parameters					
Turbidity	NTU	-?-	~	1.	Missing - required
Fluoride	mg/L	-?-		1.5	Missing - required
Nitrate	mg/L	-?-		10.	Missing - required
Nitrite	mg/L	-?-		1.	Missing - required
Antimony	mg/L	0.000 12		*0.006*	ok
Arsenic	mg/L	0.000 34		*0.01*	ok
Barium	mg/L	0.071 4		*1.*	ok
Boron	mg/L	< 0.05		*5.*	ok
Cadmium	mg/L	0.000 047		*0.005*	ok
Chromium	mg/L	< 0.000 1		*0.05*	ok
Lead	mg/L	0.000 053		*0.01*	ok
Manganese	mg/L	0.094 8		*0.5*	ok
Selenium	mg/L	< 0.000 04		*0.01*	ok
Sodium	mg/L	-?-		*800.*	Missing - required
Uranium	mg/L	0.000 231		*0.02*	ok
Aesthetic Parameters					
Odour	—	-?-		inoffensive	Missing - required field test
Colour	TCU	-?-		15.	Missing - required
Conductivity	µS/cm	-?-	~	800.	Missing - required - see TDS
TDS	mg/L	-?-	~	500.	Missing - required
Chloride	mg/L	-?-		250.	Missing - required
Sulphate	mg/L	-?-		500.	Missing - required
Hardness	mg/L	-?-	~	250.	Missing - required
Calcium	mg/L	33.8	~	*100.*	ok - see Hardness
Magnesium	mg/L	3.37	~	*30.*	ok - see Hardness
Copper	mg/L	0.000 23		*0.5*	ok
Iron	mg/L	0.032		*0.3*	ok
Manganese	mg/L	0.094 8		*0.05*	EXCEEDS (2x) aesthetic guideline.
Phosphorus	mg/L	-?-		0.1	Missing - required
Potassium	mg/L	-?-		400.	Missing - required
Sodium	mg/L	-?-		200.	Missing - required
Zinc	mg/L	0.003 8		*5.*	ok
Treatment Parameters					
pH	—	-?-		6.5 to 8.5	Core parameter - sample Missing - required.
Alkalinity	mg/L	-?-	~	30 to 500	Core parameter - sample Missing - required.
Langelier Saturation Index	—	-?-		-2 to +2	Missing - required
Ammonia	mg/L	-?-	~	1.5	Missing - required
Organic Nitrogen	mg/L	-?-	~	0.5	Missing - required
TOC	mg/L	-?-		2.5	Missing - required
UVT	—	-?-	~	80%	Optional

Distribution System Risk Assessment

Table 9. DRAFT Distribution System Risk Assessment.

northern health
the northern way of caring

Distribution System Risk Assessment Tool

Water System Name: Stewart CWS Date: Jan 2015

Data categories		
Monitoring results		
# samples tested for coliforms		552
# adverse results (any detectable total or *E. coli*, overgrown, TNTC)		2
length of sampling history (years)		19
System documentation		
judgement (0 none to 5 complete, up-to-date)*		3
Operator vigilance		
cross-connection control program (Y/N)		n
real-time water quality monitoring – any parameter (Y/N)		n
operator training acceptable (Y/N)		n
% required samples not collected		25% (2014:29;3:45;2:49;1:40;2010:45)
Connections		
average # connections active		270 (650 total)
average population served		520
Length of distribution mains		
length (km) of mains (not service connections)		16
% by length of submerged mains (below water table)		80%
Age of distribution infrastructure		
pipe materials in use (list from most common to least common)	PVC, DI, AC	unknown
median age of watermains (50% older) (years)		50
oldest watermain still in active service (years)		unknown
Hydraulic integrity		
mains pressure tested (Y/N)		y
watermain breaks (# per year)		4
unaccounted water losses (%)		unknown
number of non-secure storage reservoirs		0
Water age		
average age (days) by calculation, modelling or tracer test		1
volume of closed reservoirs (m^3)		0 (340 in mains)
minimum daily demand (eg winter flow) (m^3/d)		90
Water biostability		
source type: groundwater (G), surface water (S), mixed (M)		G
average TOC (mg/L)		unknown
average Phosphorus (ortho or total) (mg/L)		ND