THURSTON COUNTY
WASHINGTON
SINCE 1852

Appendix O

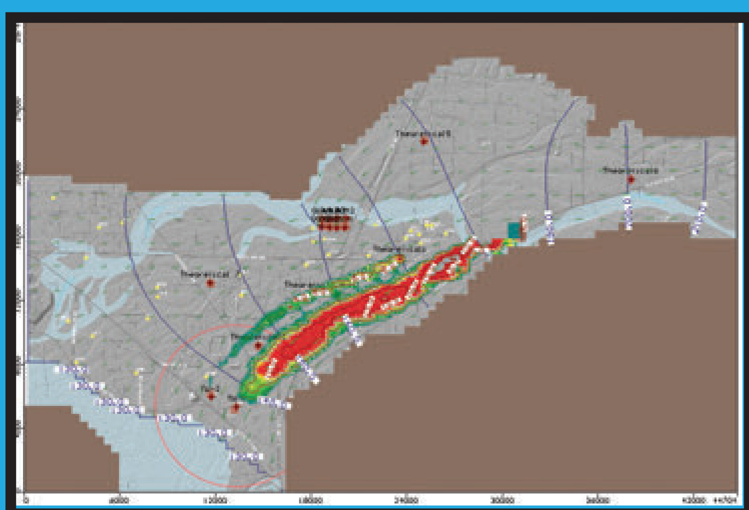
Grand Mound Model Report and Grand Mound Feasibility Report for Future Wells 3 and 4

Scatter Creek Ground Water Numerical Model: Grand Mound Municipal Well Field, Thurston County

Prepared by N. Romero, Hydrogeologist, LHG and LG
B. Zulewski, RS, Geologist

Water Resources and Environmental Health Program, TC

December 29, 2010



FINAL PROVISIONAL REPORT

FOREWORD ON GROUND WATER MODEL EFFORT 2010

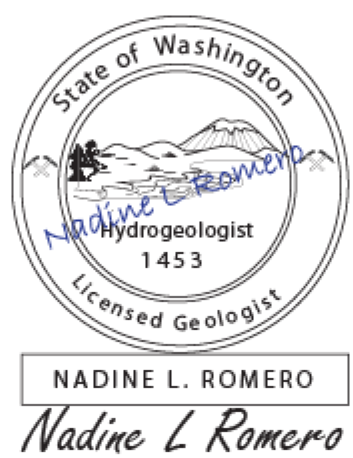
The purpose of this preliminary ground water model is to help provide insight to the hydrogeologist for new well placements at the Grand Mound Municipal Well Field. It was not intended to establish land use practices hydraulically up-gradient of the well field such as septic field impacts, at this point in time. Although some scenarios were simulated using septic there were very few hours spent on the contaminant engines and land use analysis due to a low budget.

The model is only an initial exercise in understanding aquifer behavior and aquifer characteristics. This is only a draft report for agency commentary. Most of the hydrogeologist's time was spent constructing the *physical model* using observed hydraulic heads. Because the numerical model was prepared in under *200 hours* it was not used to numerically model transient conditions or specific land use scenarios such as lot acreage for septic fields, agricultural or fish farming.

We hope to obtain another grant to complete the numerical model and contaminant fate and transport simulations. Nonetheless, despite its *early* construction phase, this ground water model was a very valuable learning exercise towards establishing the physical hydraulic properties of the Scatter Creek Aquifer as a whole. These properties in turn do lead to *potential rapid contaminant movement* and issues of susceptibility of drinking and ecosystem waters to contaminant loads. At the same time, the rapid discharge of the aquifer to the Chehalis River Basin may yield equilibrium conditions which do not exceed health standards due to dilution effects for some areas/land use scenarios. Assessing these equilibrium and transient conditions is the next phase of the modeling effort which we hope will be funded.

Sincerely,

Nadine Romero
Thurston County Hydrogeologist, LHG and LG
State of Washington 1453



MEMORANDUM

DRAFT REPORT

TO: Roger Giebelhaus, Engineering, PW
Scott Lindblom, Engineering, PW

FROM: Nadine Romero, Hydrogeologist, LHG, LG,
Water Resources Program, Resource Stewardship

Brad Zulewski, RS., Geologist,
Solid and Hazard Waste Section, Environmental Health

DATE: December 29, 2010

SUBJECT: Hydrogeologic and Ground Water Monitoring Report
Grand Mound Municipal Well Field

We have completed our preliminary hydrogeologic analysis of the Grand Mound Municipal Well field relocation project. This analysis includes preliminary findings on the Scatter Creek Aquifer hydrogeology and the results of a preliminary ground water modeling effort. We are pleased to provide you with this summary and the results of our contaminant ground water modeling.

PROJECT OVERVIEW

This project was officially started on March 5, 2010 and we were able to stay 'on track' with our initial project scope as well as complete a preliminary 3-D numerical ground water model for the study area. The project scope was to perform a hydrogeologic analysis of the Scatter Creek Aquifer (SCA) including the construction of new geologic cross-sections, analyzing recently collected ground water (nitrate, fecal coliform and other water quality parameters) collected by Thurston County Environmental Health from a 40-domestic well network.

At the mid-point of the project, we held a preliminary findings meeting on June 2, 2010 to go over the results of our research and analysis. After this meeting, we then proceeded into building the actual *conceptual* and *numerical* ground water model in August and September of 2010.

PURPOSE OF THE NUMERICAL GROUND WATER MODEL

The central purpose of constructing both the *conceptual* and *numerical* ground water model is to provide a tool to the hydrogeologist to analyze physical and chemical aquifer steady-state conditions (and transient). In creating an analytical tool to simulate observed and future aquifer conditions, the hydrogeologist can provide more insight into protecting the well field and adding new wells.

Ground water modeling is an important step in any well field analysis because it mimics the ground water system in three-dimensions and incorporates complex interactions into a comprehensive hydrogeologic settting.

Previous to this numerical model exercise, we performed a preliminary analysis of nitrate loads and constructed a very basic *analytical* model to show the rate of contaminant movement using estimated ground water velocities found in the literature (Sinclair and others, 1992). The findings from this current numerical exercise is significant because one can portray potential contaminant plumes and ground water flow directions (predicted ground water elevations) along with velocity vectors at current and future equilibrium conditions. The findings in this numerical model are also important because we can also see 'data gaps' in the ground water monitoring program and areas of unknown contamination hydraulically up-gradient in the flow field of the municipal wells.

Furthermore, the *numerical* modeling process allows us to learn about aquifer response and contaminant behavior in county ground water systems. Land use decisions and policy development in *critical areas* are increasingly reliant on well-developed models because landscape is increasingly more complex.

This numerical ground water model was constructed in approximately 200 hours. This small budget allowed us to simulate only a few land use scenarios and run a few septic calculations. We hope to find additional grant dollars to run other steady-state and transient conditions and explore contaminant engines. This ground water modeling report is in draft form and is intended to provide only a brief narrative of findings.

WORK COMPLETED

To complete this hydrogeologic analysis the following work items were done:

- Queried ground water data from the Environment Health database in March of 2010. This ground water monitoring data was collected from September 2008 thru March of 2010

- Prepared ground water flow maps for the most recent ground water sampling events

- Constructed ground water elevation and well locate tables
- Prepared nitrate concentration maps
- Researched and analyzed 1000 well logs and water rights from the WA Department of Ecology and WA Department of Health database
- Prepared two new geologic cross-sections using the latest well log information
- Calculated hydraulic gradients and ground water flow velocities and directions at high ground water (March) and low ground water (September) conditions
- Reviewed the 1997 Hydrogeologic Report prepared by Pacific Ground Water Group for Municipal Wells TW-1 and TW-2
- Downloaded and analyzed the USGS well data
- Prepared nitrate concentration graphs for the Grand Mound Municipal Well Field and fecal coliform 'presence-absense' tables.
- Conducted field visits on April 15 and September 2, 2010
- Prepared a mid-project presentation of results and findings for Public Works and Environmental Health on June 2, 2010
- Downloaded and analyzed USGS Seepage Study results from September of 2007 for the Chehalis and Scatter Creek River Systems
- Analyzed real-time gaging station data and December 2007 flood flows on the USGS Prather Bridge station
- Constructed a preliminary three-dimensional steady-state ground water numerical model which calibrated to field measured hydraulic heads (roughly completed in 200 hours) and water quality conditions in the Scatter Creek aquifer
- Prepared calibration tables of hydraulic head and residuals
- Prepared this summary report of findings
- Prepared preliminary recommendations for the municipal well field
- Conducted contaminant fate and transport simulations using MT3D.
- Performed housing 'counts' on the east side of Interstate I-5 and acreage size tabulations
- Investigated water rights for the part of the Scatter Creek Sub-Basin.

CONCEPTUAL MODEL

A conceptual model of the SCA was prepared using recent measurements and water quality data collected in the last 3 years (September of 2008 thru March of 2010). A presentation of a preliminary conceptual model was made to Public Works and Environmental Health in June of 2010 before proceeding into the construction of the numerical model. The conceptual model included an *elevational* model of land surface topography, bedrock geology, aquifer thickness and hydraulic heads and gradient, including well elevations and depths.

Hydrogeology of the Scatter Creek Aquifer

Two new geologic cross-sections were prepared for the SCA using the latest well log information provided by the WA Department of Ecology. These geologic cross-sections are provided in the appendices.

Only a few wells reach bedrock. However, we were able to confirm that the Eocene-age bedrock consisting of off-shore marine fine-grained sandstones and siltstones (as described by Snavely and others, 1958) were present at a consistent altitude of 80 feet above *msl* (mean sea level) from east to west into the Grand Mound municipal well field. The uplifted areas of the Scatter Creek area are primarily Eocene-age sandstones and volcanics. Outcrops of the Eocene-age rocks were mapped by Snavely and others (1958).

The actual geomorphic valley of the Scatter Creek aquifer above the Eocene-age rocks consists of gravel, cobbles and sand. This unit was formed from glacial outburst floods originating in Yelm. The new WA DNR geologic map for Maytown shows these units as Qgyo3 (the Yelm Lobe of the Vashon glaciation –Tanwax and Ohop Valley Outburst Floods). The Vashon glacier extended to the Tenino Range, however previous glacial maxima was as far south as Chehalis.

Land surface elevations of the Scatter Creek Aquifer range from 280 feet above msl in the east to 160 feet above msl at the municipal well field. The Chehalis River flood plain (in the geomorphic channel) elevation approximately 1000 feet from the municipal well field is around 120 feet above msl. The uplifted hill areas of Scatter Creek range from 300 to 600 feet in the area modeled.

New Hydraulic Head and Gradient Calculations

Hydraulic gradients calculated from prepared ground water elevation maps for the winter and end of summer season ranged from .0027 to .0031 ft/ft. The highest ground water elevations found in the Scatter Creek aquifer were in March of 2010 which ranged from 195.69 ft msl (Bredl) at the east end of model down to 126.42 ft msl (Schneider) at the southwest end. The lowest ground water elevations found were in September of 2008 which ranged from 181.66 ft msl (Bredl) down to 121.68 ft msl (Schneider – Sep 2009 only). The lowest ground water elevations that can be found throughout the ground water study were in domestic well 33ET01 (Cookston) at 104.40 ft msl at the far west end (northwest corner). Please refer to appendices.

Ground water in most of the domestic wells fluctuates approximately 8 to 15 feet yearly. The USGS well located in the northwest corner of the model tends to fluctuate as much as 25 feet yearly.

The ground water flow direction extends from east to west in the Scatter Creek basin and there were no noted changes in the direction during any of the sampling events. Ground water flow maps were prepared for this report as provided in the appendices.

USGS Seepage Study

One of the largest seepage studies performed in Washington State was conducted on the Chehalis River. Discharge measurements were made along an 81.6 mile reach of the river. Ironically, this study was done just prior to the largest recorded flood flow on the Chehalis River in December 1-3, 2007. The reason that the seepage study is important is that it allows calibration of the discharge (Q) in the numerical model.

The Chehalis River basin area is approximately 2800 square miles. At the end of summer, on September 11-13 of 2007 the USGS measured discharge on the river and its many tributaries including Scatter Creek. The significance of this work is that the flow measurements represent the ground water contribution only to the Chehalis River (and not snow or rainfall).

The Chehalis River gains some 76.9 *cfs* from Prather Bridge from the river mile 59.9 gaging station, to the intersection of Independence Road and the Chehalis at river mile 54.2. In this 5.7 mile stretch input from Prairie Creek and other small un-named stream may occur. However, because these were not measured during the 2007 USGS seepage study we are assuming that there was no flowing water in the streams in September that year. After discussing flow conditions on Prairie Creek with our field staff, it was confirmed that flow is virtually non-existent in September. We can also assume that flow is negligible to non-existent in the smaller un-named tributaries.

Scatter Creek, however, had a discharge of 20.7 *cfs* on September 11, 2007 as it entered the Chehalis River. However, it had a loss of minus (-) 2.6 *cfs* between the uplift area in the northwest (at Sargent Road) and James Road. The net gain into the Chehalis was 18.1cfs.

Chehalis River

The flood gage height for December 4, 2007 was 20.2 feet (peak flood stage) at the Prather Bridge, USGS gaging station in Grand Mound. The gage datum elevation is 123.65 ft msl and the peak flood stage elevation was 143.85 feet. During the February 2, 1996 peak flood event the gage height was 19.98 ft and flood stage elevation was 143.63 ft msl. The peak flood discharge was *79,100 cfs* for the December 4, 2007 event and *74,800 cfs* for the February 9, 1996 event.

The flood plain of the Chehalis River ranges from around 120 feet above msl to 116 feet above msl in the model area. Bluffs above the geomorphic flood plain rise have an elevation of around 160 feet above msl.

It was noted by county staff at the Ground Mound Waste Water Treatment facility that during the Chehalis flooding of December 2007 the southwest corner of the plant (pit bottom) was flooded.

This observation matches the flood elevations at the USGS gage of 143.83 feet as the pit bottom elevation in the southwest corner is 142 feet above *msl*. Furthermore, hydraulic head elevations denoted in the geologic cross sections are consistent with the recorded flood elevations (refer to appendices).

As will be discussed later, the ground water numerical model resulted in discharge to the Chehalis River where the actual river exists. Seepage or *daylighting* of the aquifer occurs in the geomorphic valley in the ground water model. Hydraulic head elevations simulated in the Scatter Creek aquifer model were observed to sharply decline into the Chehalis River system to elevations of 120 feet above *msl* or less.

Discharge Measurement on Scatter and Prairie Creek

Thurston County Water Resources has been measuring stream discharge at two stream gages in Grand Mound. One stream gage is on Scatter Creek at James Road and the other is on Prairie Creek and Highway 12. The highest field measured flows are show in the appendices. Prairie Creek typically dries out by early summer.

Nitrate Concentrations in the Scatter Creek Aquifer

Environmental Health (EH) program has been monitoring the water quality of the Scatter Creek aquifer for more than a decade. A new monitoring program began in September of 2008 where approximately 40 domestic wells are sampled *semi-annually*. During the first year wells were sampled quarterly. A copy of the well sampling database was obtained for this project and queried for monitoring results. Utilizing this data, water quality tables and ground water concentration maps were subsequently prepared. See appendix.

Historically, nitrate concentrations have been highest near the central to eastern part of the study area, where large dairy farms formerly operated. Nitrate concentrations at a former dairy site located less than one mile upgradient and northeast from the study area, exceeded 45 mg/l in the mid 1990's.

Nitrate concentrations in downgradient wells have steadily *decreased* following the closure of the dairy areas over the last decade. Nitrate levels in residential wells downgradient from the dairy site have decreased from 8.7 mg/l in 2004 to 4.1 mg/l in 2009 (this represents 112% decrease). Other wells located further down-gradient have experienced nitrate reductions ranging from 24-60% during the 6-year period.

Similarly, the Grand Mound Municipal well field nitrate concentrations have decreased over time. Well field nitrate concentrations for the last decade are provided in tables and maps (appendices). While there have been some intermittent 'increases' or pulses of elevated nitrate, the net impact over time has been a drop of 2 ppm.

Since the mid 1990's, the Scatter Creek Basin has experienced significant residential development. Residential septic systems have now replaced agricultural operations as the major nitrate source in the aquifer.

Other Water Quality Parameters

We downloaded available water quality data from both the DOH SENTRY system and the county water quality database to examine water quality trends. Fecal coliform has been another target analyte in county water quality studies from septic field impacts and agriculture. The 2004 water quality study shows that approximately 30% of the samples taken in the monitoring network had hits of fecal coliform. The recently acquired 2008-2010 fecal coliform samples are present in 8% of the monitoring wells which is a sharp reduction in the number of well contaminated with fecal coliform.

We briefly examined chloride concentrations and found a few anomalies in SENTRY datasets. We have had no time to further explore chloride concentrations as requested by the Planning Department. We hope to acquire 1 or 2 days of funding to go over *chloride* data in the future.

Scatter Creek Aquifer Geochemistry

A previous geochemical assessment was done in January of 2009 on the first round of ground water sampling. Major cation and anion chemistry was done during this sampling to determine the key controls on aquifer geochemistry. A *Piper-Trilinear* diagram and ionic balances were completed for these results (separate report) and show that the SCA is a high Ca-Mg-Bicarbonate controlled water. The SCA geochemistry generally "fits" in the overall Thurston County ionic ranges for natural ground waters, but are slightly *less sodic* and *more calcic*.

GROUND WATER NUMERICAL MODEL

A numerical ground water model was prepared using Visual Modflow 4.2.4 (Visual Modflow 2009.1). A steady-state, *1-layer* model was prepared for the second phase of this investigation to help the hydrogeologist assess overall hydraulic properties of the aquifer using observed hydraulic heads for calibration. In addition, the numerical model also has a *contaminant fate* and *transport* component to understand contaminant movement and nitrate concentrations at the municipal well field.

The contaminant fate and transport part of the model is still under development and was only recently started after the preliminary physical geologic model was constructed. Very few land use scenarios were simulated. Advection, dispersion and contaminant fate properties were not explored or researched under this budget. Modeling was *non-reactive transport* and only a steady state condition of 1800 days was simulated for a few land use scenarios.

The model was able to predict observed hydraulic heads in the Scatter Creek Aquifer as shown in the Appendix fairly closely. During the model construction process one of the central goals is to match theoretical to *observed* hydraulic heads under an array of hydrogeologic assumptions.

The model dimensions are tabled below.

Model Extent:	
X1, Y1 (origin):	0, 0
X2, Y2:	44,704 *ft*, 29744 *ft*
Grid:	90 columns x 60 rows
Cell Size:	500 ft x 500 ft
Model Area:	40 *sq* miles
Other:	Sy = .20
	n_e=.20
	N_{tot} = .25
	Z_{min}=0
	Z_{max}=1000 ft
	$P_{tot2008}$=46.44 in
	RCH=23 in
	$dh/dl_{mar2009}$=.0029
	$dh/dl_{sep2008}$=.0031
	$T_{TW\text{-}1pumping}$ = 525,000 gpd/ft
	$b_{TW\text{-}1}$ = 53 ft

FINDINGS

Hydraulic Conductivity

Calibration - One of the key findings in the modeling effort is that the ground water numerical model had to be 'opened up' to larger hydraulic conductivity values (larger than we had originally anticipated) in order for the hydraulic head to match observed water level elevations.

This simulation process was surprising in that most county ground water systems hydraulic conductivites (K) are typically 150 to 350 feet per day. While we know that a glacial outburst flood formed the SCA, there have been few comprehensive studies evaluating overall hydraulic properties of the aquifer. Sinclair and others (1992) had done one of the first comprehensive inventories of wells and nitrate concentrations in Scatter Creek and estimated hydraulic conductivities to be on the order of K=750 feet per day.

The numerical ground water model, however, shows that it must have a much larger K than Sinclair predicted on the order of 1000 feet per day for overall hydraulic conditions. Therefore, what the numerical model is showing is that the Scatter Creek Aquifer does indeed behave like a true outburst flood deposit which is now designated as the Qgyo3 deposit (as newly mapped by WA DNR Geology Division, Maytown). This geologic unit may have profound implications in the 'inter-connectedness' of aquifers locally including the Salmon Creek Basin and Scott Lake systems.

Pumping Well Calibration Changes: Pumping wells also helped calibrate model heads particularly in problem node areas (where residuals = +8.0 ft). After a field visit to the Scatter Creek Wildlife Area (northern area of model) we found aqua culture facility on 183rd and looked up water rights. We found large ground water pumpages and inserted 25% of these water rights into pumping wells in model. The effect was to bring down hydraulic heads close to observed. Refer to appendices. We also assumed from WA Ecology domestic wells on file that ground water was extracted at a rate of 500 gpd per home. We placed several theoretical wells into model with minus *300 gpm* pumping rates for housing areas on the east side of 1-5 and some on west side for industry. Refer to appendices.

Ground Water Flow Vectors and Isotropic Properties

The next important area of findings in the numerical model is that the Scatter Creek Aquifer has sharp directional ground water vectors which streamline ground water flow into narrow constrictions or pathways of high flow.

While one can observe 'ancestral channels' and ancestral stream geomorphology in LiDAR maps and can conclude that these may be highly transmissive channels, we did not load this variable 'channel' hydraulic conductivity into the numerical model, at this point. As we have no lithologic information about the channels, and there was also no budget to procure more information on these features. The numerical model was constructed using only isotropic conditions across the layer—anisotropic conditions were not detailed.

Shape of Contaminant Plumes and Dispersion

The effect of the vectors as discussed above is that they keep ground water contamination in narrow dispersive fields due to high ground water velocities. Furthermore, even with high pumping wells the contaminant plumes are not dispersed very widely. Although in one of the modeling scenarios it is possible to see the effects capturing a *nearby* plume of contamination.

We have not evaluated these nitrate 'plumes' very closely and have not figured out how to overlay plumes on top of each other. Again, we did not have a complete budget to do this work. What we can say about the very few land use scenarios that we simulated is that plumes can not only travel *quickly* they can also be *eliminated quickly*, too, relative to most aquifers in the county. We modeled only steady-state at 1800 days. It may be that at 3600 days that the plume will continue to dilute and that the 1800 days scenario is indeed long-term equilibrium over the course of 10 or 20 years and never affect the well field beyond water quality standards.

A question was posed about the 'fecal coliform' dispersion and whether this is similar to nitrate. We could not find any definitive pattern in the fecal coliform. One would expect that it would follow nitrate patterns. Because it does not appear to do so, we expect that other biogeochemical processes are at work and control coliform behavior such as microbes and total organic carbon. Fecal coliform do not appear to behave like non-reactive 'particles'. Nitrate on the other hand is fairly non-reactive (outside of oxidation/reduction mechanisms).

Cumulative Contaminant Impacts

The largest looming question in the contaminant modeling process is delineating the cumulative effects of 'constant concentrations', previous *point sources, background* conditions coming into the model *and historical background,* as well as future 'constant concentrations'. The contaminant fate and transport modeling effort needs to assess what happens between .33 acres lots versus the larger 1-acre ones. This evaluation was not done.

The existing municipal well field consisting of TW-1 and TW-2 shows both constant and decreasing concentrations of nitrate over the last decade. We briefly explored the reasons for these trends in the contaminant modeling process. We believe that large scale agricultural operations can quickly spike well field concentrations within 5 years in the Scatter Creek aquifer. It may be possible for nitrate concentrations to climb to greater than 3 mg/l within 10 years. However, we have not modeled the 3600 day scenario in steady state conditions to determine what predicted concentrations would be and whether dilution would over-ride ultimate impacts at the well heads 5 miles from a dairy point source.

RECENT STUDIES COMPARISON

In the last decade the USGS has completed several interesting studies characterizing nitrate in shallow aquifers. Hinkle and others (2008) completed an analysis of septic tank effluent effects in the Deschutes Aquifer near La Pine, Oregon. Unlike the SCA this aquifer does not have a hydraulic conductivity as high as SCA. La Pine shallow aquifers exceed drinking water standards of 10 mg/l because ground water moves very slowly and there is low recharge. Age-dating of ground water found that residents were drinking 30 to 50 year old ground water.

The preliminary SCA ground water numerical model shows that at the well field ground water is perhaps as old as 1 to 7 years. The La Pine Aquifer is currently contaminated near or at the water table and is moving downward. The SCA does not have data to show what is going on at depth, however, we suspect that contamination has moved downward as well.

What makes the SCA at risk is also the occurrence and *potential rapid transport* of personal care products, pharmaceuticals and viruses. At the same time the high ground water fluxes will help dilute concentration *build up* of these products, however build up can occur due to high contaminant loads from agriculture as seen in the historical ground water results.

RECOMMENDATIONS

Recommendation 1: Placement of Additional Wells

We recommend that future wells be placed in areas of *least* nitrate contamination. The numerical model shows that these areas may not have been 'hydraulically down-gradient' of past large agricultural industries (dairy and aquaculture) and current high density housing on septic. The high nitrate concentrations (historical and existing) show that past agricultural operations and homes on septic may have contributed to the high contaminant loads which are now being reduced as observed in recent ground water sampling events.

<u>Based on our findings this means that optimum locations for new municipal wells would be outside of the 1 miles radius of the existing well field (TW-1 and TW-2) towards the northwest</u>. This area currently has the least impacts by nitrate with concentrations of 2 to 3 mg/l.

We understand that Public Works' key concern is to find the best well locations in terms of water quality and future municipal well safety. At this point, we would not recommend placement of future municipal wells southeast of the current well field unless there is solid and comprehensive water quality data to support otherwise. Based on our recent meetings with Public Works we understand the southeast area was recommended by previous consultants. We would need to examine the hydrogeology rationale and logic behind this recommendation further to help Public Works better assess this possibility. Our preliminary numerical model findings, however, do not support this area due to future up-gradient septic housing development.

See Recommendation 3 for vertical well placement recommendations.

Recommendation 2: Conduct Additional Ground Water Sampling in Data Gaps Identified in Numerical Ground Water Modeling

The numerical ground water modeling exercise shows that there are clearly data gaps in the water quality assessment program (we want to clarify that the current water quality assessment program wasn't designed to protect the well field, but simply identify water quality trends in previously identified areas of concern). In order to protect the well field from future impacts due to new higher density development (or future industrial or agricultural complexes) along the Highway 99 growth corridor, then domestic well samplings should be conducted in this area, particularly directly down-gradient of the high density home subdivisions.

Recommendation 3: Vertical Well Placement--Conduct Additional Ground Water Studies in the Deeper Aquifer to Further Define Ground Water Quality Conditions

We recommend that new ground water monitoring wells be completed at depths of 90 to 100 feet below ground surface in the highest areas of ground water contamination (hydraulically up-gradient of the existing well field) and several hundred feet hydraulically down-gradient of the high density development as noted in Recommendation 2.

We also recommend additional ground water monitoring wells in the area of the future well field development (in the *shallow*, *intermediate* and *deep* aquifer).

Recommendation 4: Complete Contaminant Fate and Transport Modeling

We recommend that additional monies be sequestered for continued contaminant modeling. We recommend modeling out to 3600 days (10-years and the 20-year scenario) in *steady state* to see impacts on the Grand Mound Municipal Well Field. If we cannot secure the Centennial Grant for this effort then I would recommend finding other small grants to complete this important exercise.

Recommendation 5: Secure Previous Ground Water Assessment Reports for the Grand Mound Well Field

We did not have time to secure previous additional reports as our time was spent procuring current datasets and building the conceptual ground water model. The 1996 Pacific Groundwater Group Report is an important report to find (Update: This report was scanned and provided to us on December . We leave this recommendation in place because it is an important caveat and provides background context for our study).

Recommendation 6: Continue to Work with Strategic Planning Group to Model Future Land Use Scenarios (General Recommendation).

The planning department of the county has done a lot of research on the Grand Mound area. They will find the results of this modeling effort very insightful, and most importantly very useful in terms of planning future land use scenarios and visualization. They can set up additional land use scenarios for us to simulate and model.

Recommendation 7: Work with Emergency Services to Add River Modules To Numerical Model (General Recommendation and not intended for Public Works to Pursue)

Emergency services may find that this numerical ground water model can be developed into predicted flood elevations. We have procured MIKE11 software that can be inserted in numerical model. A preliminary exercise involving 100 hours, if funded can provide us more detail on flooding disasters and predicted hydraulic head elevations. The reason why this effort is important is to also protect the well field from both surface and ground water flooding. The current waste water treatment plant and chlorine treatment processing is placed in a former gravel pit. Our geologic cross-sections show the lower altitude and potential problem of 'ground water' backup (elevational rise of ground water during severe flooding) into the treatment area is at risk also.

Recommendation 8: Continue to Analyze the USGS Studies and Results from La Pine Aquifer

We highly recommend continued analysis and updates on what has happened for human behavior and land planning changes in the La Pine Aquifer, Oregon. The USGS conducted a very valuable set of studies for the Deschutes Basin septic impacts. We recommend funding to further research what is already being done out there for insight into what should happen to the SCA.

FINAL CONCLUSIONS

This numerical modeling effort will be extremely valuable to the county as a whole and not only Public Works Department. Several of the recommendations are intended as general commentary to other readers of this report (including the Environmental Health Department, Emergency Management, Planning Department, State Health, the WA Department of Ecology, the USGS and other agencies) . We hope to continue running model simulations as money becomes available.

This draft report will continue to evolve through upcoming presentations and input from county departments and outside agencies. Public Works may want hire us to run simulations at smaller 'scope of work' scales (on the order of 24 to 40 hours) to address specific detail and/or new questions as they come along.

REFERENCES

Logan, R and T. Walsh and others, 2009. Geologic Map of the Maytown 7.5 Minute Quadrangle, GM-72. WA DNR.

Snavely, P.D. and R.D. Brown and others. 1958. Geology and Coal Resources of the Centralia-Chehalis District, Washington. (USGS) Geologic Survey Bulletin 1053.

Hinkle, S.R. and J.K. Bohlke and others. 2007. USGS Nitrate Study Shows Water Supply Threatened from Residential Septic Systems. USGS Release Announcement.

Sinclair and Others, 1992. Master's Thesis on the Scatter Creek Aquifer. The Evergreen State College.

APPENDICES

Potentiometric Map of Scatter Creek Aquifer – March 2009
Potentiometric Map of Scatter Creek Aquifer – September of 2008
Geologic Cross-Section A-A'
Geologic Cross-Section B-B'
Nitrate Concentration Map – March 2009
Graph of Nitrate Concentrations at Grand Mound Municipal Well Field
Trilinear Diagram of Scatter Creek Aquifer
Simulation Outputs A
Simulation Outputs B
Simulation Outputs C
Table: Well Location Coordinate Table and GW Hydraulic Head Elevations
Table: Summary Nitrate Concentration Table 2008-2010
Table: Comparison Table of Hydraulic Heads (Calibrations) GW Model vs Field Measurements
Table: Well Pumpage Estimates
Table: Housing Counts

ACKNOWLEDGEMENTS

A special thank you to Brad Zulewski for assistance on background research and preparation of data tables, maps and geologic cross-sections. It was 6 months of hard work and lots of learning. We met every Tuesday to go over findings and stay 'on-top' of the project scope. Ground water numerical models take a lot of research work and preparation. This effort could not have been accomplished without solid commitment from staff.

A special thank you to the Sue Davis ground water monitoring group in EH for their sampling and analysis work of the Scatter Creek aquifer system. We are appreciative of their efforts and diligence in collecting quality information and in managing a large database system. This contaminant fate and transport model could not have been completed without their efforts.

A special thanks to Environmental Health (EH) for approving funds to build a long awaited numerical nitrate model for the Scatter Creek Aquifer in a joint project with Public Works Engineering.

A special thanks to Public Works Engineering for hiring us to complete a Phase I analysis of the Grand Mound Municipal Well Field.

THURSTON COUNTY
WASHINGTON
SINCE 1852

COUNTY COMMISSIONERS

Cathy Wolfe
District One
Sandra Romero
District Two
Karen Valenzuela
District Three

RESOURCE STEWARDSHIP DEPARTMENT

Creating Solutions for Our Future

Cliff Moore
Director

MEMORANDUM

TO: Roger Giebelhaus, Engineering, PW
Scott Lindblom, Engineering, PW

FROM: Nadine Romero, Water Resources Program, RS
Hydrogeologist, LHG, LG

DATE: July 26, 2011

SUBJECT: New Well Head Protection Area Delineations
Grand Mound Municipal Wells (Future Wells TW-3 and TW-4)

As discussed with you in our April 19, 2011 meeting, I am providing you with this brief summary on the results of our additional ground water modeling exercise which we conducted in April and May for Public Works. Per our scope of work, we completed additional 2D and 3D ground water modeling for the 2011 Water Comprehensive Plan Rewrite.

WORK COMPLETED

The following work items were completed for this project:

- Conducted additional ground water modeling simulations using the calibrated numerical model constructed in October of 2010 with Visual Modflow 4.2 to delineate the well head protection areas (WHPA's) for well TW-1 and TW-2 for the *1- year* and *3- year* capture zones.

- Downloaded and ran new well head protection software from EPA to create geographic based modeling in 2D for existing and theoretical well head protection area delineations.

- Simulated 'theoretical' future wells (TW-3 and TW-4) to discern potential well head protection areas for emergency or expanded water supplies

- Provided Public Works well head protection area maps showing the new extents of WHPA's and the new geometry/shape for the 2011 Water Comprehensive Plan rewrite.

- Went over preliminary results/finding in a meeting with Public Works on April 19, 2011
- Conducted additional simulations/modeling after the April 19, 2011 meeting.
- Prepared this brief summary report.

FINDINGS

There were a number of new findings in this modeling effort for the well head protection areas in contrast to the older previous 1994 Water Comprehensive Plan.

These new findings are as follows:

- The 1-year and 3-year well head capture zones for municipal wells TW-3 and TW-4 are more extensive than those plotted in 1994 report. Well head protection areas are longer and extend as far as 183rd Avenue on the eastern side of Interstate 5 which is some 3 miles from the well heads.

- Both ground water modeling efforts, one using a calibrated model constructed withVisual Modflow (numerical modeling) and the other using the new WhAEM2000 v 3.2.1 (analytical and geographic based) show 'arched' ground water flow paths which match the direction of ground water flow derived from our latest potentiometric maps. These maps use water level and water quality data from an existing 40 well monitoring network in the Scatter Creek Aquifer sampled by EH. These ground water flow paths follow bedrock and physiographic boundaries which were loaded into both models.

- Ground water velocities (V) are calculated at around 10 feet per day and horizontal hydraulic conductivity (K) was estimated at 1000 feet/day using the calibrated numerical model we created for the Scatter Creek Aquifer. Transmissivity derived from pumping tests conducted on the Grand Mound Wells in the 1990's also support high K values of more than 1200 feet per day.

- Narrow capture zones were defined in the WHPA delineations in both modeling efforts. These narrow zones are only around 200 feet wide on each side of the well head assuming a pumping rate of 500 gpm. While we recommend that future wells are placed at least 1500 feet apart there may be some room for less spacing distance due to the high aquifer transmissitivies and narrow ground water capture in the Scatter Creek Aquifer.

RECOMMENDATIONS

This additional modeling exercise allowed us to further refine the numerical and analytical modeling effort, in tandem, to produce new well head protection areas for the existing and future Grand Mound Well Field.

Based on these simulations we recommend the following:

1. Amend the new 2011 Water Comprehensive Plan to show the latest 1-Year and 3-Year Well Head Protection Areas (WPHA's) as provided in this summary. This means extending the WHPA for TW-1 and TW-2 to 183rd and Highway 12 on the east side of Interstate 5. This region is approximately 3 miles from well TW-1.

2. Continue with the next phase of following up with the Environmental Health Department (EH)- Solid and Hazardous Waste Section to retrieve the latest well head inspection reports for the upcoming 2011 field survey to identify the best areas for future and existing wells "free" from potential spills and human land use activity that would be detrimental to the well field.

3. Continue to sharpen and identify future well field areas for water supply expansion with the county hydrogeologist. The results of this modeling effort show 'narrow' and long well head capture areas which means future wells could expand to the northwest where ground water quality has historically been better (less than 2 mg/l for background conditions). These areas also do not appear to be in the down-gradient ground water flow path of future growth from septic fields/housing developments.

4. Recommended minimum distances between high capacity pumping wells should be at least 1500 feet but further discussions with the engineer and hydrogeologist on this aspect to go over findings may result in less distance.

Please let me know if you have further questions.

Sincerely,
Nadine Romero

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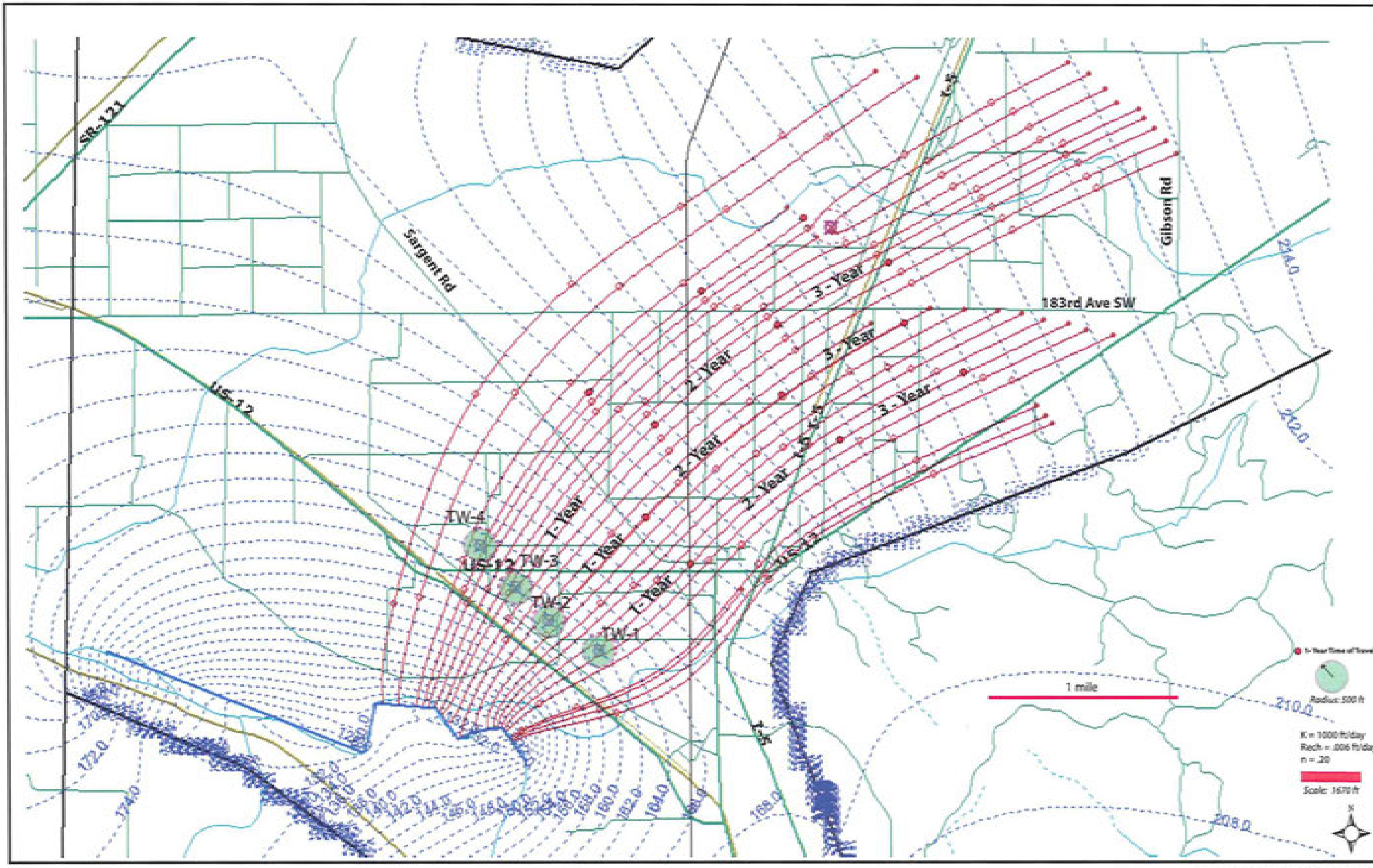

By N. Romero, Hydrogeologist, 5/16/2011

Figure 1: 1 -Year and 3 -Year Capture Zones: Existing (TW-1 & 2) and Theoreticial Wells (TW-3 & 4)
Grand Mound Well Head Protection Area - Simulation Using *WhAEM2000 V.3.2.1*

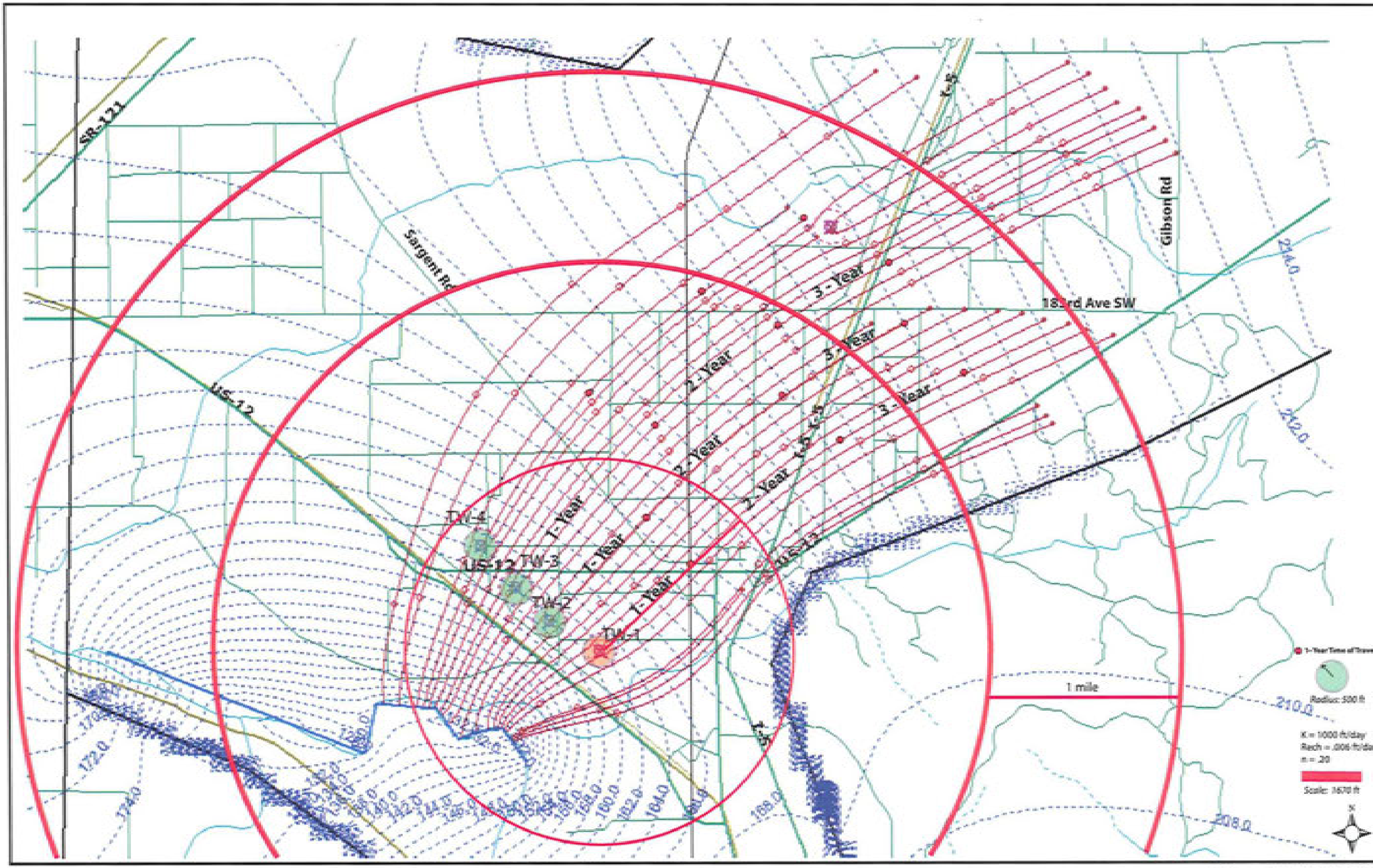

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Figure 2: 1-Year and 3-Year Capture Zones: Existing (TW-1 & 2) and Theoreticial Wells (TW-3 & 4)
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