Progress Report:

Yellowstone Controlled Groundwater Area
Technical Oversight Committee
2008

Introduction

The Technical Oversight Committee (TOC) for the Yellowstone Controlled Groundwater Area (YCGA) advised and worked with the Montana Bureau of Mines and Geology (MBMG) and the U.S. National Park Service (NPS) to accomplish the following tasks from 2000 to 2008:

- Advise the Montana Department of Natural Resources and Conservation (DNRC) on water right permitting.
- Establish long term monitoring of geothermal resources within YCGA and Yellowstone National Park (YNP).
- Evaluate and abandon the Church Universal and Triumphant (CUT) geothermal well.
- Discuss the potential for impacts to the Park geothermal system by development in the Big Sky area.

Background

The YCGA was established on January 31, 1994 under the Reserved Water Rights Compact between NPS and the State of Montana (Montana Water Law: MCA 85-20-401) (Figure 1). The purpose of YCGA is to monitor and regulate ground-water development adjacent to YNP in an effort to preserve the integrity of the hydrothermal system in and around Yellowstone Park. Applicants wishing to appropriate water in the YCGA must apply for a Permit for Beneficial Water Use from DNRC and have a meter installed to measure total volume of water used. Specific criteria for issuing permits depend on the temperature and amount of the water to be appropriated. Progressively more information is required as the temperature of the produced water increases.

Special Additional Requirements for Permits for Beneficial Water Use in the YCGA

For Ground-water Temperature <60° F

- <ins><35 gpm or <10 acre-ft/yr:</ins> may be put to use by filing for a ground-water certificate
- <ins>>35 gpm or >10 acre-ft/yr:</ins> may be put to use by obtaining a provisional permit
- TOC reviews a list of new permits annually and may recommend action as necessary

For Ground-water Temperature >60° F but <85° F

- <ins>all wells:</ins> may be put to use by obtaining a provisional permit if the proposed appropriation diverts unenhanced natural surface flow of a spring that is not located on a reserved portion of a stream, or all of the following are met:
    - the water temperature is the result of the normal thermal gradient of the earth, plus the mean annual air temperature at the site, plus 14° F
    - the concentration of soluble chloride is less than 10 ppm
    - well does not contain a production zone within the Madison Group of formations

Temperature >85° F

- <ins>all wells:</ins> may be put to use by obtaining a provisional permit if the proposed appropriation diverts unenhanced natural surface flow of a spring that is not located on a reserved portion of a stream, or an application contains credible information that the proposed appropriation does not include contribution by hydrothermal discharge water and the following procedures are followed.
    - TOC reviews information and makes a recommendation to DNRC based on best available scientific information
    - a contested-case hearing is held with the application approved by the hearings officer.

The compact established TOC to review scientific evidence related to the YCGA, to advise on administration and monitoring activities, and to recommend modifications to boundaries and restrictions. Members of the TOC are from NPS, the U.S. Geological Survey (USGS), DNRC and the Montana University System. The other members select an additional member at large. The purpose of this report is to describe the activities of TOC since 2002.

TOC members provide scientific perspective regarding protections of the hydrothermal system in YNP. The following are agency-specific roles:
DNRC - administer YCGA and regulate ground-water appropriations in YCGA.
NPS – review and evaluate applications for beneficial ground water use in YCGA.
Montana University System – advise on inventory and monitoring activities in YCGA.
USGS – conduct hydrologic and geologic studies in the vicinity of YCGA, including stream flow and water quality monitoring and geologic mapping.

Water Permitting Activities in YCGA

A total of 230 permits for the use of groundwater in the YCGA have been issued through the DNRC Office in Bozeman from the January 31, 1994, effective date of the compact through September 15, 2008 (Tables 1 and 2; Figure 1). There are 3 main areas of higher density (Figure 2): Cooke City area (furthest east), Yellowstone River valley area (north central), and Hebgen Lake/West Yellowstone area (furthest west). No permits have been issued for water of 60°F or greater. Several permits have been issued in the Corwin Springs area for water above 55°F and will be monitored periodically for change. All but 5 of the 232 permits issued through September 2008 are for 10 acre-feet or less. The 5 permits for over 10 acre-feet account for 398 acre-feet or 42 percent of the total 959 acre-feet authorized. Two permits for one development issued in 1996 account for 279 acre-feet or 29 percent of the total volume authorized.

DNRC asked for clarification regarding the formula used to trigger special review since a well near the threshold was reported. The formula uses a reasonable geothermal gradient for the stable craton to compute the expected temperature and a reasonable mean air temperature for recharge and computes whether the temperature is higher than the expected threshold.

Formula: Geothermal Gradient x Depth + Mean Air Temp + 14°F
0.01646°F/ft x depth ft + 45.3°F + 14°F

The 14°F is an adjustment factor to allow for error in the geothermal gradient mean annual temperature so that the trigger temperature for action is reasonable, but protective. This equation is used to evaluate whether the ground-water temperature is substantially above the temperature expected at the bottom of a well without heat from the Park geothermal system.

Table 1. Number of permits in YCGA by year.

1995	51	**2002**	8
1996	23	**2003**	7
1997	35	**2004**	14
1998	18	**2005**	12
1999	15	**2006**	16
2000	9	**2007**	11
2001	5	**2008**	8
Total	232		

Table 2. Number of YCGA permits by hydrologic basin.

41F - Madison River	127
41H - Gallatin River	2
43B - Yellowstone River, Above and Including Bridger Creek	101
Total	230

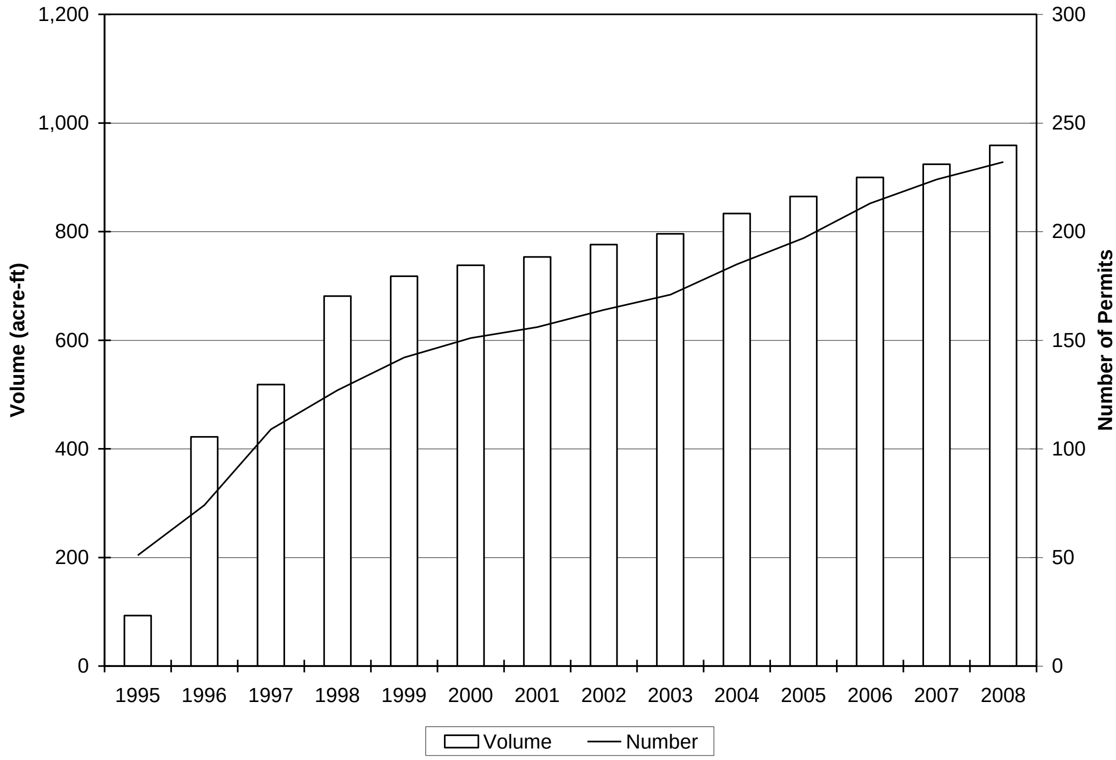

Figure 1. Number of YCGA permits and authorized volumes.

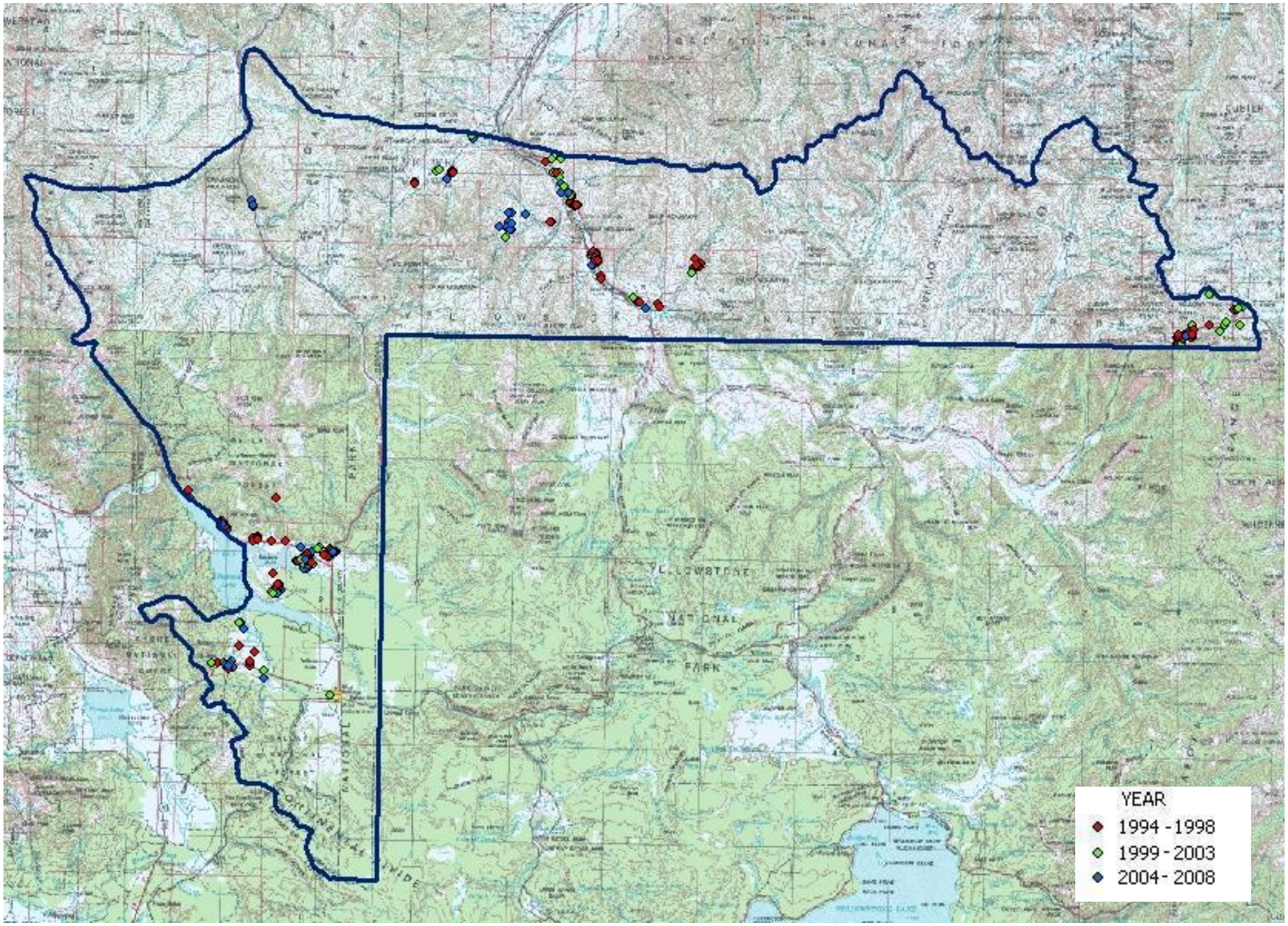

Figure 2. Map showing location of permitted YCGA wells.

Long-Term Monitoring

In 1994, the State of Montana and NPS established a water-right compact (Compact) and YCGA within Montana adjacent to YNP. Article IV, Section H.2. of that compact requires a ground-water monitoring program be implemented in the controlled groundwater area outside YNP in Montana by the MBMG in consultation with TOC. TOC believes the geothermal system must be monitored over time both inside and outside the Park. To this end, TOC pursued and received assistance from Montana Senator Conrad Burns to secure funding for monitoring through the NPS budget.

YCGA Monitoring Program

MBMG and TOC have devised a long-term ground-water monitoring program for the YCGA outside the park based on the Compact, the Working Group Report (Custer and others, 1993), and information collected in the well and spring inventories (Metesh and others, 1999 and 2000; GWIC, 2002). The Compact states that the Working Group Report will be used as a guide for selection of sampling sites and frequency until superseded by recommendations of the TOC. Critical issues to be addressed through monitoring that were identified by the Working Group include:

- Evaluation of the relationships between warm and cold wells and springs.
- Monitoring encourages discovery, inventory, and assessment of unregistered new wells.
- Identification and evaluation of changes in wells and springs through time.
- Identification and evaluation of spatial relationships of wells and springs through time.

TOC recommended the following minimum monitoring requirements for wells, springs, and water chemistry outside the Park to address these issues.

All wells with water temperatures greater than or equal to 15 °C (59 °F) shall be monitored. There are 10 known wells with water temperatures greater than 15 °C (59 °F). In addition, TOC has requested that MBMG select 5 additional wells with water temperatures less than 15 °C (59 °F) for the same monitoring. The “cold water” sites will provide base-line response to climatic and anthropogenic changes and provide insight into changes due to climate or development that might influence warm springs. Field parameters to be collected at the 15 wells shall include:

1) water levels by continuous recorders
2) field specific conductance (SC)
3) field pH
4) water temperature (°C)
5) field alkalinity (as HCO_3)
6) chloride (Cl)
7) field oxidation-reduction potential (ORP)

Field parameters shall be collected three times per year because winter access is too difficult and costly to allow quarterly measurements. The measurements will coincide with the required maintenance of the continuous recorders. Initially, both field and lab chloride will be collected from all wells. When sufficient data are collected, TOC and MBMG will select a preferred method of analysis.

All springs with water temperatures greater than or equal to 15 °C (59 °F) shall be monitored. At present, there are 15 springs with water temperatures greater than 15 °C (59 °F). TOC has requested that MBMG select 5 additional springs with water temperatures less than 15 °C (59 °F) for the same monitoring. The “cold water” sites will provide base-line response to climatic and anthropogenic changes. Field parameters to be collected at the 20 springs shall include:

1) discharge by flow metering devices
2) field specific conductance (SC)
3) field pH
4) water temperature (°C)
5) field alkalinity (as HCO_3)
6) chloride (Cl)
7) field oxidation-reduction potential (ORP)

Flow monitoring will require the installation of a flume, weir, or similar device in addition to a continuous recorder at each site. As with the wells, field parameters shall be collected three times per year coinciding with the required maintenance of the continuous recorders. Initially, both field and lab chloride will be collected from all springs. When sufficient data are collected, TOC and MBMG will select a preferred method of analysis.

Chemistry data from the baseline inventory completed by MBMG show a wide range of concentrations of dissolved constituents. Each year 12 of the total of 35 sites will be sampled 3 times and analyzed for standard inorganic chemistry for a total of 36 samples (plus 1 duplicate) per year. The intent is to collect data from all sites on a 3-year cycle. Water-chemistry sampling shall be concurrent with collection of field-parameters and recorder maintenance. In addition, the same 12 sites will be sampled once each year for the isotopes deuterium, 18-oxygen, and tritium.

1. Annual base budget.
The Compact was established to protect the geothermal resources of YNP. In order to monitor and assess any impacts by the development of ground-water and surface-water resources, it is necessary and critical that there be a commitment to long-term monitoring of wells and springs within the YCGA. At the request of TOC, MBMG has provided an estimate of annual costs of $141,000 per year for this monitoring.

2. Purchase and installation of monitoring equipment
The purchase and installation of monitoring equipment will require a significant capital investment. In order to average out the annual costs, TOC recommended that the program be phased in over a 5-year period. Each year, data will be collected from all 35 sites (3 times per year) and about 7 sites would be instrumented. The annual monitoring costs would increase each year as sites are added. Thus the annual cost will shift from installation to monitoring over the 5 year period. At the end of the 5-year period, the annual cost of monitoring, repair/replacement of equipment, and the increase or decrease of the number of sites will be evaluated. Because of the aggressive nature of hot water, equipment failure and replacement is anticipated. A replacement and maintenance program will likely be needed after the 5-year period is over.

Funding was received from NPS to begin monitoring of ground-water and springs in YCGA in mid-2005. The monitoring plan lists 35 warm and cold springs and wells to be monitored for flow/level and chemistry. Each year for the first 5 years, 7 sites will be instrumented. All data, including hydrographs are available through the MBMG Ground Water Information Center (GWIC) website (http://mbmggwic.mtech.edu/). 20 sites have been instrumented as of this 5-year report.

Monitoring Inside the Park

The objective of ground-water assessment in YNP is to collect basic data necessary to establish a baseline that allows analysis of short and long-term changes to Yellowstone's geothermal systems and to understand the interaction between cold groundwater and the geothermal systems. Funding for monitoring inside YNP is $846,400 per year. Five components of YNP's Geothermal Monitoring Plan are:

1. Groundwater inventory, monitoring and assessment

The objective is to assess Yellowstone's hot and cold ground-water resources and develop a long-term data set to detect natural and anthropogenic changes to the ground-water system. There are three types of sites with different levels of data collection intensity. Level 1 sites have continuous water level and temperature recorders sampling at 15-minute intervals and are sampled for water quality analysis quarterly. Level 2 sites have continuous water level and temperature recorders sampling at hourly intervals and are sampled for water quality analysis annually. Level 3 sites have annual water-level and field water chemistry measurements. The objective of Level 3 sites is to develop a long-term record of annual changes in water levels and water quality and to do this over the widest area possible. All Level 3 sites will be sampled once to analyze for complete water chemistry to establish a large baseline data set. Twenty wells are selected for level 1 and level 2 monitoring and up to 50 wells are selected for level 3 monitoring.

2. Chloride flux inventory, monitoring and assessment

The objective is to monitor overall changes in the amount of chloride exiting various sections of the park. Because chloride in YNP is predominately from a magmatic source and is conserved in water, chloride can be used as a proxy for heat flux and geothermal activity and can be used to monitor natural and anthropogenic changes to the geothermal system. Eight new streamflow gauging stations are installed and operated by USGS as part of the USGS National Stream-Gauging Program. These automated stations provide temperature, river flow, and gauge heights via telemetry and are available real-time on the Internet. Water samples for chloride analysis are collected 28 times a year at river gauging stations: monthly during the winter at low flow, biweekly during the early spring and fall, and weekly during spring runoff (Friedman and Norton, 1990).

3. Individual thermal feature inventory, monitoring and assessment

The objective is to monitor specific thermal features and thermal areas to provide information on natural and anthropogenic changes in the pathways of thermal waters between areas both inside and outside the Park. A partial list of parameters that are measured include temperature, flow, chemistry of water and gases (major anions, cations, metals, trace elements, isotopes, etc.), and spatial extent using techniques such as photographic surveying methods.

4. Remote sensing of hydrothermal features

The objective is to use satellite and airborne imagery to provide maps of thermal areas of the entire park that will quantify changes in thermal areas through time. The large number, complexity and rapid change of thermal features in the Park make inventory and change assessment difficult. Remote sensing may provide an effective method to inventory, monitor, and assess historic and ongoing changes in Yellowstone's thermal features. A future goal will be to quantify surface temperature and heat flux of geothermal basins and individual features. Maps of thermal area extent, distribution and change will provide the baseline data for assessing future change in Yellowstone's thermal features, both man-caused and natural.

5. Information transfer using the Yellowstone Geothermal Database
The objective is to store and disseminate information gathered as part of this plan using an Internet-based Geographic Information System. The Yellowstone Geothermal Mapper will link to other databases such as real-time hydrologic data from USGS, YCGA data available from MBMG, and University of Utah Seismic Station information. Coordination between YNP and TOC is accomplished through continued annual meetings to review data and activities.

Monitoring Activities
The following summarizes the activities of the YCGA Monitoring.

Year	Wells	Springs
2005	Altanta Darr	La Duke Hot Spring (hot)
	Richard Miller	Lonesomehurst (cold)
	Three Bears Lodge	Stinky (cold)
	West Yellowstone Campground	
2006	Bakers Hole Camp North	
	Bakers Hole Camp South	
	Kieland	
	Jim Cole	
	Gardiner Airport	
	Silver Gate WUA	
2007	C. Gonzales (105959)	USFS Lionshead
	C. Gonzales (145529)	USFS Beaver Creek
	Brauch	USFS Sheep Camp
		Jim Cole

LaDuke Hot Spring (171215) Temperature <u>60.9 °C</u> Flow <u>93.4 gpm</u>
This site was established in 2005 with the installation of a 0.75 Plasti-Fab H-Flume along with a Solinst level and temperature Levelogger transducer, set to take readings every hour. The transducer fail to give reliable data so it was replaced with an Omega high temperature pressure datalogger model OM-CP-PRTEMP1000, but again when reviewing the data the new instrument gave questionable results. An OTT Thalimedes float operated data logger has replaced the transducers resolving the data collection problem. Six water quality samples have been collected along with flow and temperature date since inception.

Stinky Spring (183268) Temperature <u>16.5 °C</u> Flow <u>33.75 gpm</u>
On October 13, 2005 a 0.6 Plasti-Fab HS-Flume was installed at Stinky spring along with a Solinst Levelogger. Freeze and thaw cycles had caused breaches to occur around the

weir making flow readings limited. Concreting in the weir eliminate breaching. Moss build-up in the weir is a problem and the data has to be adjusted.

Lonesomehurst Spring (164216) Temperature <u>8.4 °C</u> Flow <u>5.6 gpm</u>
A 0.4 Plasti-Fab HS-Flume along with a Solinst Levelogger was installed below the overflow pipe from the Lonesomehurst Water Users Association's spring house on October 13, 2005, flow was 3.9 gpm. This spring goes dry in the late fall or early winter months and starts flowing again in May.

Atlanta Darr Well (146967) Temperature <u>13.11 °C</u> SWL <u>113.42 ft</u>
This is a domestic well where a Solinst temperature pressure Levelogger transducer has been installed by suspending it with a nylon coated stainless steel cable since August 8, 2005. Home ownership has changed since monitoring began but the new owners have agreed to continue monitoring of the well. (SWL = maximum static water level below measuring point)

West Yellowstone KOA Campground Well (8935) Temperature <u>5.69 °C</u> SWL <u>15.9 ft</u>
There are 3 wells within the KOA campground. One well services the housing units for the employees. The main well, is used to provide water for the campsites, swimming pool, and other services within the campground. There is no access to get water levels from this well but water quality samples can be taken from a spigot near the pump house. The third well is a backup well to the main well which is a few feet south of the main well on top of the hill. Monitoring was started at the backup well August 8, 2005 by installing a Solinst temperature pressure transducer suspended by a nylon coated stainless steel cable.

Richard Miller Well (152216) Temperature <u>17.6 °C</u> SWL <u>3.57 ft</u>
The original owner of the Richard Miller Well has deceased and the house has become rental property. The son, Paul Miller, lives next door and gave permission to use the well. The well has been idle for some time and the pump in the well is no longer operational. MBMG agreed to replace the pump in order to collect periodic water-quality samples. Bridger Drilling was contacted and a new pump and wiring was installed in the well. Monitoring began March 22, 2006 by collecting a water-quality sample and placing a Solinst temperature-pressure transducer in the well. Consistent data has been collected from the well since inception.

Three Bears Lodge Well (106842) Temperature <u>7.09 °C</u> SWL <u>36.96 ft</u>
The owner thought this well is used only for irrigation purposes at the lodge and the pump is shut off in late September until late May or early June, but water level data shows this well gets used year round. Monitoring began on October 13, 2006 with installing a Solinst temperature-pressure Levelogger transducer.

McClaren Tailings monitoring wells near Cooke City
In 2005 at the request of the National Park Service, the MBMG installed water-level transducers in three new monitoring wells installed by the NPS and Montana Department of Environmental Quality. Although not part of the long-term monitoring plan, these data may provide information on shallow ground water in the area. Data collection continued through the summer of 2007.

Bakers Hole Camp North Well (8943) Temperature <u>18 °C</u> Flow <u>31.1 gpm</u>

This is an artesian well with an overflow pipe. A totalizing and gpm flow meter was installed on the overflow pipe with an attached metro-log digital flow recorder taking hourly flow readings on 12/13/06. Temperatures reading are taken by an installed Onset tidbit v2 temperature logger set to take one hour readings. This data logger has failed and is being replaced by a more reliable unit.

Bakers Hole Camp South Well (106775) Temperature <u>22.2 °C</u> Flow <u>13.3 gpm</u>
This is an artesian well with an overflow pipe. A totalizing and gpm flow meter was installed on the overflow pipe with an attached metro-log digital flow recorder taking hourly flow readings on 11/17/06. Temperatures reading are taken by an installed Onset tidbit v2 temperature logger set to take one hour readings. Currently this logger is still working but may need to be replaced as 2 other loggers of the same brand have failed.

Kieland Well (106778) Temperature <u>11.3 °C</u> Flow <u>1.54 gpm</u>
This is an artesian well with an overflow pipe. A totalizing and gpm flow meter was installed on the overflow pipe with an attached metro-log digital flow recorder taking hourly flow readings on 11/17/06. Temperatures reading are taken by an installed Onset tidbit v2 temperature logger set to take one hour readings.

Jim Cole Well (138764) Temperature <u>22.2 °C</u> SWL <u>106.04 ft</u>
Monitoring started at this well on October 10, 2006. A Solinst levelogger was installed in the well to monitor water level changes and temperature. Consistent data has been collected form this well except for 1 period when the transducer was hung up in the pumps wiring.

Gardiner Airport Well (105980) Temperature <u>9.88 °C</u> SWL <u>105.37 ft</u>
A Solinst levelogger was installed at the airport well on September 18, 2006 to monitor water level changes and temperature. Average temperature for the well has been 9.83 °C. Water quality samples were collected on May 10, 2007.

Silver Gate WUA Well (106030) Temperature <u>4.98 °C</u> SWL <u>4.59 ft</u>
This well is now owned by the Pine Edge Cabins in Silvergate. A Solinst levelogger was installed in the well on September 19, 2006 and contains the barologger for making barometric corrections to the leveloggers for the Cooke City area.

Kloster Well (134028) *Temperature*____ *Flow*____
A Solinst levelogger was installed at this site but was later discovered it was installed in the wrong well. The transducer was in an alluvial well like the Silver Gate well but was moved to the proper well in August, 2007 a bedrock aquifer.

Gonzales, C. Well (105959) Temperature <u>14.18 °C</u> SWL <u>66.31 ft</u>
This is the well between the house and the Yellowstone Basin Inn Lodge. A Solinst level-logger was installed in the well on May 5, 2007. Three water quality samples were collected at this site in 2007 and as part of the long term monitoring program the well will not be sampled again until 2010 on a 3-year cycle for water chemistry. No problems were encountered with the water level and temperature logger, a complete recorded for the time period has been collected.

Gonzales, C. Well (145529) Temperature <u>18.12 °C</u> Flow <u>64.62 ft</u>
This well is at the back side (north) of the Yellowstone Basin Inn Lodge. A Solinst level-logger was installed in the well on May 5, 2007. Three water quality samples were

collected at this site in 2007 and as part of the long term monitoring program the well will not be sampled again until 2010 on a 3-year cycle for water chemistry. No problems were encountered with the water level and temperature logger, a complete recorded for the time period has been collected.

USFS Lionshead Spring (181626) Temperature <u>no data</u> Flow <u>no data</u>
On May 8, 2007 the spring was sampled for water chemistry. The spring was found to be dry on the returning visits, August 8, 2007 and again on October 3, 2007. In October a 0.4 H-flume weir was installed to measure flow along with a Solinst levelogger to record water levels and temperature. In the spring of 2008 the weir was washed out and could not be found, but the data logger was found. The weir needs to be replaced.

USFS Beaver Creek Spring (181930) Temperature <u>10.7 °C</u> Flow <u>8.1 gpm</u>
The spring was sampled for water chemistry on May 9, 2007. The spring was found to be dry on the returning visits, July 31, 2007 and again on October 3, 2007. In October a 0.6 H-flume weir was installed to measure flow along with a Solinst levelogger to record water levels and temperature.

USFS Sheep Camp Spring (230654) Temperature <u>7.6 °C</u> Flow <u>1.4 gpm</u>
The spring was visited on May 9, 2007 and found to be frozen with no flow. The site was visited again on July 31, 2007. The spring was flowing at this visit, a water sample was collected and a 0.75 H-flume was installed with OTT Thalimedes float recorder and data logger. The flume was found to be to large for the amount of flow at the spring so it was replaced with a 0.6 H-flume cemented in place. A better platform and stilling well for the float recorder has also been built.

Jim Cole Spring (181620) Temperature <u>9.47 °C</u> Flow <u>3.91 gpm</u>
The spring is located directly uphill approximately 5500 feet from Mr. Cole's house. A totalizing and gpm flow meter was installed on the discharge pipe below the spring box with an attached metro-log digital flow recorder set to take hourly flow readings. Temperatures reading are taken by an installed Onset tidbit v2 temperature logger set to take one hour readings. The metro-logger at this site has failed and will be replaced with a more reliable data logger.

Sperano Spring (181621) Temperature <u>new site</u> Flow <u>new site</u>
The owner gave permission to monitor this spring in June, 2008. The spring is located approximately 0.2 miles south east of the owner's home. The spring has been sampled 3 times for water quality and flow-temperature monitor equipment will be installed in the spring of 2009.

McPherson Spring (182012) Temperature <u>new site</u> Flow <u>new site</u>
The spring is located north east of the owner's home across the pasture and up the hillside approximately 200 feet. Permission by the owner to monitor this spring was given on 09/24/08 and has been sample once for water quality. Monitoring equipment will be installed as weather permits.

Bill Powell/Irving Friedman Spring (181934) Temperature <u>new site</u> Flow <u>new site</u>
Bud Powell (Bill) is son of Bill Powell and President of the LaDuke Water Users Association. This water users association services 4 houses from a spring where water is collected underground through a series of perforated pipes that is feed to a 2000 gallon

collection tank. Permission was given by Bud Powell to monitor the spring on 9/26/08 and one water quality sample has been collected. Monitoring equipment will be installed as weather permits.

CUT Well Abandonment

In April 1986, the Church Universal and Triumphant (CUT) drilled a 140 meter (458 ft) deep well across from LaDuke Hot Spring and slightly upstream on the Yellowstone River. This well encountered hot geothermal waters and has since been known as the CUT geothermal well. In September 1986, a pump test was conducted on the well to investigate its potential to heat a number of buildings and to fill a thermal pool. Pumping the well at 25 L/s (396 gpm) for 13 hours resulted in a 92 percent reduction in flow at LaDuke Hot Spring (Sorey et al, 1991). The well has been unused since that time.

Working with the cooperation of CUT, TOC proposed sealing and abandoning the CUT geothermal well thereby protecting LaDuke Hot Spring's. To determine the best procedures for abandoning the well, MBMG conducted a three phase approach. Phase I involved well evaluation and monitoring. Phase II involved well abandonment design and solicitation of contractors. Phase III consisted of the abandonment of the well. Well evaluation and monitoring by MBMG included inspection of the well with a borehole camera and completion of temperature profiles of the water column to document breaks in the casing and locations of flow loss. MBMG also collected water samples for chemical analysis and used a current meter to attempt to identify different sources of water entering the well and to detect flow within the well. Full details of the CUT well abandonment are presented by MBMG in a report titled Abandonment of The Church Universal and Triumphant Geothermal Well (Kerschen and Metesh, 2008).

MBMG presented TOC with the results of their evaluation of the CUT geothermal well along with existing information. TOC recommended the well be abandoned by pumping a bentonite clay grout from the bottom of the well to the surface through a tremie pipe. Bentonite was chosen because it expands up to 10 times its dry volume to form a dense gel that will flow to fill voids created if there is any further movement or collapse of the casing or borehole.

Abandonment work began on 3/10/2008 with pumping a bentonite grout down the well. Much of this grout was lost to open fractures and voids in the bottom of the well along with reacting to formation water. By 5/7/08 2,145 gallons of bentonite grout had been placed in the well to seal of the open borehole with the bottom of the casing. A neat cement was used to complete the sealing of the well by pouring a 44 foot plug; allowing it to set for 48 hours before continuing with 2 more pours of neat cement grout over a 2 day period. The well was filled to 3 feet below ground surface, the casing was cut off and the hole was backfilled with natural material to complete abandonment of the well.

Re-evaluation of CGA Boundary

TOC deliberated whether the boundary of the CGA in the Big Sky area is appropriate to protect the Park geothermal resources from rapid development in that area. Mapping by Kellogg and Williams (2000) and studies by Montana State University Earth Science students Mark Schaffer and Dan Blythe provided updated information on the extent of Madison Group outcrops and interaction between ground water and surface water along the Gallatin River. Shafer documented that ground water discharges to the Gallatin River at the Madison Outcrop near Big Sky, contributing approximately one third of the flow in the River below that point. The Working group assumed that site was a recharge area for the Madison as justification for placing the CGA boundary along this reach of the Gallatin. Blythe constructed geologic cross-sections which indicate the area of contribution from the Madison Aquifer to the springs is restricted. Blythe also measured streambed temperature and found some warm areas that suggest discharge possibly linked to outflow from Snow Flake Spring, indicating the significance of discharge in the Big Sky area is not obvious. Blythe's geologic cross sections and Schaffer's discharge study support the conclusion that extensive recharge to the Madison at the point the Working Group hypothesized is unlikely. Discharge to the Gallatin at Big Sky could be Madison water, but it also could be shallow upwelling of alluvial ground water at the pinch point where alluvium thins and narrows. The important question that needs to be answered is whether the Madison is hydraulically connected to the Gallatin River, regardless of whether the Madison receives recharge from or discharges to the River. The River will serve as a hydraulic boundary to the Madison Aquifer in the Big Sky area, thereby limiting propagation of drawdown toward the Park, if there is a close hydraulic connection. Alternatively, drawdown could propagate beneath the River toward the Park and potentially affect geothermal resources if there no or a poor hydraulic connection. Overall, the available data indicate the assumption of the Working Group was incorrect, but TOC concluded there is no evidence that the boundary needs to be moved further from the Park toward Big Sky. The data may suggest that, if anything, that the boundary in the Big Sky area should be moved closer to the Park. Another complication is that the carbonates in the Park may not be Madison rocks but rather may be related to metamorphic reactions. There is a clear need for additional studies in this area to resolve open questions.

Recommendations

The Compact was established to protect the geothermal resources of YNP. Long-term monitoring of wells and springs necessary to assess impacts of future development on the Park's geothermal system is the most important means to meet this goal. TOC should continue to proactively encourage data collection, analysis and review to protect the hydrothermal flow system of YNP.

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