MICHIGAN STATE UNIVERSITY WATER SUPPLY AND CONSUMPTION REPORT

By

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ABSTRACT

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BY

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Obtaining water supply and consumption data is the first step towards formulating a water conservation program. It is important to quantify the volume of water used, the major users, and the potential sources of losses or leaks in order to be able to target areas of need.

This report quantifies and summarizes water supply and consumption on the Michigan State University (MSU) East Lansing main campus. Eleven different categories or sectors were evaluated in terms of their impact on water supply and consumption along with quantification methods. These are: Metering, Power Plant, Chilled Water, Irrigation, Research/South Campus Farms, Residence Halls, General Fund Buildings, Athletic Buildings, Water Sold by MSU, Water Bought by MSU, and a Miscellaneous category targeting flushing and unaccounted for water.

Eighty-one percent (81%) of water consumption on the MSU campus can be accounted for in 5 of these sectors. The sectors along with the estimated volumes and percentages of water utilized are: the Power Plant (411,000 KGAL per year, 21%), Research/South Campus Farms (393,000 KGAL per year, 20%), Residence Halls (336,000 KGAL per year, 18%), General Fund Buildings (290,000 KGAL per year, 15%), and Chilled Water (133,333 KGAL, 7%). Fifteen percent (15%) of the water utilized on campus cannot be unaccounted for. This is believed to be due to inaccurate metering, insufficient metering (since not all buildings are metered), and leaks.

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## Michigan State University Campus

The Michigan State University (MSU) Campus has a contiguous area of 5,200 acres (21 $km^2$), 2,000 acres (8.1 $km^2$) of which are developed. In terms of infrastructure, there are 556 buildings: 100 for academics, 131 for agriculture, 166 for housing and food service, and 42 for athletics. Overall, the university has 22,763,025 square feet (2,114,754.2 $m^2$) of total indoor space. For the sake of simplicity, in this report we have divided the campus into two sections. Main (North and South) Campus includes all property and buildings north of Mount Hope Road, bounded by Hagadorn Road on the east, Route 127 on the west and Grand River Avenue on the north. South Campus: Research Farms includes all contiguous property owned and maintained by MSU south of Mount Hope Road, west of Hagadorn Road and east of Route 127

## MSU Water Supply

The majority of the water supplied to the Michigan State University campus is pumped from the Saginaw Aquifer. However, water is also pumped from the Red Cedar River (for irrigation) and purchased from East Lansing/Meridian Township, Lansing Board of Water and Light, and from private companies, which supply bottled water to some departments.

### Wells

Water to the Michigan State University campus is supplied by 18 wells, which pump directly from the Saginaw Aquifer. These wells pump into a one million gallon reservoir where water is then chlorinated and distributed for potable use, chilled water, and irrigation. This water is also used for cooling water in the Power Plant. For simplicity, these wells will be denoted as “main” wells in this report.

In addition to the 18 wells that supply campus there are also a number of wells (estimated at 11) and are herein called “irrigation” wells. It is estimated that these wells supply significantly less water than the 18 main wells. While most of this water is used for irrigation, the water is also used for domestic purposes (hand-washing, flushing, and some human consumption) in a number of these buildings. Below are tables showing water productivity on the Michigan State University campus.

Table 1: Water System

| Water System | |
|---|---|
| # of wells | 18 |
| Nominal Well Capacity (GPM) | 9000 |
| Reservoir Storage Capacity (Gal) | 1,200,000 |
| Reservoir Pump Capacity (GPM) | 9,600 |

Source: Physical Plant Division 2008-2009 Annual Report

Table 2: Peak Annual Water Demand

| Peak Demands | 2004-2005 | 2005-2006 | 2006-2007 | 2007-2008 | 2008-2009 |
|---|---|---|---|---|---|
| Water (GPM) | 5,800 | 6,300 | 5,600 | 6,400 | 6,300 |

Source: Physical Plant Division 2008-2009 Annual Report

Table 3: Water Production

| Water Production and Consumption | | | | | |
|---|---|---|---|---|---|
| Year | 2004-2005 | 2005-2006 | 2006-2007 | 2007-2008 | 2008-2009 |
| Volume pumped from Main Wells (MGAL/yr) | 2047 | 2185 | 1878 | 1801 | 1670 |
| Volume pumped At Reservoir outlet (MGAL/yr) | 1527 | 1587 | 1554 | 1533 | 1415 |
| Volume pumped from Irrigation Wells (MGAL) | 520 | 598 | 324 | 268 | 255 |

Source: Physical Plant Division 2008-2009 Annual Report

## Red Cedar River

Water from the Red Cedar River is also used for irrigation. The Ingham County Health Department, monitors the Red Cedar River as it flows through the county for *E. coli* on a weekly basis from May through September. In East Lansing samples are collected at Hagadorn Road, the Farm Lane Bridge, and Harrison Road. The Health Department advises that significant rain events (>1/4 inch in 48 hours) may increase *E. coli* counts, making the water unsafe for recreational activities. (Results of the sampling can be found at the website: http://hd.ingham.org/environmental-health/other-services/water-quality/community-surface-water-sampling.aspx). Water from the Red Cedar River is used solely for irrigation, primarily, for the athletic fields on campus. Signs are prominently posted, where appropriate, indicating that these fields are irrigated with non-potable water. The lines are also posted as non-potable water. Below is a table of water pumped from the Red Cedar River on an annual basis from 2004-2008. The total amount of land irrigated using water from the Red Cedar River is 48.46 acres.

Table 4: Red Cedar Supply

Water Supplied from Red Cedar River

| Year | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|
| Volume pumped (MGAL/yr) | 14.05 | 28.64 | 13.53 | 13.68 | 17.71 |

Source: MSU Land Management Office, Personal Communication, 10/15/2009

## Water Bought and Sold

In addition to the water that is supplied to the MSU campus by wells; the East Lansing/Meridian Township Water Treatment Plant and Lansing Board of Water and Light supply a small portion of water used on campus for the buildings listed in Table 5.

Table 5: Water Purchased (Averaged over 2004-2008)

| | Water Purchased (KGAL/yr) |
|---|---|
| University village (East Lansing/Meridian Township) | 3,000 |
| Central School (Lansing Board of Water and Light) | 110 |
| Horse Research Facility (Lansing Board of Water and Light) | 81 |
| Henry Center (Lansing Board of Water and Light) | 1400 |

Table 5 Cont.

| | |
|---|---|
| Chemical Waste facility (Lansing Board of Water and Light) | 5 |
| Entomology (Lansing Board of Water and Light) | 43 |
| Civil Lab Jolly Road (Lansing Board of Water and Light) | 600 |
| Total | 5,200 |

Source: MSU Power Plant, Personal Communication, 3/2/2010

The total water purchased annually at MSU is 5200 KGAL. This is small compared to the amount of water pumped from the MSU main wells (0.3%).

Water supplied from the MSU main wells is also sold by MSU to the entities shown in Table 6.

Table 6: Water Sold from Main Wells

| | Average Amount of Water Bought from MSU in 2005-2009 (KGAL) |
|---|---|
| State Control Laboratory | 6500 |
| MSU Credit Union* | 1000 |
| Michigan State Police | 7600 |
| USDA Agricultural Research | 2300 |
| TOTAL | 17400 |

Source: MSU Power Plant, Personal Communication, 3/2/2010

* Although the MSU Federal Credit Union vacated the property on Crescent Rd., the January 2010 Utility Report still lists this as MSU Federal Credit Union. As such, we have used this label herein.

The average annual amount of water from the MSU main wells sold to non-MSU entities is 17,400 KGAL. This is 1% of the total amount of water pumped from the main wells on campus.

## Bottled Water

Bottled water is a source of drinking water on campus. The evaluation of bottled water use on campus needs to be completed and recommendations need to be put in place to reduce bottled water use; however details are beyond the scope of this report. Bottled water has not been included in the total water supplied to or used on the MSU campus. From 2007 to June of

2009 nearly 2 million bottles of water were sold on campus. Through measures such as the installation of filtration units in residence halls, MSU is striving to reduce bottled water use. MSU has also campaigned for reusable water bottle use in residence halls by distributing flyers and refillable bottles to new residents and providing hydration stations in the residence halls.

## Meters

Metering is important to water purveyors because it makes it possible to charge customers based on the amount of water they use. Metering can also be beneficial because it encourages users to conserve water, and holds the consumers responsible for their water use. A study completed by Steve H. Hanke of John Hopkins University concluded that domestic use of water was reduced by 36% after meter installation (Hanke, 1970). Meters also allow suppliers to keep track of the amount of water they pump and produce for the consumers. Metering also helps in determining if there are leaks in the distribution system, based on the difference between the amount of water that is pumped and the amount of water used.

### Metering at MSU

Some of the MSU buildings on campus are metered. Meter readings are checked once a week. A list of building meters with dates of installation is shown below in Table 7. (Dates listed first without months were provided by Pat Curry, all dates after given by the MSU Power Plant)

Table 7: Meters with Known Installation Dates

| Bldg # | Building Name | Meter | Date of Installation |
|---|---|---|---|
| 0189 | REGIONAL CHILLED WATER PLANT NO. 1 | 0189W1 | 1971 |
| 0059 | MUNN, CLARENCE L., ICE ARENA | 0059W1 | 1974 |
| 77 | FOOTBALL BUILDING | 0077W1 | 1980 |
| 85 | WHARTON CENTER | 0085W1 | 1982 |
| 0084 | COMMUNICATION ARTS & SCIENCES BUILDING | 0084W1 | 1984 |
| 0203A | ENGINEERING RESEARCH COMPLEX | 0203W1 | 1986 |
| 0069 | BRESLIN, JACK, STUDENT EVENTS CENTER | 0069W1 | 1989 |
| 0080 | BUSINESS COLLEGE COMPLEX (EPPLEY) (Meter Date for North Complex) | 0080W1 | 1993 |
| 0186 | FOOD SAFETY AND TOXICOLOGY BUILDING | 0186W1 | 1997 |
| 0212A | PAVILION FOR AGRICULTURE AND LIVESTOCK EDUCATION - HORSE BAR | 0212W1 | 2000 |
| 0160 | BIOMEDICAL PHYSICAL SCIENCES BUILDING | 0160W1 | 2005 |
| 0313 | BRODY HALL (East Lansing Water 2010) | 0313W1 | 2010 |
| 0175 | INTRAMURAL RECREATIVE SPORTS EAST | 0175W1 | 2010 |

Table 7 Cont.

| | | | |
|---|---|---|---|
| 0311 | RATHER HALL (East Lansing Water as of 2010) | 0311W1 | 2010 |
| 0312 | BRYAN HALL (East Lansing Water 2010) | 0312W1 | 2010 |
| 0314 | EMMONS HALL (East Lansing Water 2010) | 0314W1 | 2010 |
| 0315 | BAILEY HALL (East Lansing Water 2010) | 0315W1 | 2010 |
| 0310 | BUTTERFIELD HALL (East Lansing Water 2010) | 0310W1 | 2010 |
| 0171 | FOOD STORES | 0171W1 | 2010 |
| 167 | PHYSICAL PLANT | | 2010 |
| 158 | GROUNDS HEADQUARTERS | | 2010 |
| 0024 | NATURAL SCIENCE | 0024W1 | Jan-97 |
| 0128 | NISBET, STEVEN S., BUILDING | 0128W1 | May-97 |
| | | 0307W1 | May-97 |
| 0308 | WILLIAMS HALL | 0308W1 | Jun-97 |
| 0304 | CAMPBELL HALL | 0304W1 | Jul-97 |
| 0306 | YAKELEY AND GILCHRIST HALL | 0306W1 | Aug-97 |
| 0302 | MASON AND ABBOT HALL | 0302W1 | Jan-98 |
| 0056 | JENISON FIELDHOUSE | 0056W1 | Aug-98 |
| | | 0077W2 | Nov-98 |
| 0154 | MANLY MILES BUILDING | 0154W1 | Feb-99 |
| 0005 | HUMAN ECOLOGY | 0005W1 | May-99 |
| 0006 | UNION BUILDING | 0006W1 | Aug-00 |
| 0305 | LANDON HALL (Meter installation is expected at the given date) | 0305W1 | Aug-00 |
| 170 | VETERINARY MEDICAL CENTER | 0170W1 | Aug-00 |
| | | 0178W3 | Oct-01 |
| 0086 | PLANT & SOIL SCIENCES BUILDING | 0086W1 | Feb-02 |
| 0219 | PARKING RAMP NO.1 SHAW LANE (NEW) | 0219W1 | Sep-02 |
| 0177 | PACKAGING | 0177W1 | Apr-05 |
| 0058 | SPARTAN STADIUM | 0058W1 | Aug-05 |
| 2000 | CLINICAL CENTER | 2000W1 | Sep-05 |
| 0300 | SNYDER AND PHILLIPS HALL | 0300W1 | Aug-07 |
| 0214 | RADIOLOGY BUILDING | 0214W1 | Nov-07 |
| 0319 | VANHOOSEN HALL | 0319W1 | Nov-07 |
| | | 0170W2 | Nov-07 |
| 0013 | MUSEUM | 0013W1 | Jan-08 |
| 0163 | CHEMISTRY | 0163W1 | Jan-08 |
| | | 0203W2 | Feb-08 |
| | | 0170W3 | Jul-08 |
| 0055 | KELLOGG CENTER | 0055W1 | Mar-09 |
| 0083 | MSU COLLEGE OF LAW | 0083W1 | Jun-09 |
| 0316 | ARMSTRONG HALL | 0316W1 | Aug-09 |
| 0309 | MARY MAYO HALL | 0309W1 | Sep-09 |
| 0028 | GILTNER HALL | 0028W2 | Nov-09 |
| | | 0028W1 | Dec-09 |
| 0323 | WONDERS HALL | 0323W1 | Jan-10 |

Source: Source: MSU Power Plant, Personal Communication, 3/2/2010 and Pat Curry, Personal Communication, 9/28/2010

Below (Table 8) is a list of meters on campus with unknown installation dates; these meters are assumed to be older meters.

Table 8: Buildings with Meters of Unknown Installation Dates

| Bldg # | Building Name | Meter |
|---|---|---|
| 0002 | BERKEY HALL | 0002W1 |
| 0003 | OLIN MEMORIAL HEALTH CENTER | 0003W1 |
| 0027 | PSYCHOLOGY BUILDING | 0027W1 |
| 0029 | KEDZIE HALL (NORTH AND SOUTH) | 0029W1 |
| 0035 | COMPUTER CENTER | 0035W1 |
| | | 0055W2 |
| 0060 | CENTRAL SERVICES BUILDING | 0060W1 |
| | | 0060W2 |
| 0068 | LAUNDRY BUILDING | 0068W1 |
| 0081 | ENGINEERING BUILDING | 0081W1 |
| | | 0081W2 |
| | | 0086W2 |
| 0087 | PUBLIC SAFETY | 0087W1 |
| 0132 | ANTHONY HALL | 0132W1 |
| | | 0132W2 |
| | | 0132W3 |
| | | 0132W4 |
| 0178 | PLANT BIOLOGY LABORATORIES | 0178W1 |
| | | 0178W2 |
| | | 0303W1 |
| 0317 | SHAW HALL | 0317W1 |
| 0320 | OWEN GRADUATE HALL | 0320W1 |
| 0330 | HOLMES HALL | 0330W1 |
| 0446A | VETERINARY RESEARCH CENTER - LARGE ANIMAL BARN | 0446W1 |
| | | 0446W2 |
| 1121 | MUSIC/MUSIC PRACTICE | 1121W1 |
| 7000 | FACULTY BRICK APARTMENTS | 7000W1 |
| 91 | FARRALL AGRICULTURAL ENGINEERING HALL | 0091W1 |

Source: MSU Power Plant, Personal Communication, 3/2/2010

Michigan State University also has meters that are used to monitor water that is purchased from the University. Table 9 lists the location of meters that are used to track the consumption of purchased water.

Table 9: Meters Monitored for Water Purchased from MSU

| Water Meters | |
|---|---|
| 618 | James B. Henry Center |
| 475A | Chemical Waste Facility #1 (Jolly Rd.) |
| 475B | Chemical Waste Facility #2 (Jolly Rd.) |
| 129 | Entomology (Collins Rd.) |
| 456O | Horse Research Center |

Source: MSU Power Plant, Personal Communication, 9/29/2009

### Types of Meters

The type of meters used by MSU varies with the age of the meter. Older meters vary by manufacturer but are turbine meters. Turbine meters have a rotating element that spins as the water passes across it. The volume of water is measured by the number of rotations within the device. Since older meters do not include a strainer they are subject to scaling or the deposition of particulates, which may cause the impeller to stick, resulting in inaccurate readings, usually underestimating flow rates. Minerals may include iron, calcium, manganese, and magnesium precipitates resulting from the natural hardness of the well water. (Rick Johnson, personal comm., 4/29/2010).

At present, the preferred meter for use on campus is the Sensus Omni T2 meter. The Sensus meter utilizes an impeller, but incorporates new “floating ball” technology. The Sensus meter also includes a strainer, which helps to remove debris and particulates, therefore increasing the integrity of the data generated by the meter.

Some buildings employ a Sensus Impulse Contactor that attaches to the meter. This type of meter reads impulses and after a certain volume of water has passed through the meter, the device records that amount. This type of meter does not give total flow rates but rather a volumetric quantity. Flow rates can then be determined manually by dividing the volumetric quantity by the time interval it took to reach that volume.

Photographs of meters that were determined to be old, normal, and new, are provided below.

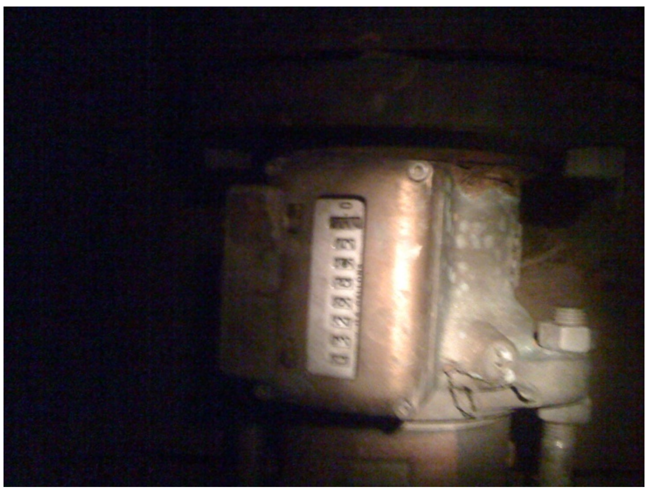

Figure 1: Water Meter (Old Unit) (From MSU Power Plant employee – Rick Johnson, personal communication. 4/29/2010)

Figure 1 was taken of a meter at Berkey Hall, one of the buildings where the installation date of the meter is unknown. This is determined to be an "old meter".


Figure 2: Water Meter (Common Unit)
(From MSU Power Plant employee – Rick Johnson, personal communication. 4/29/2010)

Figure 2 shows a Sensus meter. Although commonly found on campus, these meters are not used for new installations. This meter is located in Olin Memorial Health Center, and the date of installation is unknown.


Figure 3: Water Meter (New Unit) (From MSU Power Plant employee – Rick Johnson, personal communication. 4/29/2010)

The meter shown in Figure 3, which is located in Wonders Hall, is the meter type currently used by the university. This is a Sensus Omni T2 meter and it was installed January 2010.


Figure 4: Water Meter (Impulse Unit) (From MSU Power Plant employee – Rick Johnson, personal communication. 4/29/2010)

Figure 4 shows a meter located in Wilson Hall. This meter has an impulse contactor connected to it. The installation date for this meter is unknown; however it is assumed to be a very recent installation (2010) and is not yet on record.

## Meter Maintenance and Calibration

MSU does not currently have a meter maintenance and calibration program in place, nor is there a meter replacement program in place. Meters are simply replaced when they cease operation. Meters can typically last 15-20 years with proper maintenance, although no data exists for the average operational time for the meters on the MSU campus.

In 2005, Power Plant personnel began using a flow orifice to determine how much water was pumped from each of the 18 main wells. A flow orifice in general is thought to be more accurate than the in-line meters that have been (and continue to be) used to measure the flow rate of water pumped from the main wells. Testing was done once a year. In 2005, it was found that the in-line meters had readings that were as much as 32% greater than the readings obtained using the flow orifice. Because of this discrepancy a program was put into place to clean the in-line meters once a year. By 2009, with regular maintenance the difference between the in-line meter readings and the flow orifice readings were not greater than 7.6%. This shows how important meter maintenance can be. Over the next year (2010) the Power Plant plans to replace the current in-line meters with magnetic flow meters which are thought to be as accurate or even more accurate then the flow orifice devices. (Doug Macdonald, Personal Communication, August 2010)

Also, it is believed based on this study that well production numbers may have been overvalued in the past.

## Recommendations

It is recommended that a water meter maintenance and renewal program be explored. Meters should be checked, cleaned and calibrated every 7 to 10 years (Satterfield, Zane, P. E., and Bhardwaj, Vipin, Water Meter Tech Brief). Because the water at MSU is high in mineral content, maintenance is critically important to ensure proper operation of the meters employed on campus, and the integrity of the data collected.

A renewal program should also be explored to replace all water meters that do not meet current specifications.

Metering is the best way to determine water use, therefore accurate metering is the best way to track and document water consumption on MSU's campus.

## Power Plant

Michigan State University is provided with energy from the T.B. Simon Power Plant. The power plant is a co-generating facility, meaning the facility utilizes the steam once to power turbines to produce electricity, and then it uses the steam to heat and cool the buildings on campus. Because of this co-generation, the power plant is 60% efficient, compared to traditional systems that may only be 30% efficient. Water consumption for the power plant is expected to be high considering the power plant is the main source of energy, heating, and cooling on campus.

The Physical Plant website (http://www.pp.msu.edu/content/power.html) states that in an average year the power plant uses 450,000 KGAL of water. The source of that datum is unknown. Physical plant personnel report the average water consumption for the power plant over the last 6 years as 411,000 KGAL and over the last three years the as 375,000 KGAL(Lynda Boomer, Doug MacDonald and Amanda Groll, Personal Communication, 6/24/2010). The total water used by the power plant for 2008-2009 was 391,000 KGAL (Source: Amanda Groll, Physical Plant, Personal Communication, 10/7/2009). Based on these values (411,000 KGAL), the power plant uses roughly 21% of water consumed at MSU.

## North Campus Substation

The North Campus Sub-station is part of the condensate return system for all of North Campus which returns steam condensate to the power plant for reuse.  There are vacuum pumps that are water cooled in the North Campus Sub-station, which leads to significant water use.

Water is lost in the system when condensate goes to the drain, rather than being returned to the Power Plant. This can cause operational issues at the Power Plant as well as causing higher water consumption due to make-up water being added. (Lynda Boomer)

Water usage in the North Campus substation is not metered.

## Chilled Water Plant

Michigan State University utilizes a chilled water system to cool a large percentage of its buildings and facilities. The chilled water system acts as a steam absorption machine. The absorption chiller has five main phases; condensing, expansion, evaporation, absorption, and a generator or concentrator. In condensing, cooling water absorbs heat from a vaporized refrigerant (steam) thus turning the refrigerant (steam) into a liquid (water). The refrigerant (water) is then expanded on its way to an evaporator. During expansion the temperature of the refrigerant (water) is dropped due to a drop in pressure. The refrigerant (water) is then vaporized in an evaporator by being sprayed on tubes of chilled water; upon vaporization energy is removed from the chilled water. The vaporized refrigerant (steam) is then sprayed with a salt (lithium bromide) which absorbs the refrigerant (water). Cooling water absorbs the heat of vapor absorption. The salt and refrigerant solution (lithium bromide and water) then enters a concentrator where the solution is heated till the refrigerant (water) is vaporized and sent back to the condenser, thus completing the loop (http://www.scribd.com/doc/17553414/Basics-for-Absorption-Chillers). Because MSU's campus utilizes a central steam loop for power from the power plant, absorption chillers are a logical choice. In the summer, the steam produced to generate electricity can also be used to create chilled water, thus increasing the efficiency of the cogeneration power plant by utilizing as much of the thermal energy as possible. Winter operation includes a thermal component for heating (Lynda Boomer). Absorption chillers are also better for the environment because they use water as a refrigerant as opposed to electric chillers, which use chlorine based chlorofluorocarbons (CFCs) or hydrochlorofluorcarbons (HCFCs) refrigerants. CFCs and HCFCs, while effective refrigerants, have been implicated in the formation of the "ozone hole" and are regulated under Title VI of the Clean Air Act.  Since the absorption chillers on campus require a large volume of refrigerant for cooling purposes, a water-based system is also more economical then an electrical based system because the steam produced from the power plant is used for the refrigerant.

## Water Consumption

Chilled water is provided from the central chilled water plant and from individual chillers around campus. Because steam absorption is not 100% efficient, the system requires water to make up for evaporation in the system and other losses. Shown in Table 10 are the volumes of make-up water used during 2008 from each of the individual chillers. Building names highlighted in light green denote systems that are run year round. Data under the volume column that are highlighted in green denote "General Fund Buildings". Volumes of make-up water for 2007 can be found in the Appendix F. Furthermore, buildings that have refrigeration labels are labeled as such because they are designated as refrigerators or cold rooms. Buildings that are labeled with absorption are designated as such, as they use chilled water for cooling the air in the building. Both the refrigerated systems and the absorption systems use chilled water.

Table 10: Chilled Water Make-Up 2008

| BUILDING | Volume (KGAL) |
|---|---|
| Comm. Arts | 6 |
| Anthony - REFRIGERATION | 74 |
| CIPS Refrigeration | 102 |
| Clinical Center Refrigeration | 105 |
| Biochemistry Refrigeration | 157 |
| Natural Resources Refrigeration | 169 |
| Anthony - Dairy Plant Refrigeration | 253 |
| Olin Health Center Refrigeration | 253 |
| International Center | 511 |
| Administration Building - DATA | 601 |

| Table 10 Cont. PROCESSING | |
|---|---|
| Kedzie Hall Absorption | 684 |
| Anthony - Meat Laboratory Refrigeration | 837 |
| Breslin Center Absorption | 1,072 |
| Administration Building | 1,170 |
| Cyclotron CT-1 Refrigeration | 1,172 |
| Regional Chilled Water Plant 10 | 1,197 |
| Wells Hall Absorption | 1,296 |
| Bessey Hall Absorption | 1,396 |
| Munn Ice Arena Refrigeration | 1,396 |
| Union Building Absorption | 1,573 |
| Regional Chilled Water Plant 8 | 1,732 |
| Regional Chilled Water Plant 7 | 1,992 |
| Kellogg Center (East) | 2,225 |
| Engineering Absorption | 2,696 |
| Fee Hall Absorption | 2,782 |
| Regional Chilled Water Plant 9 | 2,898 |
| DCPAH-Diagnostic Center for Population and Animal Health | 3,385 |
| Regional Chilled Water Plant 5 | 3,437 |
| Erickson Hall Absorption | 4,107 |
| Library Absorption | 4,524 |
| Kellogg Center (West) | 4,806 |
| Anthony – ABSORPTION | 5,424 |
| Food Science Absorption | 5,511 |
| Regional Chilled Water Plant 4 | 5,675 |
| Regional Chilled Water Plant 2 | 5,879 |
| Regional Chilled Water Plant 6 | 5,977 |
| Regional Chilled Water Plant 3 | 6,077 |
| Regional Chilled Water Plant 1 | 6,299 |
| Biophysical Science | 12,690 |

Source: Physical Plant, Personal Communication, 9/18/2009 (For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis)

The total water consumption for make-up water in the chilled water absorption system was 102,000 KGAL during 2008.

Figure 5 shows the distribution of makeup water for each of the buildings listed in Table 10. Green bars indicate “General Fund Buildings”. As shown, the largest user of make-up water is the Biophysical Science Building. The cause for this is unknown.

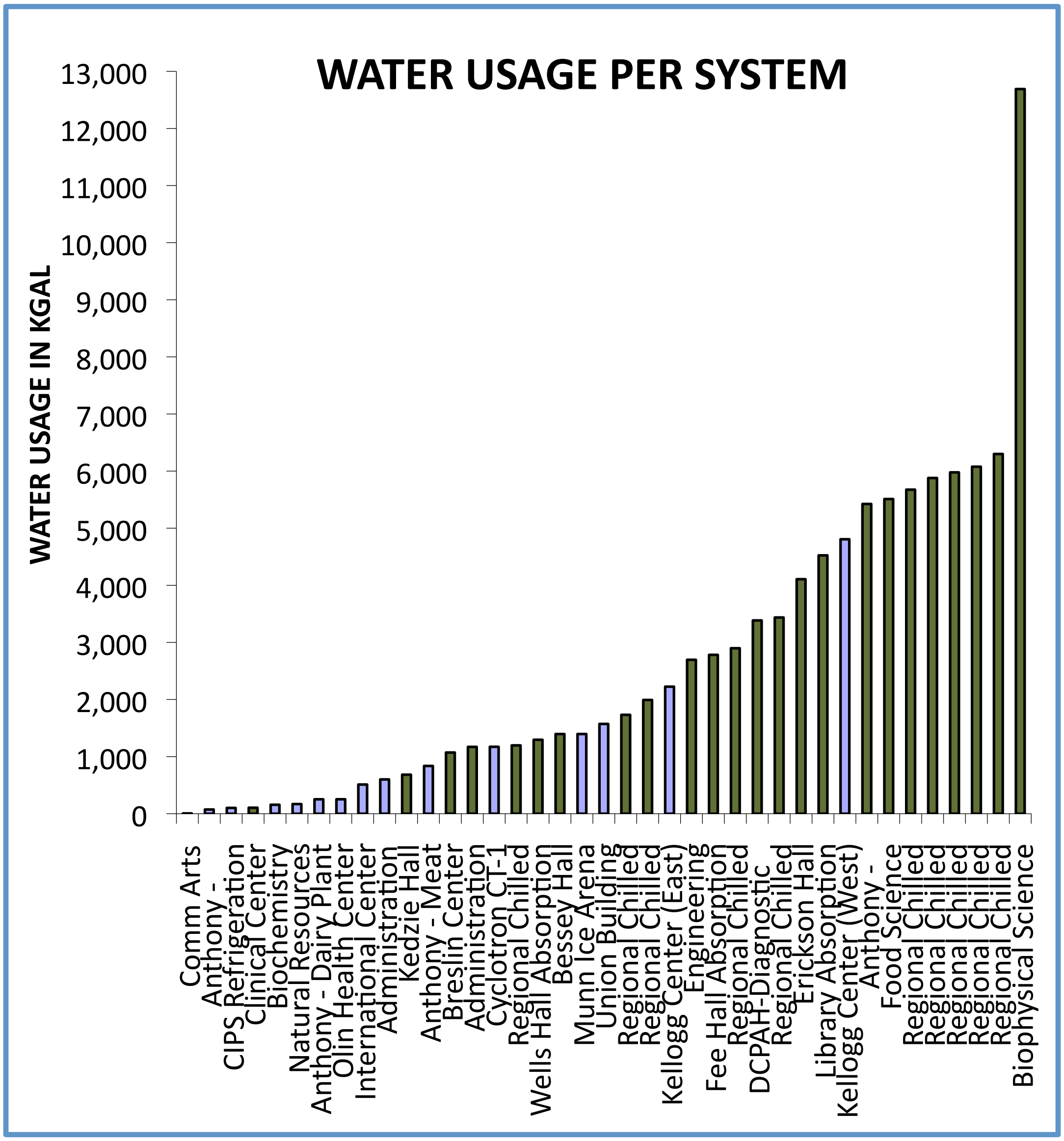


Figure 5: Chilled Water Make-Up 2008 (Source: Physical Plant, Personal Communication, 9/18/2009)

Data are also available for the consumption of water in the Regional Chilled Water Plant building. The Regional Chilled Water Plant building is responsible for providing chilled water to campus. This building is not part of the central power plant. The data for water consumption from 2005-2008 are shown below:

Table 11: Annual Water Consumption by the Regional Chilled Water Building

| Year | KGAL |
|---|---|
| 2005 | 65275 |
| 2006 | 24348 |
| 2007 | 20115 |
| 2008 | 15461 |
| Average | 31300 |

Source: Power Plant, Personal Communication, 9/29/2010

The average value given above is the total amount of water consumed in the plant, not only for chilled water purposes, but also for potable water uses such as sinks and toilets in restrooms. As shown in Table 11, water use in the regional Chilled Water Building shows a decrease from 2005-2008. The reason for this decrease is unknown, but volumes are significant.

When the volume of make-up water from each individual chiller is added to the volume of water consumed at the Regional Chilled Water Plant, the total estimated annual water consumption due to chilled water is 133,300 KGAL or roughly 7% of water used on campus.

It should be noted that the North Campus Chilled Water Sub-station is not monitored. Because of this it is expected that the consumption of water for the chilled water system is actually greater than that reported herein.

## Recommendations

A study to determine the efficiency of the chilled water system and whether there are newer technologies that can increase the efficiency of the system is recommended. However, considering that chilled water accounts for only approximately 7% of the total water consumption, efforts might be better focused in a higher use category.

## Irrigation

Water for irrigation is supplied from three sources: irrigation wells, the University well system, and the Red Cedar River. Eleven irrigation wells are used to irrigate Main Campus and South Campus Farms. The University well system, consisting of 18 wells and feeding a main reservoir (1 million gallon storage tank), is also used for irrigation of a limited number of locations. Water from the Red Cedar River is used to irrigate 48.46 acres. (See Table 12 for complete list of acreage irrigated on campus). Maps showing the areas on campus that are irrigated are provided in Appendix G.

### Irrigation Water Supply – Main Campus

Irrigation water for the Main (North and South) Campus is obtained from three sources: the university well system, two irrigation wells, and the Red Cedar River. Where water is used from the university well system, the water is supplied from the potable water lines supplied to the adjacent building(s).

A complete listing of areas on campus that are irrigated with water from the university well system is not available. However, it is thought that the gardens surrounding the Biophysical Science and old-Horticulture Buildings are irrigated using water from the university well system. In fact, water meters were installed in these buildings to monitor water used for irrigation. No data has been supplied for this report. (Personal Communication, Pat Curry, 9/28/2010).

Although the withdrawal is denoted as “Well Red Cedar SW”in the water use reports, water that is supplied by the Red Cedar River is pumped directly from the river. The water is initially filtered by a fine mesh filtration system. In 2002, a computerized Toro Sentinel Central Control system was installed to ensure that irrigation water is not obtained from the river after a rainfall of greater than 1/8 inch. After such rainfall events, the system is programmed to skip an irrigation cycle, thus complying with MSU policy. It is believed that the aeration of the water through the pump and sprinkler head diminishes the number of *E-coli* bacteria in the water (Frank, personal comm., 1/6/2010). A list of areas that are irrigated by the Red Cedar River is provided in Table 12. The east lawn of Brody Complex is the only area surrounding residence halls that is irrigated.

Table 12: Areas on Main Campus Irrigated with water from the Red Cedar River

| Locations Irrigated by Red Cedar |
|---|
| Adams Field |
| Admin Bldg |
| Breslin |
| Kellogg Center |
| Cowles House |
| Baseball Diamond |
| Demonstration Hall |
| Football Practice Field |
| Munn Ice Arena |
| Soccer Fields |
| Track |
| Beal Garden |
| Brody Complex |
| Munn Field |
| Lot 79 |

Source: Steve Frank, Personal Communication, 2/10/2010

Irrigation water for the Main (North and South) Campus is also obtained from two wells: IM East and Stadium, which are used to irrigate the grounds around IM East and the Stadium, respectively. The location and acreage irrigated along with the Well ID are provided in Table 13.

Table 13 Wells Supplying Irrigation Water on Main Campus

| Facility | Well ID | Area irrigated in 2008 (acres) |
|---|---|---|
| Grounds - IM East | IM East | 13.5 |
| Stadium | Stadium | 2 |

Source: MSU Land Management Office, Personal Communication, 10/15/2009

### Irrigation Water Supply – South Campus: Research Farms

On the South Campus: Research Farms, water for irrigation is obtained from the main university well system and from 10 irrigation wells. The main University well system serves the Golf Courses, Turf Grass, Plant Pathology, Tree Research, and Horticulture-Sand Hill. The irrigation wells supply the remaining areas of the South Campus: Research Farms. Table 14 lists the wells along with their locations and areas irrigated in 2008.

Table 14: Irrigation Wells on South Campus: Farms

| Facility | Well ID | Area Irrigated in 2008 (acres) |
|---|---|---|
| Agronomy | Quonset | 6.5 |
| Agronomy | Soils Farm | 0 |
| Grounds – EDC | EDC | 4 |
| Horticulture | Domestic Well | 11 |
| Horticulture | Irrigation Well | 50.6 |
| Inland Lakes | Lake #1 | 8.1 |
| Plant Pathology | Irrigation Well | 4 |
| Upper Fish Lab | #1-New-West | 0 |
| Upper Fish Lab | #2-Old-East | 0 |
| Vet Farm - Bennett | Bennett Farm | 0 |

Source: MSU Land Management Office, Personal Communication, 10/15/2009

## Consumption of Water

It is difficult to determine the exact volume of water that is used for irrigation. As mentioned earlier, on the Main Campus several areas are irrigated using water from the distribution system fed by the University wells. No sub-metering of buildings is conducted, so it is not possible to distinguish between volumes of water used for irrigation from those used for drinking and bathroom and laboratory use. For example, the grounds surrounding the Plant and Soil Sciences building and the Horticulture Demonstration Gardens are irrigated using water obtained from a General Fund Building, and as such would not be reported as irrigation water use, but as water consumed by a specific "building".

As mentioned earlier, the Golf Courses, Turf Grass, Plant Pathology, Plant Pathology-East, Tree Research, and Horticulture - Sand Hill Farm are irrigated using water from the main University water system. Water is supplied directly from the wells before it enters the reservoir. As such, the total volume of University well water used directly for irrigation can be determined using the equation:

$$\text{Volume} = (\Sigma Q_n - Q_r)\ t$$

where Q = flow rate from each individual well
n = well number
r = Flow rate from the reservoir
t = time.

Using this equation and data from the "Physical Plant Division 2008-2009 Annual Report", the average volume of water pumped directly from the main University well system and used for irrigation and research was 393,000 KGAL during 2004-2008. This is roughly 20% of the annual water consumption on campus for 2004-2008. The complete data set is presented in Appendix A.

One source of error in this data set may include losses of water in the distribution system between the wellhead/pump and the outlet of the reservoir. Another source of error may be due to inaccuracy of the meters. Because there are no meter validation or leak detection programs currently in place, we are not able to assess the magnitude of these errors.

The irrigation wells on both the Main and South Campus; Research Farms are not metered. Volumes of water used for irrigation are estimated from the following equation:

Volume = (t)(Q)(n)
where, t = the time (h) each sprinkler head is turned on
Q = the flow rate from each sprinkler head (gal/h)
n = number of sprinkler heads.

The flow rate, Q, is not measured; the rate is obtained based on manufacturer specifications provided at the time of purchase. The flow rate will vary due to differences in a number of parameters, including the pressure at the well and in the nozzle, length of hose, and in the size of the sprinkler nozzle aperture. The aperture is likely to decrease in size with time due to the deposition of minerals near or in the nozzles or clogging of the aperture by organic material. Another challenge in accurately determining flow rates is that the irrigation well water may be used for other purposes. For example, the well at Horticulture (identified as “Domestic”) feeds both the irrigation line and the plumbing for domestic toilet flushing and hand-washing.

The estimated average annual volume of water consumed from irrigation wells during the period from 2004 to 2008 for irrigation using water from the irrigation wells is documented in Table 15, and a complete set of data is shown in Appendix G. It should be noted that this list includes irrigation wells on both Main Campus and South Campus: Research Farms.

Table 15: Water Consumption from Irrigation Wells

| Facility | Well ID | Average Annual Usage (KGAL) |
|---|---|---|
| Agronomy | Quonset | 101 |
| Agronomy | Soils Farm | - |
| Grounds – EDC | EDC | 843 |
| Grounds - IM East | IM East | 6,163 |
| Horticulture | Domestic Well | 541 |
| Horticulture | Irrigation Well | 1,846 |
| Inland Lakes | Lake #1 | 5,005 |
| Plant Pathology | Irrigation Well | 210 |
| Stadium | Stadium | 640 |
| Upper Fish Lab | #1-New-West | 259 |
| Upper Fish Lab | #2-Old-East | 1,589 |
| Vet Farm - Bennett | Bennett Farm | 59 |
| | Total | 18,255 |

Source: MSU Land Management Office, Personal Communication, 10/15/2009
(Complete data presented in Appendix G).

Based on this data, the average volume of water pumped annually from the irrigation wells is estimated to be 18,300 KGAL per year, amounting to roughly 1% of the total water use on campus.

It should be noted that water used for irrigation on the South Campus Farms is necessary for research, extension and demonstration. Very little irrigation water is used on the South

Campus: Research Farms for general production and activities. (MSU Land Management Office, Personal Communication, 7/2/2010)

The average volume of Red Cedar River water consumed (during the period of time from 2004 to 2008) for irrigation is 17,522 KGAL/yr. The volume is determined from the average of the annual volume pumped from the Red Cedar River and metered at the "well" designated Red Cedar – SW. This amounts to approximately 1% of the total water used on campus.

Summing the volumes from the irrigation well, the Red Cedar River, and main well system together (Research and South Campus Farms), the total annual water consumption on the MSU campus for irrigation is approximately 429,000 KGAL and roughly 22% of total water use on campus.

### Conservation Measures

The Land Management Office oversees the irrigation of South Campus: Research Farms while Physical Plant-Landscape Services manages irrigation on the Main Campus. Numerous conservation measures have been implemented across campus. These include, but are not limited to: low mow and water conserving turf, expanded use of drip irrigation, drip lines and a computerized system. A computerized system allows for a more advanced and accurate system for irrigation, and also allows for leak detection and automated shutdown. A complete list of conservation practices is provided in Appendix G.

## Recommendations

Because the irrigation sources are either not metered or the metered data is not collected and evaluated, if additional water conservation measures for irrigation are to be implemented, it is advisable to better quantify the volumes of water used for irrigation. Therefore, it is recommended that a metering program be put in place. This includes metering of irrigation wells, as well as sub metering of buildings that provide domestic water for irrigation purposes.

## Residence Hall Water Consumption

Residence Halls at MSU are divided into six areas or "neighborhoods": Brody, East, Red Cedar, River Trail, South, and West Circle. In addition there are four University apartment areas: Spartan Village, Faculty Bricks, Cherry Lane and University Village (newly opened 2007). Eighty-eight buildings came to the end of their expected useful life between 2002-2009 and have been demolished in Spartan Village and Old University Village area. Numerous renovations of residence halls have been completed in the last 10 years, including Shaw (residential wings), Snyder-Phillips (residential wings and The Gallery Cafeteria), Mason Abbot (residential wings) and Holden (center section) and Mayo Hall. Hubbard Hall (center section), Emmons Hall and Brody Building were renovated during Summer 2010.

The most significant and most recent renovation is that of the center building in Brody Complex, which will be completed by September 2011. Once complete, Brody Complex will be served by East Lansing/Meridian Township water treatment plant. University Village was opened in 2007 and is on East Lansing/Meridian Township water. Cherry Lane and Faculty Bricks Apartments are due to be closed and demolished beginning in summer of 2011. Details regarding these and other renovations will be discussed later in this report.

Use of residence halls during the summer months is highly variable and this complicates the interpretation of water consumption data. . For example South Complex residence halls are used extensively for sports camps. Case and Wilson halls are currently used for Academic and Parent Orientation Programs (AOP/POP). Snyder-Phillips and Owen Halls are used extensively for summer school and conferences. East Complex halls are also used extensively for summer conferences, (two of the East Complex Halls were used in Summer 2009 and 2010 for conferences and two were off line for a majority of the both summer sessions because of construction activities). Hubbard Hall was not used in Summer 2010 because of center section renovations.

As of May 2010, all 24 residence halls are metered for water consumption. However, until August 2007, the only halls that were metered were: Brody, Williams, Campbell, Yakeley and Gilchrist, Mason and Abbot, Rather, Landon, Bryan, Emmons, Bailey, Shaw, Owen, and Butterfield. Meters were installed in Snyder-Phillips and Van Hoosen Halls in August and November 2007, respectively. Prior to the installation of meters in Holden, Wilson, Case, Wonders, McDonel, Hubbard, Akers, Holmes, and Mayo, water usage in these buildings was estimated by Physical Plant. Estimates for Holmes, Wonders, and Mayo have been included in our analysis. Based on the data reported for the period from 2004 to 2008 (i.e., the data that was available when this report was begun), residence hall metering data has been extensively analyzed. Eighteen (18) of the 24 residence halls on the Michigan State (MSU) campus have water consumption data available for this time period. Data for Van Hoosen Hall and Snyder-Phillips became available for 2008. Average water consumption for each of the residence halls is presented in Table 16 data was averaged for the period from 2004 to 2008. Data from Snyder-Phillips and Van Hoosen Halls for 2008 were included.

Table 16: Average Water Consumption for Residence Halls

| Resident Hall | Average Water Consumption (KGAL) | | | | |
|---|---|---|---|---|---|
| | | School Term (Sept-April) | | Summer Term(May-Aug) | |
| | Yearly | Total Average | Monthly Average | Total Average | Monthly Average |
| Akers | NA | NA | NA | NA | NA |
| Holmes | 29721 | 25116 | 3140 | 4605 | 1151 |
| Holden | NA | NA | NA | NA | NA |
| Hubbard | NA | NA | NA | NA | NA |
| Wilson | NA | NA | NA | NA | NA |
| Wonders | 16861 | 13696 | 1712 | 3165 | 791 |
| McDonel | NA | NA | NA | NA | NA |
| Shaw* | 17338 | 13993 | 1749 | 3345 | 836 |
| Case | NA | NA | NA | NA | NA |
| Mason/Abbot* | 10252 | 8156 | 1020 | 2096 | 524 |
| Snyder-Phillips† | 10101 | 8255 | 1032 | 1845 | 461 |
| Owen* | 19839 | 14655 | 1832 | 5185 | 1296 |
| Yakeley/Gilchrist* | 10046 | 7801 | 975 | 2245 | 561 |
| Armstrong | 10389 | 6812 | 852 | 2223 | 556 |
| Rather* | 5822 | 4989 | 624 | 834 | 208 |
| Emmons* | 13093 | 8612 | 1077 | 4481 | 1120 |
| Bailey* | 14935 | 10502 | 1313 | 4433 | 1108 |
| Bryan* | 12925 | 9794 | 1224 | 3131 | 782 |
| Butterfield* | 4412 | 3871 | 484 | 541 | 135 |
| Landon* | 6950 | 6093 | 762 | 858 | 214 |
| Campbell* | 3331 | 2721 | 340 | 610 | 152 |
| Mayo | 2707 | 2144 | 268 | 228 | 57 |
| Williams* | 3493 | 3011 | 376 | 481 | 120 |
| Van Hoosen† | 1184 | 941 | 118 | 243 | 61 |
| Totals | 193400 | 151000 | | 40500 | |

Source: Residential and Hospitality Services (RHS), Personal Communication, 2009 NA denotes residence halls that were not metered within the 2004-2008 timeframe. All halls listed above and marked with either an asterisk or dagger are metered; those with an asterisk were metered for the entire period from 2004-2008; those with a dagger were metered after 2007. Halls for which data are reported but are unmarked are not metered and the data reported are estimates from Physical Plant.

As shown in Figure 6, as one would expect, there is a linear relationship trend between water consumption and the number of residents in each hall. However, there is some variability as shown by the scatter in the data and the R-value.

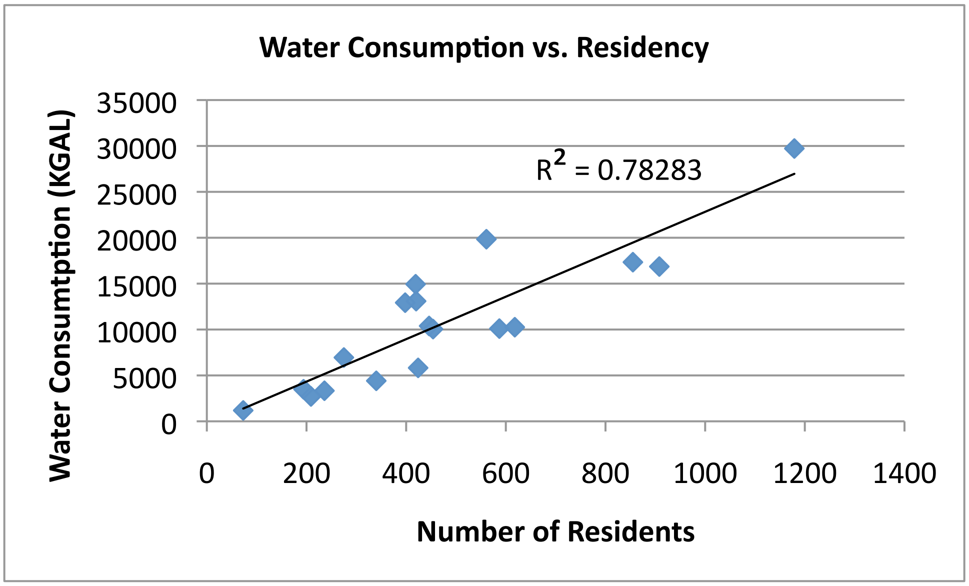


Figure 6: Water consumption vs. number of Residents (Raw data provided in Appendix H)
Source: Residential and Hospitality Services (RHS), Personal Communication, 2009

## Water Consumption

The metering data was evaluated and per capita water consumption rates were calculated for each residence hall. Per capita water usage rates were compared for residence halls with cafeterias versus residence halls without cafeterias. We attempted to determine why some buildings with fewer residents use more water on a per capita basis than others. A likely explanation is that some buildings have cafeterias while others do not. Another possibility is that some residence halls (namely, Holmes) have laboratories. Some residence halls also contain classrooms and academic offices (Holmes, Akers, McDonel, Hubbard, Wilson, Wonders, Case, Holden, Brody Building, and Snyder-Phillips). Snyder-Phillips, Holmes, Case, and Wilson

Halls all contain Living Learning Colleges, which increases the number of academic offices as compared to that in other halls. Several of the residence halls, including Case, Holden, and Wilson have several classrooms with capacities of 60-100 students and most have a large auditorium, which seats approximately 225.

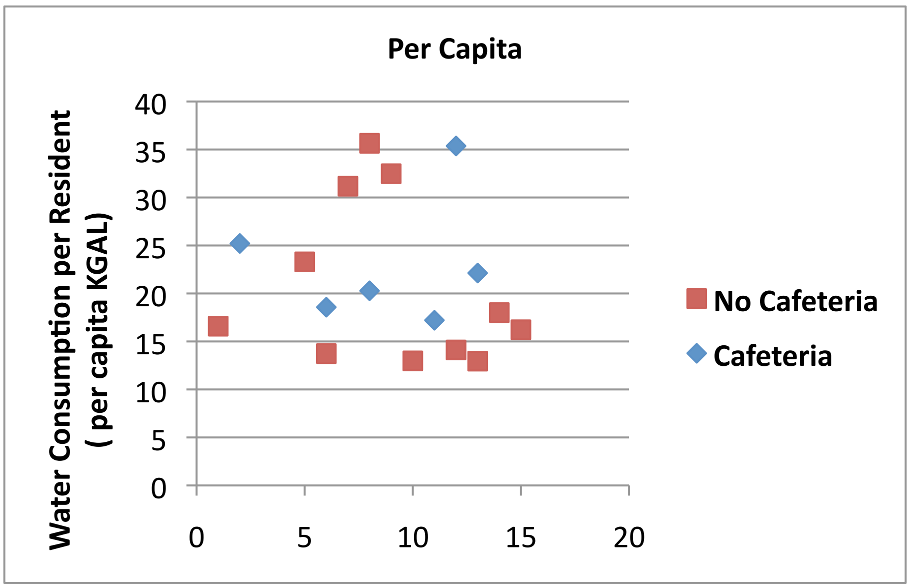


Figure 7: Per Capita Data for Each of the Residence Halls
Source: Residential and Hospitality Services (RHS), Personal Communication, 2009

There are 14 residence halls on campus that have cafeterias. However, only 6 (Holmes, Landon, Owen, Shaw, Snyder-Phillips, Wonders, Yakeley/Gilchrist) of these halls have been metered since 2004. As such, the data for residence halls with cafeterias is limited compared to data obtained for residence halls without cafeterias (the list of cafeterias was found at eatatstate.com). Nonetheless, in general per capita water use is higher for residence halls that have cafeterias. The average per capita water use for residence halls without cafeterias was found to be 20.6±8.2 KGAL/yr, while the per capita water use for residence halls with cafeterias was found to 23.4±6.1 KGAL/yr (± standard deviations).

Table 17 lists the per capita water usage for the residence halls for which data was available. It should be noted that four residence halls have extremely high per capita water use: Emmons, Bailey, Bryan, and Owen. The reason for the high consumption in Emmons, Bailey, and Bryan Halls is because prior to the summer of 2009 these halls had community bathrooms with old style tank urinals that have since been converted to low-flow 1/8th gallon urinals. The reason for the high consumption in Owen Graduate Center is unknown.

Table 17: Residence Hall Per Capita Water Usage

| Residence Hall | Per Capita Water Usage (KGAL/person) |
|---|---|
| Holmes | 25 |
| Wonders | 19 |
| Shaw | 20 |
| Mason/Abbot | 17 |
| Snyder-Phillips | 17 |
| Owen | 35 |
| Yakeley/Gilchrist | 22 |
| Armstrong | 23 |
| Rather | 14 |
| Emmons | 31 |
| Bailey | 36 |
| Bryan | 32 |
| Butterfield | 13 |
| Landon | 25 |
| Campbell | 14 |
| Mayo | 13 |
| Williams | 18 |
| van Hoosen | 16 |
| Average | 22 |
| STDEV | 7.5 |

Source: Residential and Hospitality Services (RHS), Personal Communication, 2009

Values were determined from annual data (including summer months) for the period of 2004-2008, except for Van Hoosen and Snyder-Phillips, which were not metered until 2007.

### Effect of Renovations on Water Consumption

Major renovations of several residence halls are part of the MSU Master Plan. Brody Complex has been under construction for the last year and will be ready for the September 2010 school year. The goal of the plumbing renovations in this complex is to ensure that the buildings meet minimum LEED standards with the potential for LEED certification. Grey water reuse for toilet flushing is incorporated into the renovations of Brody Hall. By July 2009, tank urinal and low flow fixture renovations of the restrooms in all of Brody Complex Residential Buildings (Emmons, Bailey, and Bryan) were complete. Tank urinals, which flowed constantly, were replaced with low flow urinals. It is yet to be seen how these renovations have affected water consumption in these buildings since data is not available after 2008 for any of the buildings except Bryan Hall. However, in Bryan Hall water use dropped by more than fifty percent. Table 2 illustrates the reduction in water usage between 2007 and 2008, and between 2007 and 2009. As shown from the table, fixture upgrades have led to a significant reduction in water usage in Bryan Hall, the first of the halls to be fully renovated. Similar reductions are expected for the other Brody Complex halls.

Table 18: Bryan Restroom Upgrades

Bryan Restroom Upgrades

| | 2007-KGAL | 2008-KGAL | 2009-KGAL | 2008 Percent Reduction | 2009 Percent Reduction |
|---|---|---|---|---|---|
| January | 1408 | 1498 | 549 | NC | 61 |
| February | 1482 | 1041 | 552 | NC | 63 |
| March | 1109 | 1029 | 399 | NC | 64 |
| April | 1638 | 1266 | 668 | NC | 59 |
| May | 1813 | 584 | 329 | 68 | 82 |
| June | 1773 | 214 | 14 | 88 | 99 |
| July | 191 | 59 | 100 | 69 | 48 |
| August | 490 | 330 | 300 | 33 | 39 |
| September | 1060 | 739 | 300 | 30 | 72 |
| October | 1295 | 562 | NA | 57 | NA |
| November | 1477 | 500 | NA | 66 | NA |
| December | 890 | 150 | NA | 83 | NA |

Source: Residential and Hospitality Services (RHS), Personal Communication, 2009

NC: Not calculated since the fixture replacements were completed until April 2008.

### Estimation of Water Consumption for Non-metered Residence Halls

Using the per capita averages for water usage in residence halls, water consumption was estimated for the 6 residence halls that do not have meters. Since all six of the residence halls contain cafeterias, the 23.5 KGAL per resident average value was used. The estimated values were added to the metered data and it was determined that the water use for residence halls is approximately 336,000 KGAL per year. This number includes water use for the cafeterias.

## Cafeteria Water Use

Cafeteria water use was estimated using the per capita data. New “cafeteria-less” water consumption was estimated for each of the 13 halls with cafeterias, by recalculating their water consumption rates using the number of residents and 20.6 KGAL per resident average. The difference between the estimated “cafeteria-less” water consumption and the water consumption rates already determined for the 13 residence halls is the estimated water use for cafeterias. Cafeteria water use is estimated to be approximately 28,000 KGAL per year.

## Discussion

Some important issues arise when evaluating this data. Actual water consumption data (not estimated data) is lacking for six of the residence halls. Four of these residence halls are in the top five in terms of numbers of residents. If data for water consumption in these residence halls were available, it would make our analysis much more accurate and complete.

When the per capita values were calculated there were some interesting observations. For three of the residence halls in the Brody Complex; Emmons, Bailey, and Bryan, per capita water usage was nine or more KGAL/capita greater than the average. As mentioned earlier, the high consumption in these three residence halls is believed to be due to the type of urinals used in the community bathrooms. However, these residence halls have been renovated (July 2009) and it is believed that the renovations will decrease water consumption to normal levels. Table 18 illustrates this, as Bryan Hall shows a dramatic decrease in water consumption from renovations. As new data becomes available Emmons, Bailey, and Bryan should be monitored to determine whether or not water consumption is decreased to average levels. Also, Owen Hall has the highest per capita water consumption. The reason for this is unclear, although higher rates for 2009 may be due to construction activities. Averages were found without removing these outlier data. This is because it was determined that removing the data does not significantly affect the overall average values.

## Conservation Measures

The Residential and Hospitality Services (RHS) at MSU is very active in promoting and instituting water conservation measures. RHS is always seeking ways to conserve water while maintaining an enjoyable living experience for residents. Among conservation measures explored includes the installation of low flow shower heads and LEED-certified fixtures. Because of the state of water at MSU (water pumped from the wells contains a high iron and mineral content) it was found difficult to implement low flow shower heads because of clogging. However, low flow shower heads and other alternatives will continue to be explored, especially in cases where the water will be supplied by softened water from the East Lansing/Meridian Township Water Treatment Plant. The use of tray-less cafeterias has also been explored. It was also found that tray-less cafeterias are effective in small cafeterias as opposed to larger ones. A trial for a tray-less cafeteria was done at Yakeley and was found to be successful; implementing this in larger cafeterias is still being explored.

Another option that is being used on a trial basis is a pulper, which chops food waste with minimal additional water. The goal is minimize water use in the dish room and look for potential opportunities to divert food waste from the landfill. A pulper has been installed in the Brody cafeteria and is under evaluation. In 2010-2011, a study will be conducted to evaluate the use of composting or anaerobically digestion of food waste.

The Master Plan calls for kitchen renovations in Case and Shaw Halls in the next five years. With these and all other renovations, appliances and processes are being studied to replace equipment and fixtures with water conserving fixtures that meet LEED and energy-star guidelines.

In 2005, reverse osmosis units were placed in each of the residence halls to meet the demand of residents for treated drinking water. However, these older units waste excessive amounts of water as only a fraction (typically 50-70%) of the water fed to the unit is fit for consumption. The remainder of the water is waste and is discharged to the sewer. In order to conserve water, these units have been replaced in fall 2010, with newer and improved filter technology, allowing 90-95% of the water treated to be used for human consumption. Brody Complex has been switched to East Lansing/Meridian Township water, eliminating the need for softening units in buildings and kitchens and the associated salts, along with reverse osmosis or filtration units in the hydration stations.

Along with the conservation measures that are being explored, other measures have been undertaken and have proven successful. Among these are using “Green” methods for cleaning, which use less chemicals and conserve water and are environmentally friendly. In cafeterias, dishwashing units are now shut off in between meals; whereas in the past they were sometimes allowed to run. High use public area restroom renovations are currently in progress and are being completed on a regular basis. Furthermore, all remaining (un-renovated) residence halls are scheduled for renovations. (A complete listing is shown in Appendix H). As shown by the decrease in water consumption in Bryan Hall, these renovations could leave to a significant water reduction in residence halls. As of May 2010, water meters have now been installed in all residence halls, making it easier to assess water use in the residence halls.

Along with the conservation measures listed above, RHS has promoted decreased water bottle purchases at MSU. Upon entering the residence halls residents were given reusable water bottles and encouraged to refill water bottles at filling stations located in each residence hall.

## Conclusions

Total water consumption was estimated using per capita data calculated from metered data. The total water consumption for residence halls (including cafeterias) is estimated to be 336,000 KGAL per year. Water consumption for cafeterias is estimated to be 28,000 KGAL per year. Water consumption for residence halls as a whole makes up for almost a quarter of the total water consumed on campus. The water consumption for cafeterias is relatively small compared to all water consumed on campus.

## Recommendations

Since residence halls are and will continue to be a significant water user, conservation measures should continue to be explored. Since new water meter data will become available for all the residence halls, further evaluation of water consumption in these residence halls should take place.

Further investigation in some residence halls such as Owen Graduate Center, which has a high per capita water use, should also be completed.

Presently the cafeterias are not sub-metered; however, the kitchen in Brody Complex will be sub-metered as part of the ongoing renovations. Case and Shaw cafeterias will be sub-metered during planned renovations. This data should be carefully evaluated to better assess water consumption in the cafeterias and determine potential additional conservation measures.

## General Fund and Athletic Buildings

The General Fund buildings are among the largest consumers of water on campus. This is not surprising due to high traffic volumes and bathroom and laboratory use. Although not all buildings on campus are metered, there is sufficient data on water usage for the General Fund buildings on campus to obtain a general picture of the consumption of water in these facilities.

Water is also consumed in the athletic buildings and complexes. Since athletic buildings are not supported from the General Fund they are discussed separately in this report.

### General fund buildings

Using the data currently available, water usage in the General Fund buildings is tabulated in Table 19. The water consumption reported is the arithmetic average of the yearly consumption during the period from 2004-2008.

Table 19: General Fund Building Water Consumption

| Bldg # | Bldg Name | Meter | Annual Water Usage (KGAL) |
|---|---|---|---|
| 0055 | KELLOGG CENTER | | 48560 |
| 0446A | VETERINARY RESEARCH CENTER - LARGE ANIMAL BARN | 0446W1 | 46560 |
| 0086 | PLANT & SOIL SCIENCES BUILDING | 0086W1 | 44470 |
| 0189 | REGIONAL CHILLED WATER PLANT NO. 1 | 0189W1 | 32130 |
| 0160 | BIOMEDICAL PHYSICAL SCIENCES BUILDING | 0160W1 | 29150 |
| 0178 | PLANT BIOLOGY LABORATORIES | 0178W1 | 12770 |
| 0132 | ANTHONY HALL | 0132W1 | 12350 |
| 170 | VETERINARY MEDICAL CENTER | 0170W1 | 9250 |
| 0081 | ENGINEERING BUILDING | 0081W1 | 7770 |

Table 19 Cont.

| | | | |
|---|---|---|---|
| 0203A | ENGINEERING RESEARCH COMPLEX | 0203W1 | 6900 |
| 0068 | LAUNDRY BUILDING | 0068W1 | 6800 |
| 0186 | FOOD SAFETY AND TOXICOLOGY BUILDING | 0186W1 | 4570 |
| 0006 | UNION BUILDING | 0006W1 | 3960 |
| 0024 | NATURAL SCIENCE | 0024W1 | 3470 |
| 0212A | PAVILION FOR AGRICULTURE AND LIVESTOCK EDUCATION - HORSE BAR | 0212W1 | 2450 |
| 0083 | MSU COLLEGE OF LAW | 0083W1 | 2060 |
| 0029 | KEDZIE HALL (NORTH AND SOUTH) | | 1730 |
| 0003 | OLIN MEMORIAL HEALTH CENTER | 0003W1 | 1600 |
| 0084 | COMMUNICATION ARTS & SCIENCES BUILDING | 0084W1 | 1300 |
| 0080 | BUSINESS COLLEGE COMPLEX (EPPLEY) | 0080W1 | 1090 |
| 0002 | BERKEY HALL | | 940 |
| 85 | WHARTON CENTER | 0085W1 | 900 |
| 0035 | COMPUTER CENTER | 0035W1 | 850 |
| 0128 | NISBET, STEVEN S., BUILDING | 0128W1 | 790 |
| 0087 | PUBLIC SAFETY | 0087W1 | 770 |
| 1121 | MUSIC/MUSIC PRACTICE | 1121W1 | 740 |
| 0027 | PSYCHOLOGY BUILDING | 0027W1 | 620 |
| 0005 | HUMAN ECOLOGY | 0005W1 | 570 |
| 0163 | CHEMISTRY | 0163W1 | 550 |
| 0177 | PACKAGING | 0177W1 | 520 |
| 0171 | FOOD STORES | 0171W1 | 430 |
| 0214 | RADIOLOGY BUILDING | 0214W1 | 430 |
| 0154 | MANLY MILES BUILDING | 0154W1 | 330 |
| 91 | FARRALL AGRICULTURAL ENGINEERING HALL | 0091W1 | 300 |
| 0219 | PARKING RAMP NO.1 SHAW LANE (NEW) | 0219W1 | 270 |
| 0060 | CENTRAL SERVICES BUILDING | 0060W1 | 80 |
| 2000 | CLINICAL CENTER | 2000W1 | 40 |

Source: Power Plant, Personal Communication, 12/23/2009

The data presented in Table 19 is given in KGAL/yr and are listed from the building with the highest water consumption to that with the lowest. There are several unexpected findings. For example, we did not expect water consumption in the Chemistry Building to be so low because of the many laboratories. This can be explained, however, because the piping in the Chemistry Building is not completely metered. It has been determined that only the North addition of the Chemistry building is metered, thus, the unexpected low water consumption. On the contrary the Plant and Soil Sciences Building, a building with many laboratories, consumes approximately 90 times the amount of water consumed by the Chemistry Building. It is unclear why this is the case.

Several changes in water use will occur in the future. For example, the Kellogg Center, which is the building with the highest water consumption, will be purchasing water from the East Lansing/ Meridian Township Water Treatment Plant in the near future.

Another forthcoming change is that there is a meter at the Diagnostic Center for Population and Animal Health (DCPAH) that was not being read by the Power Plant. However, personnel from the Power Plant will assume responsibility for this meter and data regarding the DCPAH building will be available.

It is also important to note that the Clinical Center building only has a meter in the new Radiology wing. The majority of the Clinical Center building is not metered.

These 37-metered buildings have a total annual water consumption of about 290,000 KGAL and account for 15% of the total water consumption on campus. Unfortunately, without metered data we do not have any way of estimating water consumption in the numerous unmetered buildings on campus. Water usage in these other buildings is therefore included in the "unaccounted for" category.

### Athletic Facilities

Shown below in Table 20 is average annual water use for athletic facilities over the period of time from 2004 to 2008.

Table 20: Athletic Building Water Consumption

| Bldg # | Bldg Name | Meter | Annual Water Usage (KGAL) |
|---|---|---|---|
| 0058 | SPARTAN STADIUM | 0058W1 | 9960 |
| 0069 | BRESLIN, JACK, STUDENT EVENTS CENTER | 0069W1 | 4780 |
| 0059 | MUNN, CLARENCE L., ICE ARENA | 0059W1 | 2780 |
| 0056 | JENISON FIELDHOUSE | 0056W1 | 2220 |
| 77 | FOOTBALL BUILDING | 0077W1 | 1720 |

Source: Power Plant, Personal Communication, 12/23/2009

These five sports facilities are the most utilized on campus, featuring the facilities that house football, basketball, and hockey. The Intramural Sports buildings are not metered with the exception of Intramural East, which is metered, but according to Power Plant personnel the meter is not accurate. Spartan Stadium urinals previously ran year round. Urinals are now shut off between games unless there is a possibility of freezing (for games in November), and immediately after the season ends, water is shut off to the stadium and the stadium is winterized. It is not known how long this has been common practice for Spartan Stadium, but data from 2004-2008 suggest that there was no change in policy over that time as water consumption for Spartan Stadium only increased from 2004-2008. The overall water consumption for these 5 facilities is about 21,500 KGAL and 1% of water use on campus. Earlier reports did imply that urinals at the Spartan Stadium were allowed to run 24/7 during the season, but later reports dispute this original claim.

## Bathrooms

Restroom use was evaluated in many general fund buildings on the MSU main campus. To estimate the amount of water used, the janitorial staff recorded the amount of paper towel rolls used for each restroom. It was assumed that on average 24 inches of paper towel is used per person per restroom visit. The total number of flushes were estimated from paper towel usage, assuming that paper towel use can be correlated with water use in the restrooms. Volumes of 3.5 gal/flush for toilets and 3 gal/flush for urinals were used to calculate water usage.

Estimated annual cost savings were estimated for each building. The annual savings were estimated by determining the predicted water saved if the plumbing fixtures were to be replaced with low flow technology (using 1.6 gal/flush for toilets and 0.125 gal/flush for urinals). Water was assumed to cost $3.0321 per KGAL to produce (Gus Gosselin, 4/20/2010). A sample calculation is included in Appendix I. It is important to also take into account the onetime cost for fixture upgrades.

Shown in Table 21 are the top 11 buildings analyzed with respect to potential savings by upgrades. Data in this table are sorted based on highest to lowest savings. These buildings were chosen because the data for these buildings were found to be reliable and complete.

The estimated one-time costs for upgrades are listed in the Appendix I. Every estimated bathroom upgrade has a return on investment of less than 2 years.

Table 21: Estimated Water Savings from Bathroom Upgrades

| Bldg # | Bldg Name | Annual Paper Towel Use (Rolls) | Estimated Savings | Estimated Water Savings (KGAL) | Rank Based on Potential Savings | Rank Based on Metered Water Usage |
|---|---|---|---|---|---|---|
| 78 | Wells Hall | 282000 | $19,720 | 6500 | 1 | NA |
| 84 | Comm. Arts | 165600 | $12,785 | 4200 | 2 | 25 |
| 169 | Intl. Center | 150000 | $8,446 | 2800 | 3 | NA |
| 163 | Chemistry | 236400 | $8,365 | 2760 | 4 | 35 |
| 327 | Fee (East) | 144000 | $7,717 | 2550 | 5 | NA |
| 168 | Biochemistry | 122400 | $7,154 | 2360 | 6 | NA |
| 79 | Bessey | 132000 | $6,883 | 2300 | 7 | NA |
| 178 | Plant Biology | 170400 | $6,619 | 2200 | 8 | 6 |
| 170 | Vet Clinic (North) | 159600 | $5,916 | 1950 | 9 | 9 |
| 183 | Life Sciences | 97200 | $4,465 | 1500 | 10 | NA |
| 47 | Olds Hall | 84000 | $2,369 | 800 | 11 | NA |

Source: Gus Gosselin, Personal Communication 6/18/2010

The last column in the table shows the water consumption rank by metered data. High bathroom use does not seem to correlate to high water use within the buildings. Moreover, many of these buildings with high bathroom use are not metered.

It should be noted that tank type urinals had been installed in the Auditorium, Kresge Building, and Student Services Building. They were all replaced in 2009/2010 with 1/8 gallon per flush urinals. Since these buildings do not have water meters we cannot evaluate the effect of these renovations.

## Labs

Below is a list of the top 25 General Fund buildings with respect to the number of laboratory and laboratory research support rooms in each building.

Table 22: Top 25 Buildings with Respect to Number of Labs

| Rank Based On # of Labs | Bldg # | Bldg Name | Labs | Metered Rank |
|---|---|---|---|---|
| 1 | 160 | BIOMEDICAL PHYSICAL SCIENCES | 183 | 5 |
| 2 | 28 | GILTNER HALL | 182 | NA |
| 3 | 86 | PLANT AND SOIL SCIENCE | 139 | 3 |
| 4 | 178 | PLANT BIOLOGY LABORATORY | 137 | 6 |
| 5 | 163 | CHEMISTRY | 131 | 35 |
| 6 | 81 | ENGINEERING BUILDING | 102 | 10 |
| 7 | 168 | BIOCHEMISTRY | 95 | NA |
| 8 | 24 | NATURAL SCIENCE | 94 | 17 |
| 9 | 179 | FOOD SCIENCE | 83 | NA |
| 10 | 183 | LIFE SCIENCE | 79 | NA |
| 11 | 215 | DCPAH - DIAG CNTR POP ANIM HEALTH | 79 | NA |
| 12 | 170 | VETERINARY MEDICAL CENTER | 78 | 9 |
| 13 | 132 | ANTHONY HALL | 77 | 7 |
| 14 | 186 | FOOD SAFETY AND TOXICOLOGY | 68 | 14 |
| 15 | 0203A | ENG RESEARCH COMPLEX | 64 | 11 |
| 16 | 180 | NATURAL RESOURCES | 55 | NA |
| 17 | 164 | CYCLOTRON | 47 | NA |
| 18 | 0181A | CENTER INTEGRATIVE PLANT SYS - LAB | 46 | NA |
| 19 | 327 | FEE HALL | 31 | NA |
| 20 | 27 | PSYCHOLOGY BUILDING | 27 | 33 |
| 21 | 84 | COMMUNICATION ARTS | 25 | 25 |
| 22 | 144 | ERICKSON HALL | 25 | NA |
| 23 | 0473B | POULTRY-LAB BLDG | 25 | NA |
| 24 | 91 | FARRALL AG ENGINEERING HALL | 23 | 40 |
| 25 | 201 | CLINICAL CENTER - OFFICE/LAB WING | 22 | NA |

Source: Facilities Planning and Space Management, Personal Communication, 5/3/2010

Also listed in Table 21 is the ranking of water use from the metered data. Out of the 13 buildings on the list that are metered, 10 of these buildings are also in the top 25 of metered buildings with respect to water use. This list seems to indicate that high lab use correlates with high water consumption. Figure 7 shows the correlation between the number of labs and water consumption. As shown, there is a linear trend between high water consumption and buildings with a large number of laboratories. The value of $R^2$ shows how well the data follows a linear model. $R^2$ values range from 0 to 1, with an $R^2$ value of 1 showing a perfect linear fit. With an $R^2$ value of 0.6, this data suggest that there is not a strong correlation, but a significant correlation between water consumption and the number of laboratories. The more laboratories a building tends to lead to higher water consumption.

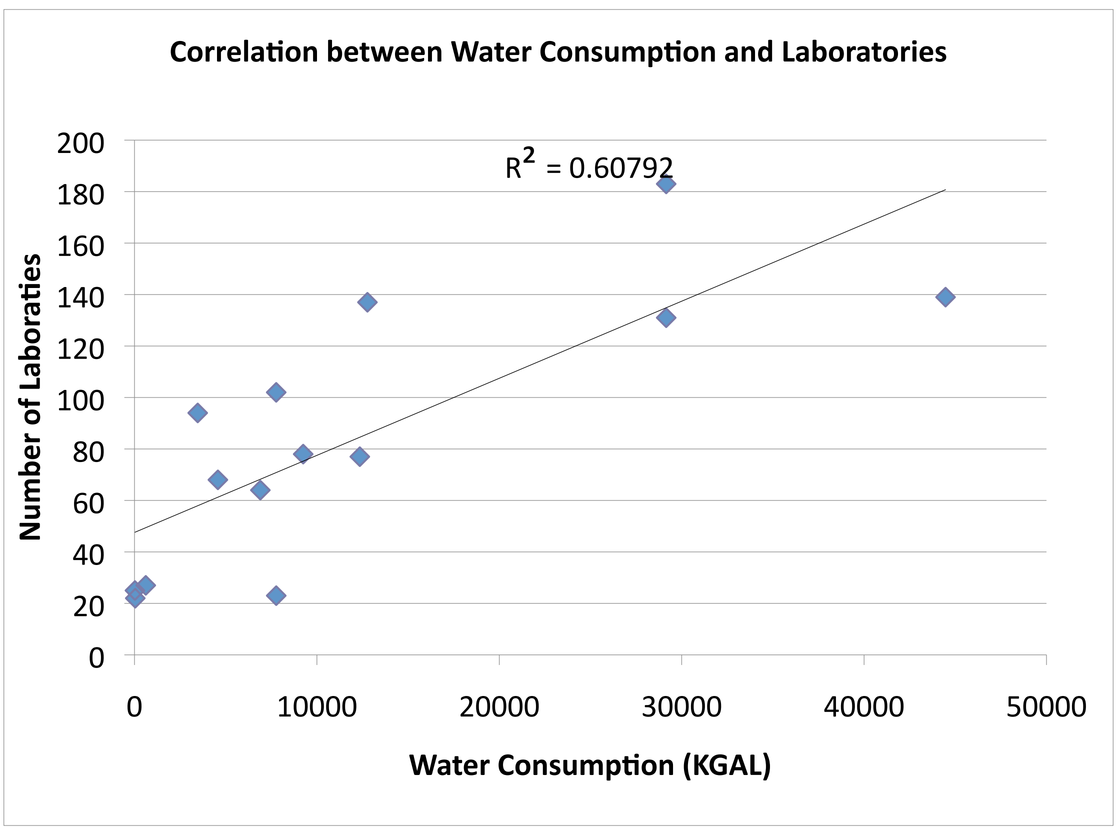


Figure 8: Water Consumption with Respect to Laboratories

## Recommendations

Buildings that are listed in Table 21 have been recommended for restroom upgrades, based on water and cost saving estimations (Gus Gosselin, personal communication, 2010).

It is recommended that buildings be metered for future study to determine accurate water usage. The buildings that should be given high priority for the installation of water meters are listed in Table 23.

Table 23: Buildings That Should be Metered for Future Study

| Building | Ranking Based On Potential Savings from Bathroom Upgrades | Number of Laboratories |
|---|---|---|
| Erickson | NA | 22 |
| Fee | 5 | 19 |
| Biochemistry | 6 | 7 |
| Life Science | 10 | 10 |
| Chemistry | 4 | 5 |

Four of these five buildings listed are in Table 23 as being recommended for bathroom upgrades, and all of them are on the top 25-laboratory list. As stated earlier only a portion (North addition) of the Chemistry Building is metered making it necessary to meter the rest of the building. In addition to these 5 buildings, any buildings that are on the list of 11 buildings suggested for significant bathroom upgrades or any buildings that are in the top 10 of laboratories should be considered for metering if not already metered.

The top ten buildings that are currently metered that should be studied to determine the reasons for the high water consumption are shown in Table 24.

Table 24: Top 10 Buildings to Study

| Building | Meter Rank | Ranking Based On Potential Savings from Bathroom Upgrades | Number of Laboratories |
|---|---|---|---|
| Kellogg Center | 1 | NA | NA |
| Veterinary Research Center | 2 | 9 | 12. |
| Plant and Soil Sciences | 3 | NA | 3 |
| Biomedical Physical Sciences | 4 | NA | 1 |
| Plant Biology | 6 | 8 | 4 |
| Anthony Hall | 7 | NA | NA |
| Spartan Stadium | 8 | NA | NA |
| Engineering Building | 10 | NA | 6 |
| Natural Science | 17 | NA | 8 |
| Communication Arts | 25 | 2 | 21 |

Two other buildings not on the list in Table 24 that should be evaluated are Giltner Hall and the Clinical Center. Giltner Hall should be evaluated because of the significant number of labs located within (Rank 2 on number of laboratories) and therefore may have significant water consumption. An Omni meter was recently installed in 2010 for Giltner Hall and this data should be evaluated to assess water usage. Another building to consider is the Clinical Center. The Clinical Center is expected to show a significant amount of water use, however only the Radiology wing is metered. Therefore, the water consumption for the Clinical Center is likely to be undervalued, and another meter may be needed to obtain an accurate account of water use for the Clinical Center.

## Miscellaneous

### Autoclaves

Autoclaves are used in laboratories throughout campus to sterilize equipment. Autoclaves utilize saturated steam in the sterilization process, thus resulting in the loss of water and water consumption. It is believed that modifications can be made to autoclaves to reduce water consumption by 62%. There is no current supplied to this report listing autoclaves or autoclave use on campus.

### Reverse Osmosis Units

Reverse Osmosis (RO) is a pressure based membrane filtration process used to treat water. RO is a relatively new technology and vast improvements have been made in the last five years. Older RO units often have a low efficiency of water production, typically around 60 % production of clean water. The remaining 40% is the “reject” stream and disposed of into the sanitary sewer. Currently, new systems can run at 90% or higher efficiency for the production of clean water. It is believed that switching to newer systems can help save money as these units use less energy and consume less water. MSU currently uses RO in some of its buildings to treat both drinking and laboratory water. A list of general fund buildings with RO units is shown below in Table 25.

Table 25: List and Location of RO units

| Building | Location/Room # |
|---|---|
| Anthony | MR B-263 |
| Bio Med Phys Sci. | Sparty's |
| Biochemistry | Penthouse |
| Chemistry | B-19 MR |
| CIPS | 2nd Fl. Cust. |
| Clinical Ctr | Mr #AB-13 |
| Clinical Ctr | Sparty's |
| DCPAH | Bas. MR #31 |
| Eng. Res. Comp. | MR 3200 |
| Engineering | MR #B-120 |
| Engineering | MR # Penthouse S.W. |
| Engineering | Sparty's |
| Erickson | Sparty's |
| Giltner | West Penthouse #370A MR |
| Giltner | MR #35 |
| Intn'l Center | Sparty's |
| Library | Sparty's |
| Life Sci. | S. Pent. |
| Munn | MR #24 |
| Plant & Soil Sci. | MR A-51 |
| Plant Bio | MR # S-28 |
| Un. Res. Cont. | MR |
| Vet Med | MR #A-50 |
| Vet Med | Rm. G138E (Purification System) |

Source: Gus Gosselin, Personal Communication, 20/4/2010

It is important to note that the capacity and age of the systems are unknown. Also, this list may be incomplete and other RO units may be operational. One example being the Biomedical Physical Science Penthouse RO filtration unit. This unit is not on the list, but is believed to have a high water consumption (Personal Communication, Pat Curry, 9/28/2010).

Although many of the residence halls used RO units, many of these units have been replaced with newer filtration technology as discussed in the section specific to Residence Halls. A list of residence halls and the RO units that were in place at the start of this project (Fall 2009) is shown in Table 26.

Table 26: List of RO Units in Residence halls

| Building | Location/Room # | RO unit | Make | output |
|---|---|---|---|---|
| Akers | B-38 West Lobby DF | BP 3S Plus | Culligan | 15.5 gph |
| Armstrong | MR C-1 lobby DF | BP 3S Plus | Culligan | 15.5 gph |
| Bailey | MR C-1 lobby DF | BP 3S Plus | Culligan | 15.5 gph |
| Bryan | MR C-1 lobby DF | BP 3S Plus | Culligan | 15.5 gph |
| Butterfield | MR C-1 lobby DF | BP 3S Plus | Culligan | 15.5 gph |
| Case Hall | MR 46A North utility sink laundry | BP 2L Plus | Culligan | 25 gph |
| Emmons | MR C-1 Off Line | renov now | Culligan | |
| Holden | MR G-48 East lobby faucet main | BP 2L Plus | Culligan | 25 gph |
| Holden | Sparty's | BP 2L Plus | Culligan | 25 gph |
| Holmes | 1st Fl. Comp. East lobby | BP 2L Plus | Culligan | 25 gph |
| Holmes | 1st Fl. Comp. West lobby | BP 2L Plus | Culligan | 25 gph |
| Holmes | Sparty's | BP 2L Plus | Culligan | 25 gph |
| Hubbard | MR G-75 N Hubb DF | renov now | Culligan | |
| Mas./Ab | C114B Abbott lobby | BP 2L Plus | Culligan | 25 gph |
| McDonel | MR #B-8-A E lobby | BP 2L Plus | Culligan | 25 gph |
| McDonel | MR #32A W lobby | BP 2L Plus | Culligan | 25 gph |
| Owen Grad | Bas. B-1 basement center area | BP 2L Plus | Culligan | 25 gph |
| Rather | MR C-1 lobby lobby DF | BP 3S Plus | Culligan | 15.5 gph |
| Shaw Hall | Rm 106 lobby East | BP 3S Plus | Culligan | 15.5 gph |

Table 26 Cont.

| | | | | | |
|---|---|---|---|---|---|
| Sny/Phi | Bas. MR lobby Phillips lobby | BP Plus | 2L | Culligan | 25 gph |
| Sny/Phi | Sparty's | BP Plus | 2L | Culligan | 25 gph |
| Wilson Hall | MRR West W109 | BP Plus | 2L | Culligan | 25 gph |
| Wonders Hall | B-2 North Lobby Utility sink laundry | BP Plus | 2L | Culligan | 25 gph |
| Mayo Hall | 239 | ac 30 | | Culligan | 30 gpd |
| Mayo Hall | 225 | ac 30 | | Culligan | 30 gpd |
| Mayo Hall | 325 | ac 30 | | Culligan | 30 gpd |
| Mayo Hall | 339 | ac 30 | | Culligan | 30 gpd |
| Campbell | G-29 | ac 30 | | Culligan | 30 gpd |
| Campbell | G-11 | ac 30 | | Culligan | 30 gpd |
| Landon | G-11 | ac 30 | | Culligan | 30 gpd |
| Yakeley | E-54 | ac 30 | | Culligan | 30 gpd |
| Yakeley | E-53 | ac 30 | | Culligan | 30 gpd |
| Gilchrist | W-3 | ac 30 | | Culligan | 30 gpd |
| Williams | C-3 | ac 30 | | Culligan | 30 gpd |
| Williams | C-12 | ac 30 | | Culligan | 30 gpd |
| Williams | 211A | ac 30 | | Culligan | 30 gpd |
| Williams | 261A | ac 30 | | Culligan | 30 gpd |
| Williams | 311A | ac 30 | | Culligan | 30 gpd |
| Williams | 361A | ac 30 | | Culligan | 30 gpd |

Source: Diane Barker, Personal Communication, 6/23/2010

The majority of these units are small units used to produce drinking water for residents. It is also important to note that all of these systems are to be replaced with alternatively efficient filtration devices by October 2010. A complete list is found in the Appendix J.

Considering the potential financial and energy savings of new RO units, it is recommended that large systems (whose age and size are not known) be surveyed to determine the age and size of each system so that action can be taken accordingly. An example of how upgrading to a new RO unit can save water and money is shown in Table 27.

Table 27: RO Evaluation

| | | |
|---|---|---|
| Efficiency of RO System (percent recovery of clean water) | 50 | 90 |
| Clean Water Produced (GAL) per KGAL | 500 | 900 |
| Water Lost (GAL) per KGAL produced | 500 | 100 |
| Expenditure per KGAL produced ($) | 1.52 | 0.30 |
| | Savings ($) per KGAL produced | 1.21 |

Calculations are shown in Appendix J.

According to Crittenden (2005) the recovery of clean water for RO systems ranges from 50% to 90%. The upper and lower limits have been used to show the potential financial savings for high efficiency RO units. Using the universal cost of water for the MSU campus of $ 3.0321 per KGAL the savings from the installation of a high efficiency RO system vs. a low efficiency RO system is $1.2128 per KGAL. Therefore, if a RO unit on campus treats 1 MGAL of water per year (0.06% of total water pumped on campus) the total savings in water would be $ 1,212.8. If a high efficiency RO unit were to cost $6,000 the payback period for this system would be roughly 4.8 years.

## Flushing the Distribution System

Once a year water is used to flush the well mains (well piping) on campus. This is done for sanitary reasons and maintenance. It is estimated that flushing uses 6,000 KGAL of water annually.

Every other year the distribution mains are flushed. It is estimated that every other year 4,000 KGAL of water is used (Doug Macdonald, Personal Communication, 2/1/2010).

Summing both of these volumes used for flushing to obtain a maximum annual water volume for flushing yields a total of 10,000 KGAL. This is only 0.5% of the overall water consumption on campus.

## Leak Study

Based on numerous discussions with various personnel, it appears that there has not been a leak study performed on the distribution system at MSU in the last several decades. If one was performed, the report no longer exists and the results are unknown. While major leaks are more easily identified and repaired, it is smaller leaks that may go undetected for years. Over time these small leaks can add up and lead to a sufficient waste of water (AWWA, 2009). Table 28 shows an example of how a leak study can help save money and water.

Table 28: Leak Study

| | |
|---|---|
| Cost for Leak Study ($) | 20,000 |
| Water saved per year (KGAL) | 1700 |
| Money Saved Per Year | 5,154.57 |
| Payback Period (Years) | 4 |

If the leak study has a one time cost of $20,000 and helps saves 1700 KGAL of water per year (0.1% of total water pumped by MSU), the annual savings based on the universal MSU cost of water of $3.0321 per KGAL would be $5,154.57 per year. This yields a payback period of only 4 years.

## Water Use Summary

Below is a sample pie chart showing the distribution of water on campus. A baseline of 1,916,200 KGAL was used for the total amount of water pumped from the wells on campus. This value was attained from averaged data from 2004-2008, and Table 29 shows the contribution of water supplied.

Table 29: Water Supply

| | Total Water Supplied(KGAL) |
|---|---|
| Pumped from 18 Main Wells | 1916200 |
| Pumped from Irrigation Wells | 18255 |
| Pumped from Red Cedar | 17522 |
| Purchased | 5200 |
| Total | 1957177 |

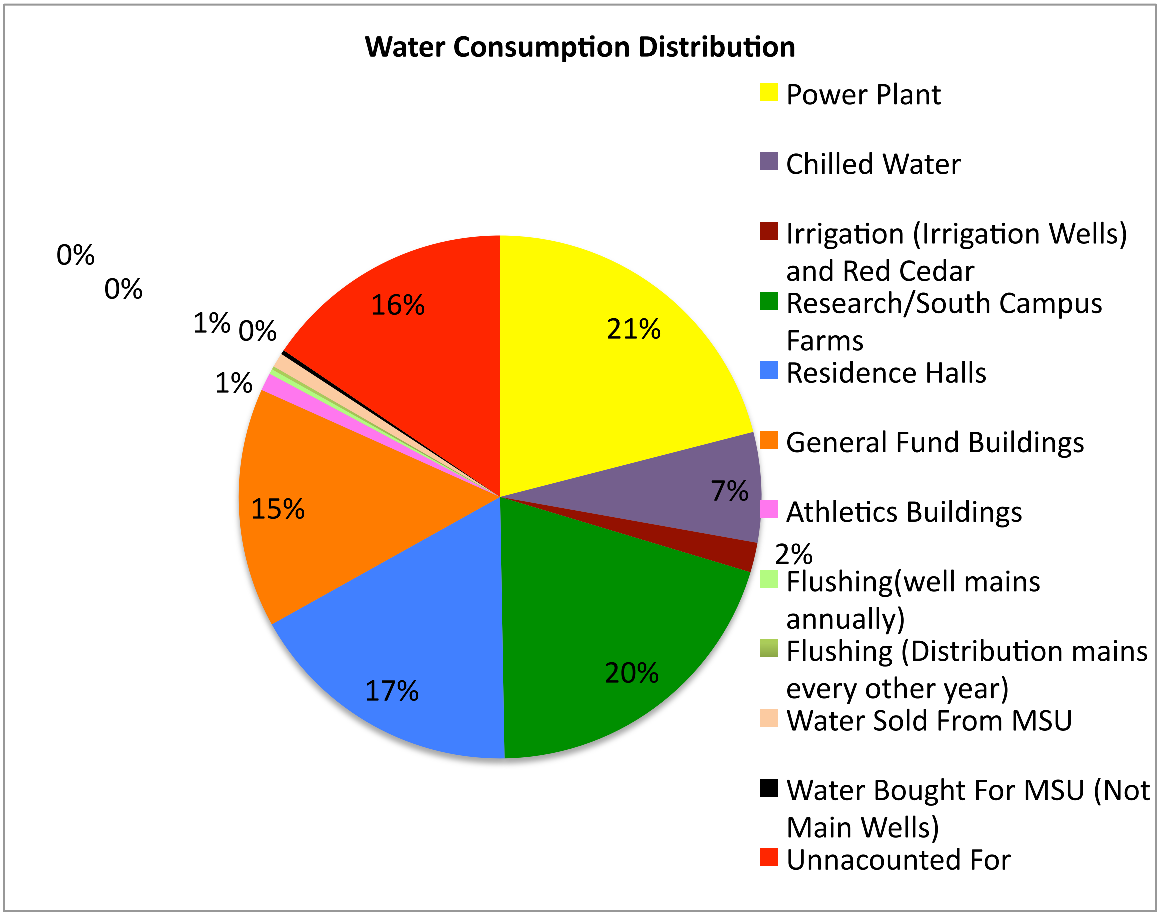


Figure 9: Water Consumption Distribution

Table 30: Total Water Consumption

| | KGAL | % of Total |
|---|---|---|
| Power Plant | 411,000 | 21 |
| Chilled Water | 133,300 | 7 |
| Irrigation (Irrigation Wells) and Red Cedar | 36,000 | 2 |
| Research/South Campus Farms | 393,000 | 20 |
| Residence Halls | 353000 | 18 |
| General Fund Buildings | 290000 | 15 |
| Athletics Buildings | 21500 | 1 |
| Flushing (well mains annually) | 6000 | 0.3 |
| Flushing (Distribution mains every other year) | 4000 | 0.2 |
| Water Sold From MSU | 17,400 | 1 |
| Water Bought For MSU (Not Main Wells) | 5200 | 0.3 |
| Unaccounted For | 286,777 | 15 |
| Total | 1,957,177 | |

As shown from this data water on the MSU campus is primarily used by five main sources. These are: Power Plant, South Campus: Research Farms, Residence Halls, General Fund Buildings, and Chilled Water. These five sectors are estimated to account for 81% of the water consumption at MSU.

It is important to note that 15% of water use is not accounted for. This error is believed to be the result of more than one problem. Firstly, it is believed and assumed that there will always be some inaccuracies with respect to meters. Another problem is that not all buildings on campus are metered, thus the General Fund building consumption is estimated to be undervalued. Lastly, the possibility of leaks in the distribution system could lead to unaccounted for water.

## Summary of Recommendations

The recommendations that arose from this report have been divided into four sections:

Preventative/Maintenance

Monitoring/Data Collection

Updating Equipment

Further Study and needs

In order to build a sustainable and economically-efficient water system, a feedback loop needs to be developed with oversight of the entire water supply system, from the point of pumping from the wells to the release of the water into the sewer system or on land (irrigation) given to a single individual or office. In the same way that the Office of Campus Sustainability monitors energy consumption in buildings, water consumption needs to be monitored and evaluated on a regular basis. If MSU is serious about developing a comprehensive strategy to achieve efficient use of energy, steam, and water, it is imperative that the diffuse authority be place in a central office.

### Preventative Maintenance

At present, there is no clearly defined program for maintaining and replacing water meters. It is, therefore, recommended that a water meter maintenance and renewal program be developed. The responsibility for maintaining, scheduling maintenance, and assessing water meters needs to be designated. Meters should be checked, cleaned and calibrated every 7 to 10 years (Satterfield, Zane, P. E., and Bhardwaj, Vipin Water Meter Tech Brief ). Because the water at MSU is high in mineral content, maintenance is critically important to ensure proper operation of the meters employed on campus, and the integrity of the data obtained. As discussed earlier in the section of this report on meter maintenance, a study conducted by the Physical Plant showed that with increased maintenance and meter replacement, the accuracy of the well meters improved significantly.

## Equipment Installation and Replacement

The water usage in the North Sub-station is anticipated to be high, although the exact amount is unknown since it is not metered. However, as the pumps are water cooled, they should be evaluated to determine if newer, more energy- and water-efficient pumps could replace the existing pumps. It is important to develop such a plan for replacement so that when money becomes available for such efforts, the project can be mobilized quickly.

A replacement program should be developed to replace all water meters that do not meet current specifications.

At present, none of the sources for irrigation are metered. If water consumption for irrigation is to be fully evaluated, it is recommended that a metering program be put in place. This would include metering of irrigation wells, as well as sub metering of buildings that provide domestic water for irrigation purposes. To maintain the integrity of these meters a maintenance plan should also be put in place to manage and secure the validity of the meter system.

It is recommended that select General Fund buildings be metered to determine accurate water usage. The buildings that should be given high priority for the installation of water meters are listed in Table 23. They are included in this table because they have a large number of high-use restrooms or a large number of laboratories, and are expected to have significant water consumption.

Table 23: Buildings That Should be Metered

| Building | Ranking Based On Potential Savings from Bathroom Upgrades | Number of Laboratories |
|---|---|---|
| Erickson | NA | 22 |
| Fee | 5 | 19 |
| Biochemistry | 6 | 7 |
| Life Science | 10 | 10 |
| Chemistry | 4 | 5 |

Four of these five buildings listed are in Table 18 as being recommended for bathroom upgrades, and all of them are on the top 25-laboratory list. As stated earlier only a portion (North addition) of the Chemistry Building is metered; given the large number of laboratories, it would be prudent to meter the rest of the building.

If funding allows, additional metering of any of the unmetered buildings that have been suggested for significant bathroom upgrades or any buildings that are in the top 10 in terms of the number of laboratories should be considered. Metering will assist with future planning in terms of restroom renovations or other conservation measures.

Another building that should be metered is the Clinical Center. The Clinical Center is expected to use a significant amount of water, however only the Radiology wing is metered. Therefore, the water consumption for the Clinical Center is most likely significantly undervalued.

Buildings that are listed in Table 21 are recommended for restroom upgrades, based on water and cost saving estimations. Once upgrades are completed, these buildings should be metered and consumption should be monitored to determine the cost-effectiveness of these renovations and their return on investment. Such data is important for evaluating future bathroom upgrades and similar renovations.

In particular bathroom upgrades should be considered. Toilets that were installed pre 1990 can consume 3.5 gallons per flush while urinals installed before 1990 consume over 3 gallons per flush. These toilets can be retrofitted to be reduced to 1.6 gallons per flush for toilets and less than 1 gallons per flush for urinals. Also all tank type urinals should be replaced, specifically in Giltner Hall.

### Monitoring

Metering is the best way to determine water use, therefore accurate metering is the best way to document water consumption on MSU's campus. However, unless the data is routinely evaluated, its collection serves little purpose. We recommend that the data be collected and evaluated in the same way that energy consumption data is evaluated. In this way, outliers would be identified and the reason for the unanticipated water consumption could be addressed by either maintenance or equipment replacement.

Within the last year, meters have been installed in all residence halls. As these water consumption data become available, further evaluation of residence halls should take place. For example, some residence halls, such as Owen Hall, show higher than average per capita water use. Water usage in Owen hall and other halls (including Bryan, Emmons, and Bailey) that appear to have above average per capita usage should be further investigated. Recent renovations of Bryan Hall have resulted in a significant decrease in water consumption. Now that Emmons and Bailey Halls are also renovated and meters have been installed, it would be prudent to monitor their water consumption to determine if similar reductions have been attained.

Considering the potential financial and energy savings of new RO units and retrofitted autoclaves, it is recommended that all RO systems (whose age and size are not known) and autoclaves are surveyed to determine the age and size of each system so that appropriate action can be taken. It is also recommended that the Office of Campus Sustainability be given the authority to collect and maintain data on the location, age, specifications, and water consumption data for all RO units and autoclaves on campus.

## Future Studies

At present we are unable to benchmark the water usage in the chilled water facility to determine if it is reasonable or not. As such, a study to determine the efficiency of the chilled water system and whether there are newer technologies that can increase the efficiency of the system is recommended. However, considering that chilled water accounts for only approximately 7% of the total water consumption, efforts might be better focused in a higher use category.

Presently the cafeterias are not sub-metered; however, the kitchen in Brody will be sub-metered as part of on-going renovations. Case and Shaw cafeterias will be sub- metered during planned renovations. This data should be carefully evaluated to better assess water consumption in the cafeterias and determine potential conservation measures.

The top ten buildings that are currently metered that should be studied to determine the reasons for the high water consumption are shown in Table 24.

Table 24: Top 10 Buildings to Study

| Building | Ranking Based On | | |
|---|---|---|---|
| | Meter Rank | Potential Savings from Bathroom Upgrades | Number of Laboratories |
| Kellogg Center | 1 | NA | NA |
| Veterinary Research Center | 2 | 9 | 12 |
| Plant and Soil Sciences | 3 | NA | 3 |
| Biomedical Physical Sciences | 4 | NA | 1 |
| Plant Biology | 6 | 8 | 4 |
| Anthony Hall | 7 | NA | NA |
| Spartan Stadium | 8 | NA | NA |
| Engineering Building | 10 | NA | 6 |
| Natural Science | 17 | NA | 8 |
| Communication Arts | 25 | 2 | 21 |

One other building that should be evaluated is Giltner Hall. New Omni Meters were recently installed (2010) and once water consumption data is available Giltner Hall should be included in the list of buildings to study. Giltner Hall has a significant number of labs (Rank 2 on number of laboratories) and therefore may have significant water consumption.

No leak studies have been performed in recent years on the distribution system at MSU. While major leaks are more easily identified and repaired, smaller leaks may go undetected for years. Over time these small leaks can add up and lead to a sufficient waste of water (AWWA, 2009). Therefore, it is recommended that a leak study be explored.

# APPENDICES

# Appendix A

## Water Supply

Some parts of Appendix A are not listed in this report due to formatting difficulties. For a report with a complete Appendix please contact:

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## Appendix B

## Water Bought

Some parts of Appendix B are not listed in this report due to formatting difficulties. For a report with a complete Appendix please contact:

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## Appendix C

## Water Sold

Table 31: Complete List of Water Sold

| State Control Laboratory | | Jan | Feb | March | April | May | June | July | August | Sept | October | Nov | Dec | GAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2004 | | | | | | | 587000 | 543000 | 581000 | 605000 | 505000 | 603000 | 3424000 |
| | 2005 | 412000 | 460000 | 462000 | 816000 | 477000 | 568000 | 655000 | 629000 | 467000 | 524000 | 543000 | 463000 | 6476000 |
| | 2006 | 566000 | 522000 | 567000 | 564000 | 615000 | 624000 | 592000 | 621000 | 611000 | 525000 | 547000 | 469000 | 6823000 |
| | 2007 | 547000 | 577000 | 641000 | 612000 | 505000 | 512000 | 680000 | 675000 | 692000 | 620000 | 575000 | 453000 | 7089000 |
| | 2008 | 462000 | 456000 | 491000 | 525000 | 660000 | 572000 | 606000 | 673000 | 503000 | 530000 | 432000 | 421000 | 6331000 |
| | 2009 | 395000 | 316000 | 415000 | 428000 | 536000 | 524000 | 593000 | 654000 | 435000 | 426000 | 347000 | 442000 | 5511000 |
| | | | | | | | | | | | | | AVERAGE | 6446000 |
| Credit Union | | Jan | Feb | March | April | May | June | July | August | Sept | October | Nov | Dec | |
| | 2004 | | | | | | | 32300 | 26100 | 23500 | 310700 | 69400 | 30500 | 492500 |
| | 2005 | 28000 | 26300 | 30300 | 28000 | 26300 | 30300 | 145400 | 163600 | 136400 | 103900 | 25100 | 24200 | 767800 |
| | 2006 | 27500 | 26900 | 32500 | 30700 | 86800 | 272200 | 238700 | 256900 | 117800 | 25300 | 25700 | 28000 | 1169000 |
| | 2007 | 28600 | 24200 | 26100 | 27300 | 47300 | 82700 | 164700 | 196300 | 204300 | 137100 | 24400 | 21800 | 984800 |

| | | Jan | Feb | March | April | May | June | July | August | Sept | October | Nov | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Table 31 Cont. | 2008 | 27400 | 26000 | 27600 | 29000 | 30000 | 116000 | 130300 | 128300 | 102400 | 155900 | 5400 | 5600 | 783900 |
| | 2009 | 5600 | 4900 | 5900 | 24900 | 69400 | 82600 | 954000 | 97400 | 77000 | 74600 | 17700 | 11700 | 1425700 |
| | | | | | | | | | | | | | AVERAGE | 1026240 |
| Credit Union Metered Irrigation | | Jan | Feb | March | April | May | June | July | August | Sept | October | Nov | Dec | |
| | 2004 | | | | | | | 277100 | 291000 | 312400 | 282700 | 43100 | 200 | 1206500 |
| | 2005 | 0 | 0 | 0 | 240 | 16080 | 13050 | | | | | | | 29370 |
| | 2006 | | | | | | | | | | | | | 1235870 |
| | 2007 | | | | | | | | | | | | | |
| | 2008 | | | | | | | | | | | | | |
| | 2009 | | | | | | | | | | | | | |
| Michigan State Police | | Jan | Feb | March | April | May | June | July | August | Sept | October | Nov | Dec | |
| | 2004 | | | | | | | 473000 | 517000 | 554000 | 560000 | 591000 | 444000 | 3139000 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Table 31 Cont. | 2005 | 330000 | 251000 | 490000 | 658000 | 861000 | 964000 | 1139000 | 1293000 | 903000 | 923000 | 845000 | 473000 | 9130000 |
| | 2006 | 610000 | 372000 | 735000 | 560000 | 627000 | 878000 | 1732000 | 802000 | 947000 | 690000 | 690000 | 724000 | 9367000 |
| | 2007 | 731000 | 709000 | 700000 | 893000 | 1112000 | 1128000 | 1281000 | 1280000 | 1280000 | 1421000 | 650000 | 920000 | 12105000 |
| | 2008 | 1420000 | 284000 | 962000 | 807000 | 819000 | 129000 | 235000 | 168000 | 173000 | 220000 | 93000 | 199000 | 5509000 |
| | 2009 | 104000 | 112000 | 191000 | 170000 | 376000 | 86000 | 200000 | 150000 | 160000 | 224000 | 96000 | 175000 | 2044000 |
| | | | | | | | | | | | | | AVERAGE | 7631000 |

| USDA Ag research | | Jan | Feb | March | April | May | June | July | August | Sept | October | Nov | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2004 | | | | | | | 167860 | 172990 | 161350 | 152420 | 177370 | 147360 | 979350 |
| | 2005 | 141370 | 142630 | 159000 | 129230 | 145850 | 172370 | 143680 | 164010 | 170130 | 170080 | 154430 | 118210 | 1810990 |
| | 2006 | 143610 | 131070 | 166530 | 206410 | 225840 | 180490 | 189800 | 199030 | 393020 | 140170 | 152410 | 116770 | 2245150 |
| | 2007 | 118550 | 106520 | 137270 | 144440 | 182430 | 260530 | 395130 | 387260 | 235610 | 389080 | 245350 | 269300 | 2871470 |
| | 2008 | 473850 | 152080 | 346120 | 368070 | 420930 | 334410 | 276850 | 322990 | 126890 | 147820 | 96810 | 104910 | 3171730 |
| | 2009 | 100630 | 99400 | 173070 | 100810 | 147150 | 113520 | 124560 | 130970 | 185410 | 23060 | 3750 | 311370 | 1513700 |
| | | | | | | | | | | | | | AVERAGE | 2322608 |

Some parts of Appendix C are not listed in this report due to formatting difficulties. For a report with a complete Appendix please contact:

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# Appendix D

# Meters

Table 32: Complete List of Meters

| | | | |
|---|---|---|---|
| 0313 | BRODY HALL | 0313W1 | Apr-96 |
| 0024 | NATURAL SCIENCE | 0024W1 | Jan-97 |
| 0128 | NISBET, STEVEN S., BUILDING | 0128W1 | May-97 |
| | | 0307W1 | May-97 |
| 0308 | WILLIAMS HALL | 0308W1 | Jun-97 |
| 0304 | CAMPBELL HALL | 0304W1 | Jul-97 |
| 0306 | YAKELEY AND GILCHRIST HALL | 0306W1 | Aug-97 |
| 0302 | MASON AND ABBOT HALL | 0302W1 | Jan-98 |
| 0056 | JENISON FIELDHOUSE | 0056W1 | Aug-98 |
| | | 0077W2 | Nov-98 |
| 0154 | MANLY MILES BUILDING | 0154W1 | Feb-99 |
| 0005 | HUMAN ECOLOGY | 0005W1 | May-99 |
| 0175 | INTRAMURAL RECREATIVE SPORTS EAST | 0175W1 | Jul-99 |
| 0311 | RATHER HALL | 0311W1 | Jan-00 |
| 0006 | UNION BUILDING | 0006W1 | Aug-00 |
| 0305 | LANDON HALL | 0305W1 | Aug-00 |
| 170 | VETERINARY MEDICAL CENTER | 0170W1 | Aug-00 |
| | | 0178W3 | Oct-01 |
| 0160 | BIOMEDICAL PHYSICAL SCIENCES BUILDING | 0160W1 | Jan-02 |
| 0086 | PLANT & SOIL SCIENCES BUILDING | 0086W1 | Feb-02 |
| 0219 | PARKING RAMP NO.1 SHAW LANE (NEW) | 0219W1 | Sep-02 |
| 0312 | BRYAN HALL | 0312W1 | May-04 |
| 0314 | EMMONS HALL | 0314W1 | May-04 |
| 0315 | BAILEY HALL | 0315W1 | May-04 |
| 0310 | BUTTERFIELD HALL | 0310W1 | Mar-05 |
| 0177 | PACKAGING | 0177W1 | Apr-05 |
| 0058 | SPARTAN STADIUM | 0058W1 | Aug-05 |
| 0171 | FOOD STORES | 0171W1 | Aug-05 |
| 2000 | CLINICAL CENTER | 2000W1 | Sep-05 |
| 0300 | SNYDER AND PHILLIPS HALL | 0300W1 | Aug-07 |
| 0214 | RADIOLOGY BUILDING | 0214W1 | Nov-07 |
| 0319 | VANHOOSEN HALL | 0319W1 | Nov-07 |
| | | 0170W2 | Nov-07 |
| 0013 | MUSEUM | 0013W1 | Jan-08 |
| 0163 | CHEMISTRY | 0163W1 | Jan-08 |

| | | | |
|---|---|---|---|
| | Table 32 Cont. | 0203W2 | Feb-08 |
| | | 0170W3 | Jul-08 |
| 0055 | KELLOGG CENTER | 0055W1 | Mar-09 |
| 0083 | MSU COLLEGE OF LAW | 0083W1 | Jun-09 |
| 0316 | ARMSTRONG HALL | 0316W1 | Aug-09 |
| 0309 | MARY MAYO HALL | 0309W1 | Sep-09 |
| | | 0028W2 | Nov-09 |
| 0028 | GILTNER HALL | 0028W1 | Dec-09 |
| 0323 | WONDERS HALL | 0323W1 | Jan-10 |
| 0002 | BERKEY HALL | 0002W1 | |
| 0003 | OLIN MEMORIAL HEALTH CENTER | 0003W1 | |
| 0027 | PSYCHOLOGY BUILDING | 0027W1 | |
| 0029 | KEDZIE HALL (NORTH AND SOUTH) | 0029W1 | |
| 0035 | COMPUTER CENTER | 0035W1 | |
| | | 0055W2 | |
| 0059 | MUNN, CLARENCE L., ICE ARENA | 0059W1 | |
| 0060 | CENTRAL SERVICES BUILDING | 0060W1 | |
| | | 0060W2 | |
| 0068 | LAUNDRY BUILDING | 0068W1 | |
| 0069 | BRESLIN, JACK, STUDENT EVENTS CENTER | 0069W1 | |
| 0080 | BUSINESS COLLEGE COMPLEX (EPPLEY) | 0080W1 | |
| 0081 | ENGINEERING BUILDING | 0081W1 | |
| | | 0081W2 | |
| 0084 | COMMUNICATION ARTS & SCIENCES BUILDING | 0084W1 | |
| | | 0086W2 | |
| 0087 | PUBLIC SAFETY | 0087W1 | |
| 0132 | ANTHONY HALL | 0132W1 | |
| | | 0132W2 | |
| | | 0132W3 | |
| | | 0132W4 | |
| 0178 | PLANT BIOLOGY LABORATORIES | 0178W1 | |
| | | 0178W2 | |
| 0186 | FOOD SAFETY AND TOXICOLOGY BUILDING | 0186W1 | |
| 0189 | REGIONAL CHILLED WATER PLANT NO. 1 | 0189W1 | |
| 0203A | ENGINEERING RESEARCH COMPLEX | 0203W1 | |
| 0212A | PAVILION FOR AGRICULTURE AND LIVESTOCK EDUCATION – HORSE BAR | 0212W1 | |
| | | 0303W1 | |
| 0317 | SHAW HALL | 0317W1 | |
| 0320 | OWEN GRADUATE HALL | 0320W1 | |
| 0330 | HOLMES HALL | 0330W1 | |
| 0446A | VETERINARY RESEARCH CENTER – LARGE ANIMAL BARN | 0446W1 | |
| | | 0446W2 | |

| Table 32 Cont. | | |
|---|---|---|
| 1121 | MUSIC/MUSIC PRACTICE | 1121W1 |
| 7000 | FACULTY BRICK APARTMENTS | 7000W1 |
| 77 | FOOTBALL BUILDING | 0077W1 |
| 85 | WHARTON CENTER | 0085W1 |
| 91 | FARRALL AGRICULTURAL ENGINEERING HALL | 0091W1 |

Table 33: MSU Supply Meters

| MSU Supply Meters<br>Bldg Complex<br>Num | Complex Bldg Name |
|---|---|
| 1121 | MUSIC/MUSIC PRACTICE |
| 7000 | FACULTY BRICK APARTMENTS |
| 77 | FOOTBALL BUILDING |
| 91 | FARRALL AGRICULTURAL ENGINEERING HALL |
| 85 | WHARTON CENTER |
| 2000 | CLINICAL CENTER |
| 0055 | KELLOGG CENTER |
| 170 | VETERINARY MEDICAL CENTER |
| 0163 | CHEMISTRY |
| 0171 | FOOD STORES |
| 0177 | PACKAGING |
| 0128 | NISBET, STEVEN S., BUILDING |
| 0024 | NATURAL SCIENCE |
| 0027 | PSYCHOLOGY BUILDING |
| 0029 | KEDZIE HALL (NORTH AND SOUTH) |
| 0058 | SPARTAN STADIUM |
| 0060 | CENTRAL SERVICES BUILDING |
| 0068 | LAUNDRY BUILDING |
| 0080 | BUSINESS COLLEGE COMPLEX (EPPLEY) |
| 0214 | RADIOLOGY BUILDING |
| 0160 | BIOMEDICAL- PHYSICAL SCIENCES BUILDING |
| 0006 | UNION BUILDING |
| 0083 | MSU COLLEGE OF LAW |
| 0186 | FOOD SAFETY AND TOXICOLOGY BUILDING |
| 0446A | VETERINARY RESEARCH CENTER – LARGE ANIMAL BARN |
| 0056 | JENISON FIELDHOUSE |
| 0059 | MUNN, CLARENCE L., ICE ARENA |
| 0002 | BERKEY HALL |
| 0003 | OLIN MEMORIAL HEALTH CENTER |
| 0005 | HUMAN ECOLOGY |
| 0013 | MUSEUM |
| 0028 | GILTNER HALL |
| 0035 | COMPUTER CENTER |
| 0069 | BRESLIN, JACK, STUDENT EVENTS CENTER |
| 0081 | ENGINEERING BUILDING |
| 0084 | COMMUNICATION ARTS & SCIENCES BUILDING |
| 0086 | PLANT & SOIL SCIENCES BUILDING |
| 0087 | PUBLIC SAFETY |

| | Table 33 Cont. |
|---|---|
| 0132 | ANTHONY HALL |
| 0154 | MANLY MILES BUILDING |
| 0175 | INTRAMURAL RECREATIVE SPORTS EAST |
| 0178 | PLANT BIOLOGY LABORATORIES |
| 0189 | REGIONAL CHILLED WATER PLANT NO. 1 |
| 0300 | SNYDER AND PHILLIPS HALL |
| 0305 | LANDON HALL |
| 0308 | WILLIAMS HALL |
| 0309 | MARY MAYO HALL |
| 0310 | BUTTERFIELD HALL |
| 0311 | RATHER HALL |
| 0312 | BRYAN HALL |
| 0313 | BRODY HALL |
| 0314 | EMMONS HALL |
| 0315 | BAILEY HALL |
| 0319 | VANHOOSEN HALL |
| 0203A | ENGINEERING RESEARCH COMPLEX |
| 0302 | MASON AND ABBOT HALL |
| 0304 | CAMPBELL HALL |
| 0306 | YAKELEY AND GILCHRIST HALL |
| 0316 | ARMSTRONG HALL |
| 0317 | SHAW HALL |
| 0320 | OWEN GRADUATE HALL |
| 0323 | WONDERS HALL |
| 0330 | HOLMES HALL |
| 0212A | PAVILION FOR AGRICULTURE AND LIVESTOCK EDUCATION – HORSE BAR |
| 0219 | PARKING RAMP NO.1 SHAW LANE (NEW) |
| 215 | DCPAH |
| | State Control Lab |
| | Michigan State Police |
| | MSUFCU |

Purchased Water Meters

| | |
|---|---|
| 618 | James B. Henry Center |
| 475A | Chemical Waste Facility #1 (Jolly Rd.) |
| 475B | Chemical Waste Facility #2 (Jolly Rd.) |
| 129 | Entomology (Collings Rd.) |
| 456O | Horse Research Center |

# Appendix E

# Power Plant

Some parts of Appendix E are not listed in this report due to formatting difficulties. For a report with a complete Appendix please contact:

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Appendix F

Chilled Water

Table 34: 2007-2008 Chilled Water Make-Up

Water Usage Per System 2008

| BUILDING | KGAL |
|---|---|
| Comm Arts | 6 |
| Anthony - REFRIGERATION | 74 |
| CIPS Refrigeration | 102 |
| Clinical Center Refrigeration | 105 |
| Biochemistry Refrigeration | 157 |
| Natural Resources Refrigeration | 169 |
| Anthony - Dairy Plant Refrigeration | 253 |
| Olin Health Center Refrigeration | 253 |
| International Center | 511 |
| Administration Building - DATA PROCESSING | 601 |
| Kedzie Hall Absorption | 684 |
| Anthony - Meat Laboratory Refrigeration | 837 |
| Breslin Center Absorption | 1,072 |
| Administration Building | 1,170 |
| Cyclotron CT-1 Refrigeration | 1,172 |
| Regional Chilled Water Plant 10 | 1,197 |
| Wells Hall Absorption | 1,296 |
| Bessey Hall Absorption | 1,396 |
| Munn Ice Arena Refrigeration | 1,396 |
| Union Building Absorption | 1,573 |
| Regional Chilled Water Plant 8 | 1,732 |
| Regional Chilled Water Plant 7 | 1,992 |
| Kellogg Center (East) | 2,225 |
| Engineering Absorption | 2,696 |
| Fee Hall Absorption | 2,782 |
| Regional Chilled Water Plant 9 | 2,898 |
| DCPAH-Diagnostic Center for Population and Animal Health | 3,385 |
| Regional Chilled Water Plant 5 | 3,437 |
| Erickson Hall Absorption | 4,107 |
| Library Absorption | 4,524 |
| Kellogg Center (West) | 4,806 |
| Anthony - ABSORPTION | 5,424 |
| Food Science Absorption | 5,511 |
| Regional Chilled Water Plant 4 | 5,675 |
| Regional Chilled Water Plant 2 | 5,879 |

| | |
|---|---|
| Table 34 Cont. | |
| Regional Chilled Water Plant 6 | 5,977 |
| Regional Chilled Water Plant 3 | 6,077 |
| Regional Chilled Water Plant 1 | 6,299 |
| Biophysical Science | 12,690 |
| | 102,139 |

GENERAL FUND

Water Usage Per System 2007

| Building | Gallons |
|---|---|
| Comm Arts | 9700 |
| Anthony - REFIGERATION | 65070 |
| CIPS Refrigeration | 112150 |
| Clinical Center Refrigeration | 137380 |
| Natural Resources Refrigeration | 194150 |
| Anthony - Dairy Plant Refrigeration | 248400 |
| Biochemistry Refrigeration | 255170 |
| Olin Health Center Refrigeration | 306160 |
| Administration Building - DATA PROCESSING | 527670 |
| Kedzie Hall Absorption | 862400 |
| Anthony - Meat Laboratory Refrigeration | 1003940 |
| Cyclotron CT-1 Refrigeration | 1059370 |
| Munn Ice Arena Refrigeration | 1209220 |
| Administration Building | 1453400 |
| International Center | 1519100 |
| Breslin Center Absorption | 1560900 |
| Bessey Hall Absorption | 1754100 |
| Union Building Absorption | 1822600 |
| Wells Hall Absorption | 1953900 |
| Erickson Hall Absorption | 2002000 |
| Kellogg Center (West) | 2384000 |
| Fee Hall Absorption | 2973600 |
| Chilled Water Plant 10 | 3012800 |

| Table 34 Cont. | |
|---|---|
| Chilled Water Plant 5 | 3111500 |
| Engineering Absorption | 3327200 |
| Chilled Water Plant 9 | 3349300 |
| DCPAH | 3648700 |
| Chilled Water Plant 4 | 3959300 |
| Chilled Water Plant 8 | 5126300 |
| Chilled Water Plant 6 | 5757400 |
| Kellogg Center (East) | 6086400 |
| Food Science Absorption | 6967100 |
| Anthony - ABSORPTION | 7138900 |
| Library Absorption | 7780800 |
| Chilled Water Plant 3 | 7924800 |
| Chilled Water Plant 2 | 8526500 |
| Chilled Water Plant 1 | 8683400 |
| Biophysical Science | 15303000 |
| Chilled Water Plant 7 | 50426320 |
| Total Water Used : | 173,544,100 |

CHILLED WATER USAGE 99,877,620

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# Appendix G

# Irrigation

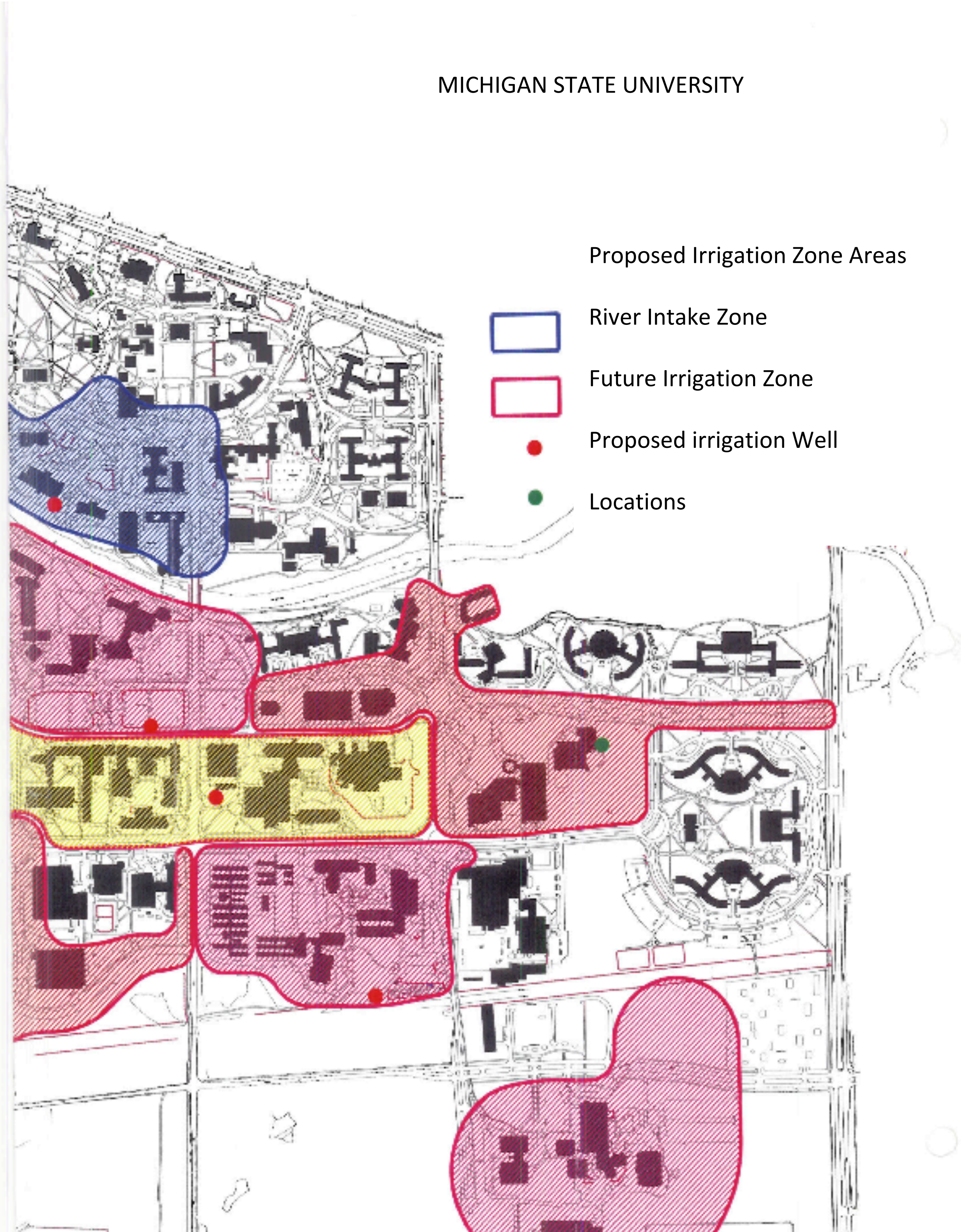


Figure 10: Irrigation Proposed Zone Map

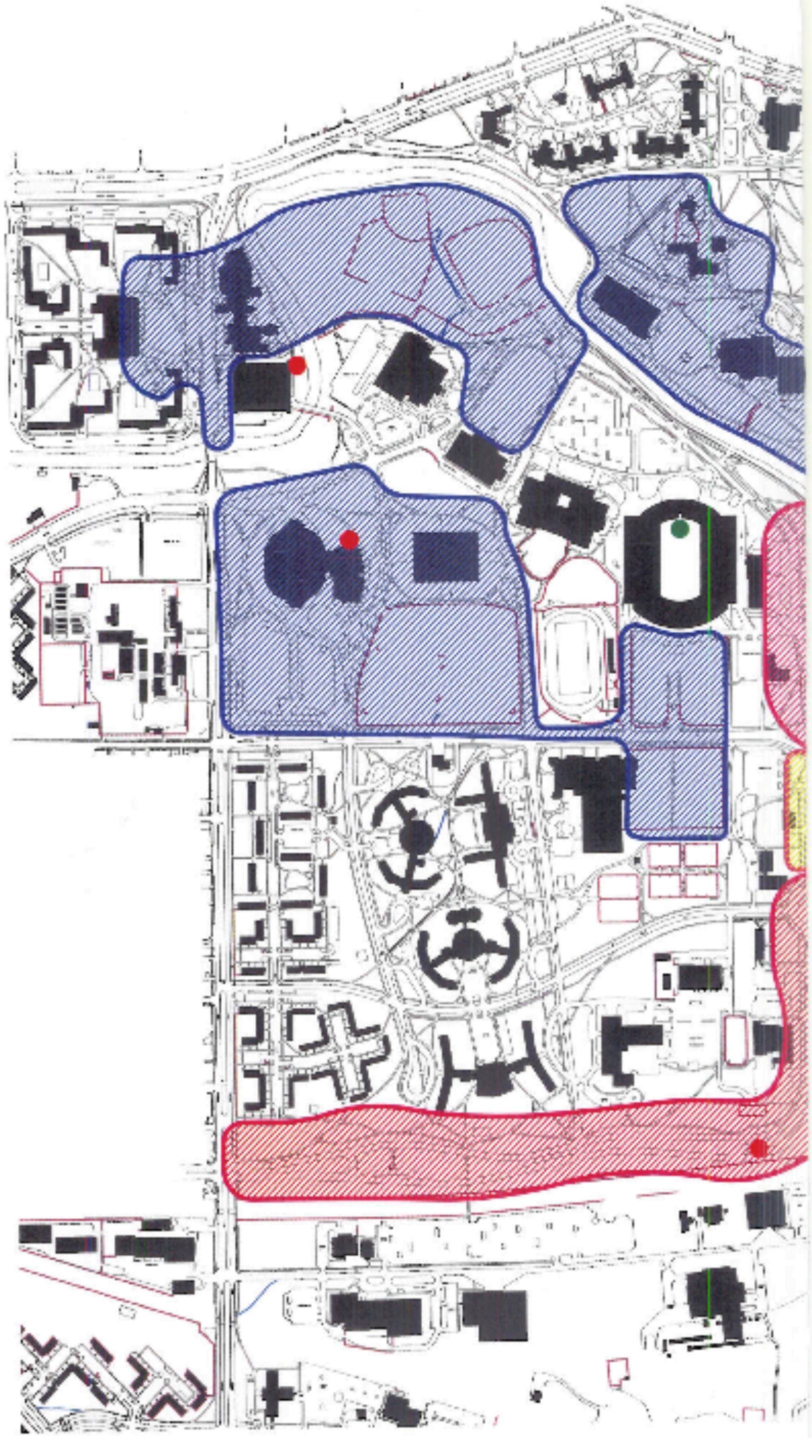

Figure 10 Cont.

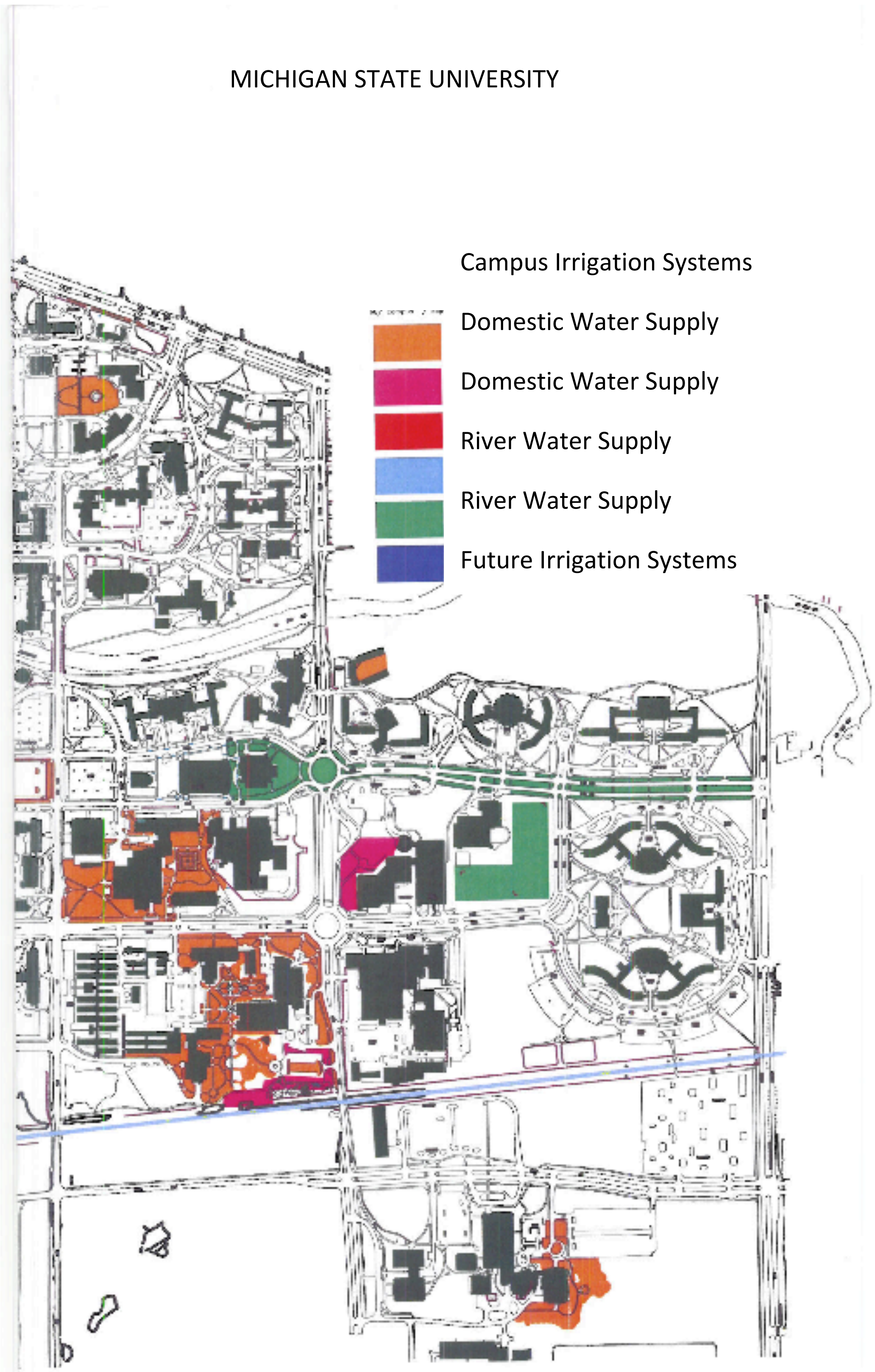


Figure 11: Campus Irrigation Map

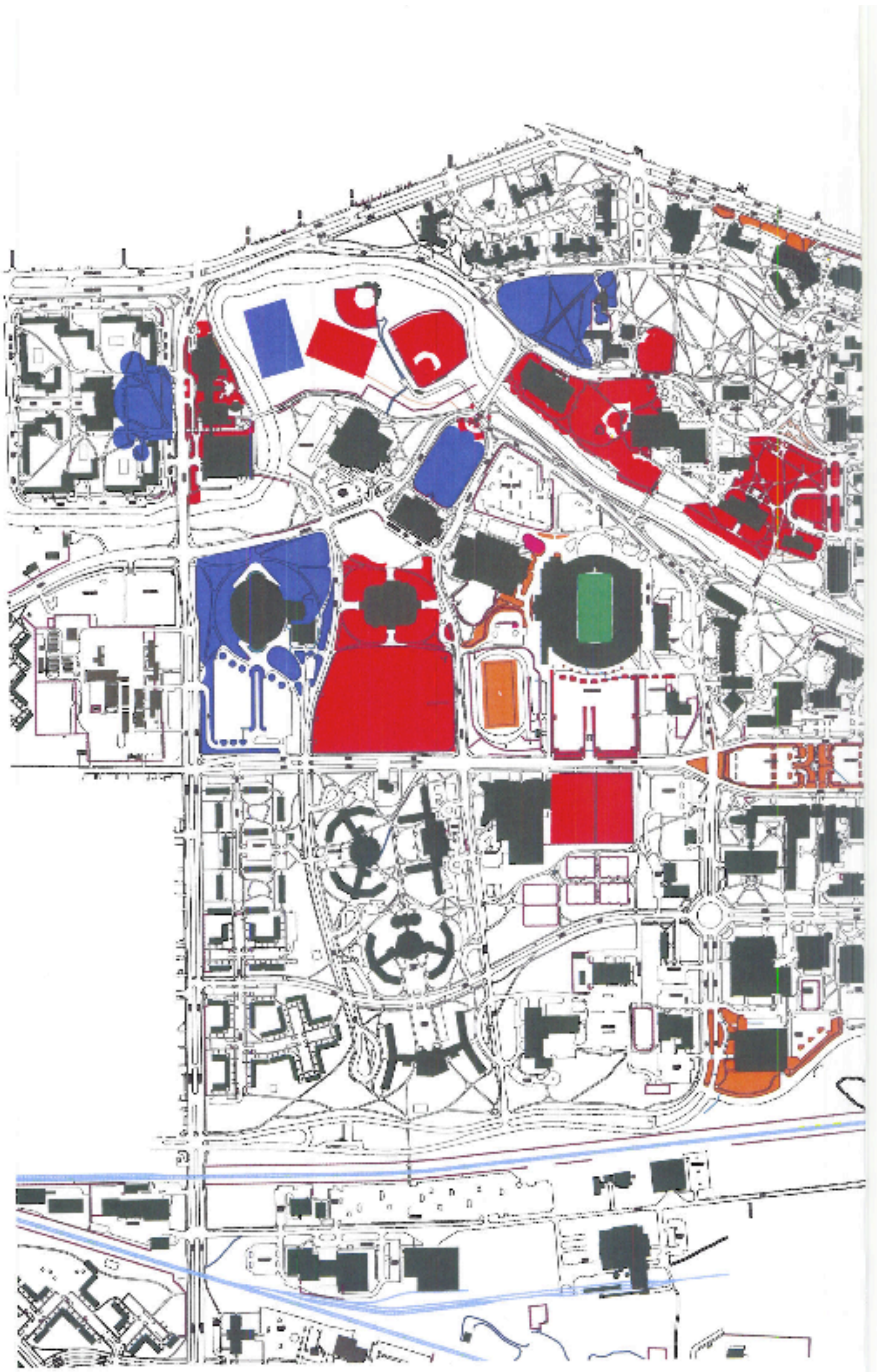

Figure 11 Cont.

Table 35: Campus irrigation Sites

| Irrigation Systems | Area | Water |
|---|---|---|
| Adams Field | Acad | River |
| Admin Bldg | Acad | River |
| Biomedical & Physical Sciences | Acad | Dom |
| Breslin | Acad | River |
| Clancie Lewis | Acad | Dom |
| Law Bldg. | Acad | Well |
| Grand River 1 & 2 | Acad | Well |
| Kellogg | Acad | River |
| Plant Biology | Acad | Dom |
| Presidents House | Acad | River |
| Radiology | Acad | Dom |
| Shaw Lane | Acad | Well |
| Soil Science | Acad | Dom |
| Stud Serv Grdn | Acad | Dom |
| Toxicology | Acad | Dom |
| Wharton | Acad | Dom |
| Baseball | Athletic | River |
| Dem Hall | Athletic | River |
| Football Practice | Athletic | River |

Table 35 Cont.

| | | |
|---|---|---|
| Munn Ice Arena | Athletic | River |
| Soccer | Athletic | River |
| Track | Athletic | River |
| Beal Gardens | Beal | River |
| Brody | Housing | River |
| Van Hoosen | Housing | Dom |
| IM East 'Fields" | IM | Well |
| Munn Field | IM | River |
| Lot 39 | Park | Dom |
| Lot 40 | Park | Dom |
| Lot 79 | Park | River |
| Ramp 1 | Park | Dom |
| Ramp 5 | Park | Well |

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Appendix H

Residence Halls

Table 36:Residence Hall Summary

| **Resident Hall** | **Enrollment** | **Cafeteria** | **Water Consumption** | **Per Capita** | **Water Consumption Estimates** | **Water Consumption Total Estimated** | **Estimates without cafeteria** | **Cafeteria Consumption** |
|---|---|---|---|---|---|---|---|---|
| Akers | 1250 | Y | NA | | 29290.98574 | 29291 | 25815.03207 | 3476 |
| Holmes | 1179 | Y | 29721.2 | 25.20882103 | | 29721 | 24348.73825 | 5372 |
| Holden | 1079 | Y | NA | | 25283.97889 | 25284 | 22283.53568 | 3000 |
| Hubbard | 1057 | Y | NA | | 24768.45754 | 24768 | 21829.19112 | 2939 |
| Wilson | 983 | Y | NA | | 23034.43118 | 23034 | 20300.94122 | 2733 |
| Wonders | 908 | Y | 16860.8 | 18.569163 | | 16861 | 18752.0393 | -1891 |
| McDonel | 882 | Y | NA | | 20667.71954 | 20668 | 18215.08663 | 2453 |
| Shaw | 855 | Y | 17338.2 | 20.27859649 | | 17338 | 17657.48194 | -319 |
| Case | 838 | Y | NA | | 19636.67684 | 19637 | 17306.3975 | 2330 |
| Mason/Abbot | 618 | | 10252.2 | 16.58932039 | | 10252.2 | | |
| Syder/Phillips | 587 | Y | 10100.52 | 17.20701874 | | 10100.52 | 12122.73906 | -2022 |
| Owen | 561 | Y* | 19839.4 | 35.36434938 | | 19839.4 | 11585.78639 | 8254 |
| Yakeley/Gilchrist | 454 | Y | 10046 | 22.1277533 | | 10046 | 9376.019649 | 670 |
| Armstrong | 446 | | 10388.67 | 23.2929820 | | 10388.67 | | |

Table 36 Cont.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | 6 | | | |
| Rather | 424 | | 5822.4 | 13.73207547 | 5822.4 | | |
| Emmons | 420 | | 13093 | 31.17380952 | 13093 | | |
| Bailey | 419 | | 14935.2 | 35.64486874 | 14935.2 | | |
| Bryan | 398 | | 12925 | 32.47487437 | 12925 | | |
| Butterfield | 340 | | 4412.2 | 12.97705882 | 4412.2 | | |
| Landon | 275 | Y | 6950.3 | 25.27381818 | 6950.3 | 5679.307056 | 1271 |
| Campbell | 236 | | 3331.08 | 14.11474576 | 3331.08 | | |
| Mayo | 209 | | 2706.5 | 12.94976077 | 2706.5 | | |
| Williams | 194 | | 3492.7 | 18.00360825 | 3492.7 | | |
| VanHoosen | 73 | | 1184 | 16.21917808 | 1184 | | |

| | | |
|---|---|---|
| **Average Per Capita without Cafeteria** | 20.65202566 | 8.205666986 |
| **Average Per Capita with Cafeteria** | 23.43278859 | 6.096077059 |
| **Total Water Consumption** | 336082 | |

| | |
|---|---|
| **Table 36 Cont.** | |
| **Total Cafeteria Consumption** | 28266 |

Sample Calculation

For McDonel Hall

Water consumption estimate= Enrollment * Average Per Capita with Cafeteria

Water Consumption = 882 Residents * 23.43 KGAL per Resident = 20668 KGAL

Some parts of Appendix H are not listed in this report due to formatting difficulties. For a report with a complete Appendix please contact:

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# Appendix I

# Buildings

Sample Calculations for restroom savings

Estimated Water Savings for Vet Clinic =((# of toilets *(3.5 gal/flush-1.6 gal/flush) + # of urinals * (3 gal/flush - .125 gal/flush)+ # of sinks *2) * # of paper towel use * 3.0321 $/KGAL/1000 KGAL)

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# Appendix J

## Miscellaneous

Calculations on how an updated RO system can save money.

Efficiency of RO system = 50%, Water Lost per 100 gallons= 1000*.5 = 500 gal, Money lost per 1000 gal = 500 * 3.0321 $/1000 GAL= $1.52 lost per 1000 per gal.

Table 37: RO System Information – RHS Residence Halls (Updated 7/21/10)

| Hall | RO Location | Water/Ice Dispenser location (s) | Type of Ice Maker /Dispenser/Faucet | RO Removed, Date | Filter System Proposed |
|---|---|---|---|---|---|
| East Neighborhood | | | | | |
| Akers | C-38 | West corridor | Drinking Fountain | | CFS22, BEV145 |
| Holmes | 1st Floor East Comp Rm | East Lobby Alcove | Hoshizaki DCM-270BAH | Yes, 7/10 | CFS22, ICE45-S |
| | 1st floor West Comp Rm | West Lobby Alcove | Manitowoc SY0424A (floor unit) | Yes, 3/10 | CFS22, ICE45-S |
| Hubbard | MR G-75 | North 1st floor corridor | Drinking Fountain<br>Will be adding a Manitowoc SY042A (floor unit) in the North Laundry Room | | CFS22, ICE45-S |
| Riverwalk Neighborhood | | | | | |
| McDonel | MR B-8-A | East Lobby Alcove | Hoshizaki DCM-270BAH | | CFS22, ICE45-S |
| | MR 32 A | West Lobby Alcove | Hoshizaki DCM-270BAH | | CFS22, ICE45-S |
| | | | *Both McDonel alcoves also have Coster water stations for filling large containers | | |
| Owen | B1 Basement | West Elevator lobby – small room off lobby | Hoshizaki DCM-270BAH<br>Plus sink with gooseneck faucet | | CFS22, ICE45-S |
| Shaw | Room 106 | Right of East Desk | Manitowoc SY0424A (floor unit) | | CFS22, ICE45-S |
| Red Cedar Neighborhood | | | | | |
| Mason/Abbot | Storage by Kitchenette | New Kitchenette old cafeteria | Manitowoc SY0424A (floor unit) | | CFS22, ICE45-S |

| | | | | | |
|---|---|---|---|---|---|
| Table 37 Cont. Sny/Phi | MR W031 | Phillips Main Lobby Vendor Alcove | Manitowoc SY0424A (floor unit) | | CFS22, ICE45-S |
| South Neighborhood | | | | | |
| Case | MR 46A | North Laundry<br>North Lobby | Hoshizaki DCM-270BAH<br>Faucet Fill in North Laundry<br>Drinking fountain in North Lobby | | CFS22, ICE45-S |
| Holden | MR A (inside MR G-48) | West Laundry | Manitowoc SY0424A (floor unit) | | CFS22, ICE45-S |
| Wilson | 1st floor West W109 | West Main Corridor | Faucet Fill | | CFS22, BEV145 |
| Wonders | B2 Basement (non-MR) (SS Storage) | North Laundry | Faucet Fill | | CFS22, BEV145 |
| Brody Neighborhood | | | | | |
| Armstrong | MR C-1 | Main Lobby | Drinking Fountain | | None–City Water |
| Bailey | MR C-1 | Main Lobby | Drinking Fountain | | None–City Water |
| Bryan | MR C-1 | Main Lobby | Drinking Fountain | | None–City Water |
| Butterfield | MR C-1 | Main Lobby | Drinking Fountain | | None–City Water |
| Emmons | MR C-1 | Main Lobby | Drinking Fountain | | None–City Water |
| Rather | MR C-1 | Main Lobby | Drinking Fountain | | None–City Water |
| West Circle Neighborhood | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Table 37 Cont. Campbell | G-29 | G-29 | Direct to Water Dispenser | | CFS22, BEV145 |
| Campbell | G-11 | G-11 | Direct to Water Dispenser | | CFS22, BEV145 |
| Gilchrist | W-3 | W-3 | Direct to Water Dispenser | | CFS22, BEV145 |
| Landon | G-11 | G-11 | Direct to Water Dispenser | | CFS22, BEV145 |
| Mayo | 225 | 225 | Bottle Fill | | CFS22, BEV145 |
| Mayo | 239 | 239 | Bottle Fill | | CFS22, BEV145 |
| Mayo | 325 | 325 | Bottle Fill | | CFS22, BEV145 |
| Mayo | 339 | 339 | Bottle Fill | | CFS22, BEV145 |
| Williams | C-3 | C-3 | Faucet in Kitchenette | | CFS22, BEV145 |
| Williams | C-12 | C-12 | Faucet in Kitchenette | | CFS22, BEV145 |
| Williams | 211A | 211A | Faucet in Kitchenette | | CFS22, BEV145 |
| Williams | 261A | 261A | Faucet in Kitchenette | | CFS22, BEV145 |
| Williams | 311A | 311A | Faucet in Kitchenette | | CFS22, BEV145 |
| Williams | 361A | 361A | Faucet in Kitchenette | | CFS22, BEV145 |
| Yakeley | E-53 | E-53 | Direct to Water Dispenser | | CFS22, BEV145 |

| | | | | | |
|---|---|---|---|---|---|
| Table 37 Cont. Yakeley | E-54 | E-54 | Direct to Water Dispenser | | CFS22, BEV145 |

System Description and Costs

CFS22 & BEV145: This system is to be used in areas where there is no ice maker in place. It includes a 20" sediment filter and a single cartridge filter to provide purified water for consistent high quality taste and appearance. A one-time cost for the filter bracket and housing is $250.54. The first set of filters will cost (CFS210-2 = $41.70 and HF45 = $69.44), for a total of $111.14. The CFS210 will be replaced quarterly, while the HF45 will be replaced every 6 months. Annual filter replacement costs will be $305.68 per system.

CFS22 & ICE45-S: This system is to be used in areas where there are ice makers in place. It includes a 20" sediment filter and a single cartridge filter to provide purified water for consistent high quality taste and appearance. In addition, the filter has a built-in scale inhibitor for equipment protection and clearer ice. A one-time cost for the filter bracket and housing is $252.55. The first set of filters will cost (CFS210-2 = $41.70 and HF45-S = $71.35), for a total of $113.05. The CFS210 will be replaced quarterly, while the HF45-S will be replaced every 6 months. Annual filter replacement costs will be $309.50 per system.

Installation: Installation costs will vary, based upon the complexity of the install (e.g., access, material required), but should not exceed $150 per system.

NOTE: Red in Filter System column indicates that these filters have been installed.

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