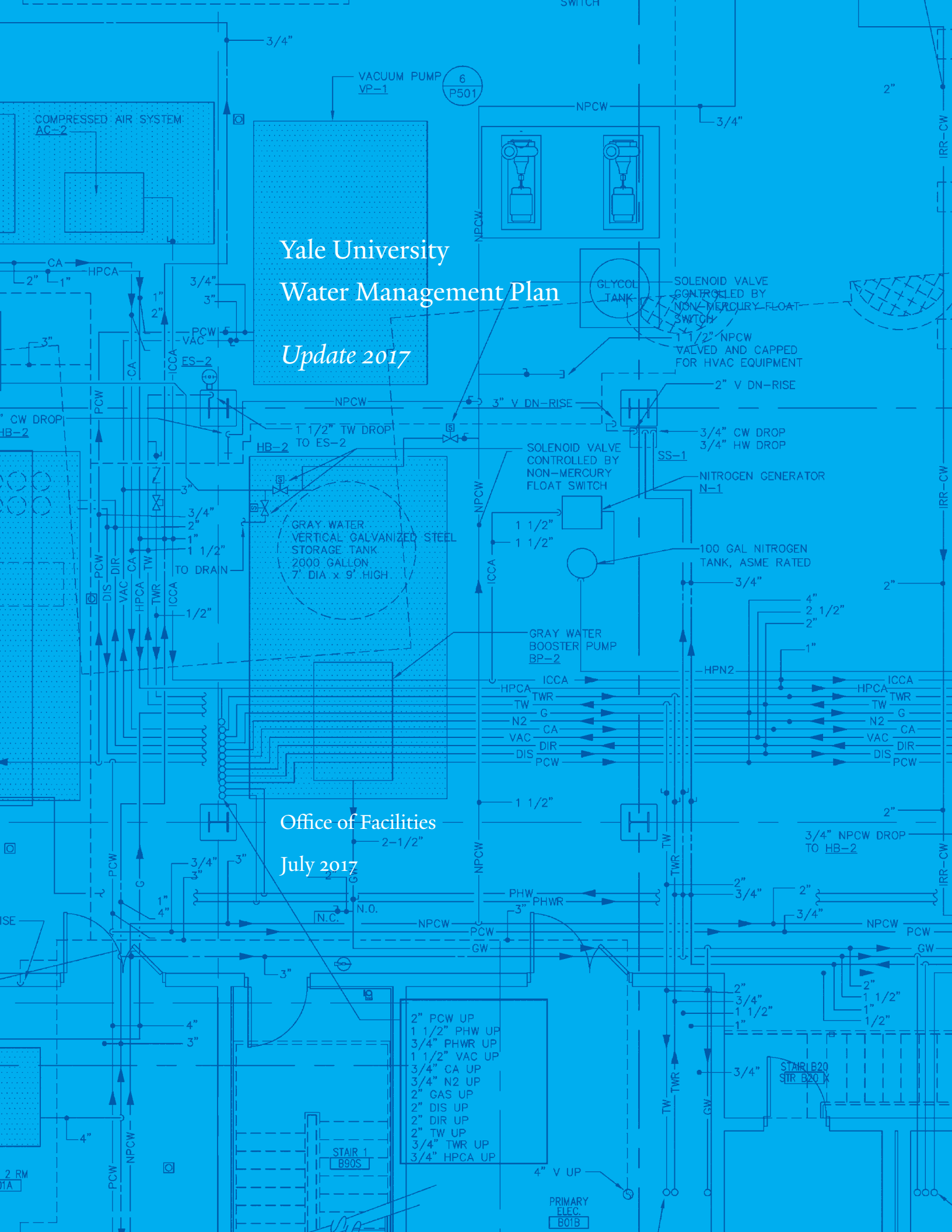

Yale University
Water Management Plan

Update 2017

Office of Facilities

July 2017

Yale University
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July 2017

Contents

Introduction

In 2013, the Yale Water Management Plan 2013–2016 was released, detailing the importance of water management on campus; various approaches taken to date with campus metering, building, irrigation, and process systems; and methodology for analyzing water data and metrics. The plan also presented a suite of strategies identified toward a university-wide 5% water-use reduction goal.

In 2016, the Office of Sustainability released the Yale Sustainability Plan 2025, which presents a comprehensive approach to connect scholarship and operations at Yale under one sustainability vision. The plan sets a specific goal "to update the campus water management plan in alignment with local priorities."

This document provides an update to the Water Management Plan 2013–2016 and initial fulfillment of the Yale Sustainability Plan 2025. Moving forward, the University intends to incorporate water management progress and planning into the Campus Resilience Plan, High Performance Design Standards, Sustainability Progress Reports, and supporting documents. Collectively, these plans invite generative work and collaboration between the academic and operational sides of the University. The significance of operational commitments is expanded beyond Yale's campus with related applied research, teaching, and service.

Vision for Water Management

Yale University envisions a campus where water is actively and adaptively managed as a highly valuable resource.

Water is a critical utility for Yale, accounting for 6–8% of its annual utility budget. In addition to serving the daily domestic needs of more than 28,000 people, water is used for energy production, laboratory and critical research processes, dining services, and ground maintenance for a campus consisting of more than 19 million square feet and 1,000 acres.

Water also connects to the nine ambitions of the Yale Sustainability Plan 2025, particularly Health & Well-Being, Climate Action, Stewardship, and Built Environment.

Future efforts in water management planning shall be guided by a set of shared principles. Like the Sustainability Planning Principles, these principles capture the strength of near-term activities, provide direction for future development, and should be taken collectively to motivate and focus work:

Recognize water as a critical resource. Water is essential to Yale's daily operations. In addition to providing for domestic needs, water supports laboratory and critical research, and energy production on campus. Yale shall recognize the value of water beyond its utility costs to position the campus well for long-term resiliency.

Promote water metering, conservation technologies, and conservation research. Collecting water-use data and related activities offer and necessitate robust research and educational opportunities for students and faculty at and beyond Yale. Yale shall encourage university-wide participation and stewardship of water management strategies on campus, as well as applied research that informs regional and global efforts.

Prioritize adaptive management strategies. Strategies to inform and improve water management decisions and activities enable the most positive outcomes at Yale and across the region. Yale shall commit to collecting water-use data, sharing data broadly, and using an iterative decision-making process for ongoing water management on our campus and beyond.

Progress to Date

The following section describes the most current system and performance metrics on campus, reflecting changes since the Water Management Plan was initially released in 2013.

Metering

The campus metering system includes 269 revenue meters installed and maintained by the South Central Connecticut Regional Water Authority (RWA).

Included in this analysis are 219 meters tied to 144 electronically billed accounts, and 50 meters tied to 32 paper-billed accounts. The meters are read on a monthly or quarterly basis either automatically or manually. Yale receives water-use data as part of the billing statement from RWA. In addition to the 269 RWA meters, one meter is installed at the Central Campus chiller plant as a submeter of a revenue meter owned by others. Because the water use measured by this meter is substantial, it is recorded by Facilities on a regular basis.

For a more accurate and detailed analysis, we looked at meters on the building account level. Under the current billing system, meters are linked to building accounts rather than strictly to individual buildings. There are 197 building accounts included in this analysis.

Our evaluation of the current metering and billing system demonstrates that:

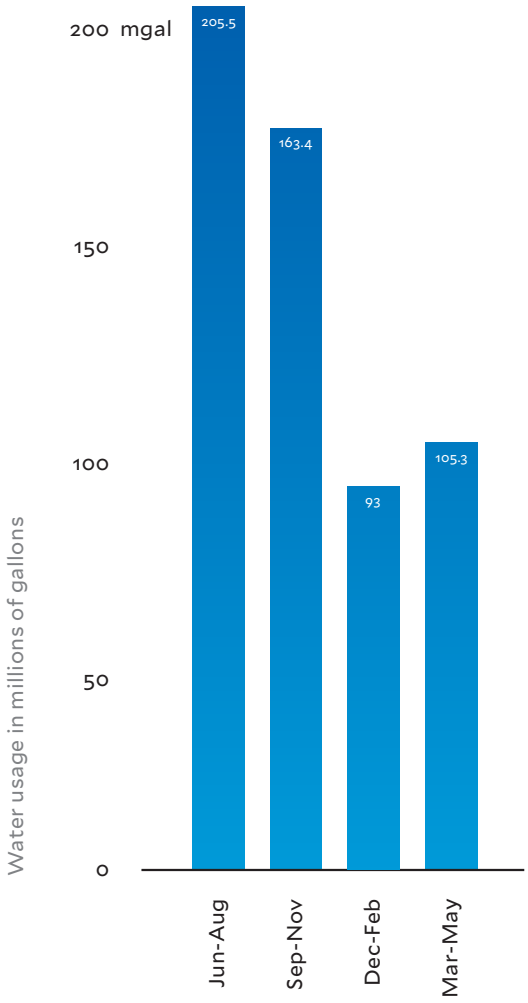
- Approximately 90% of meters are read and billed quarterly. Therefore, approximately 10% of meters are read and billed either monthly or quarterly depending on capacity.
- Approximately 7% of water use by volume is estimated on an annual basis rather than determined by actual meter readings. The percentage includes internal estimations of the Central Campus chiller plant as well as estimations based on billing data provided by RWA.
- There is a high number of meters and buildings on campus. However, 53 unique meters correlate to 27 building accounts and represent 80% of the annual water use. These meters may be considered the highest priority for maintenance, calibration, and obtaining actual values as opposed to estimated values. Priority buildings and their meters are listed in the Appendix.

Metrics

We used data from the four quarters of fiscal year (FY) 2016 for the analysis. Due to the format in which we receive RWA water meter billing data, we define the fiscal year as the quarter beginning on May 31 to the quarter ending on June 1 of the following year.

During FY2016, Yale used approximately 567 million gallons of potable water which are tracked on a quarterly basis.

Chart 1 Annual Total Water Use by Quarter

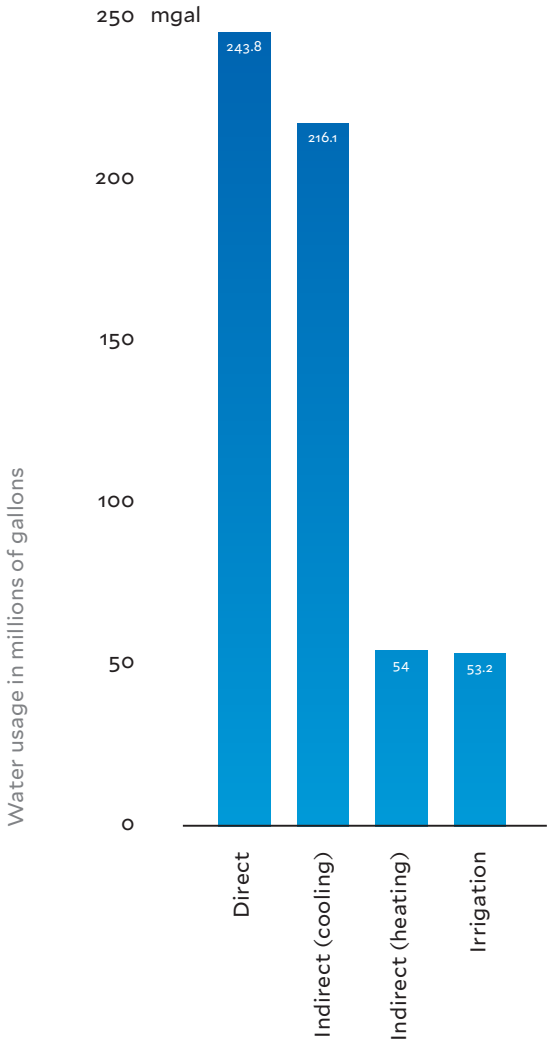


The 567 million gallons of potable water used at Yale during FY2016 may be apportioned to four major end-use categories:

- Direct: Potable water for domestic use, dining services, laboratory processes, critical research, as well as some building-level mechanical equipment.
- Indirect (Cooling): Potable water used for cooling tower makeup and chilled water makeup at the central plants.
- Indirect (Heating): Potable water used for steam condensate makeup, emissions control, and some direct humidification.
- Irrigation: Potable water used to irrigate grounds and athletic fields.

The consumption rate for each end-use category was developed by analyzing metered data and by benchmarking. Cooling and heating data were estimated by taking total power plant water use and making it proportional to past data.

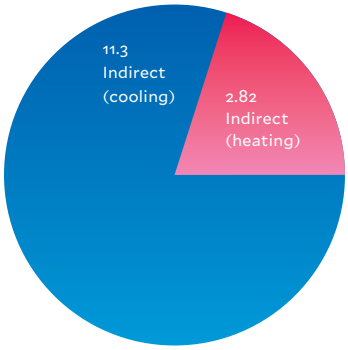
Chart 2 Annual Total Water Use by Major End Use



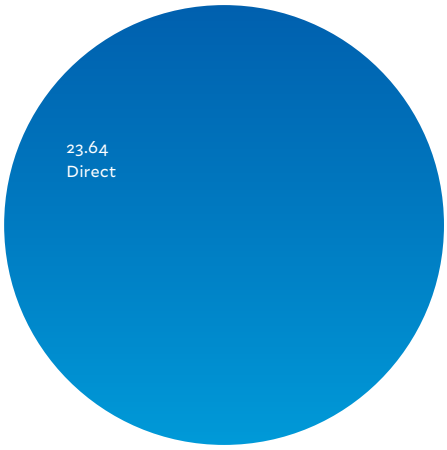
The potable water used at Yale during the representative year may be normalized based on campus gross square footage and campus users (Chart 3) to offer more context. Normalized metrics may be further used to benchmark Yale's performance compared with peer institutions if those data were validated and available.

Chart 3 Daily Total Water Use

Daily Total Indirect Water Use per Campus Gross Square Foot (GSF)



Daily Total Direct Water Use by Campus User



On average, the campus requires 14 gallons of potable water for heating and cooling a square foot of building space, with cooling representing 80% of the total. Consequentially, water use increases during the summer months.

On average, each person on campus uses 24 gallons of potable water for domestic needs. The University is opening Pauli Murray and Benjamin Franklin Colleges this academic year representing approximately 440,000 GSF of space. At full capacity, the two Residential Colleges will accommodate approximately 800 new undergraduate students on campus. Using these averaged values, water use may be projected to increase approximately 7 million gallons annually due to direct water use and 6 million gallons annually due to indirect water use.

Please note that for these charts, the following metrics were used:
Campus GSF: 19,127,321
Campus Users: 28,256
Days per Year: 365

The GSF is consistent with the calendar year (CY) 2015 GSF value reported to The Climate Registry for the operational boundary of university greenhouse gas emissions. While metered water use data is not available for all the square footage included, Yale intends to standardize on the operational boundary for consistent sustainability reporting. Moving forward, additional building accounts may be included in our water use analyses.

Progress

We updated the baseline year used in our first Water Management Plan from CY2012 to FY2013. We made the update for the following reasons:

- To align with the values provided in our annual progress report that compares years on the fiscal timeline.
- To include two significant meters that were omitted in the original baseline year.
- To provide a parallel timeframe for our new representative year used in this analysis.

In 2013, Yale made a goal to reduce potable water use on campus 5% below 2013 levels by June 2016. While Yale did not meet its 5% reduction goal in water consumption, the University did reduce water consumption by 0.5% from its baseline value. Yale used 570.2 million gallons of potable water in FY2013 and 567.3 million gallons of potable water in FY2016.

A key initiative towards the water reduction goal involved replacing existing showerheads within residential and athletic facilities with high-performance, low-flow showerheads. Water use data shows the impact of this initiative. Potable water use decreased by 12% at Yale's twelve Residential Colleges (Chart 4) and 13% at Payne Whitney Gym (Chart 5) between FY2013 and FY2016.

Chart 4 Annual Total Water Use at the Residential Colleges

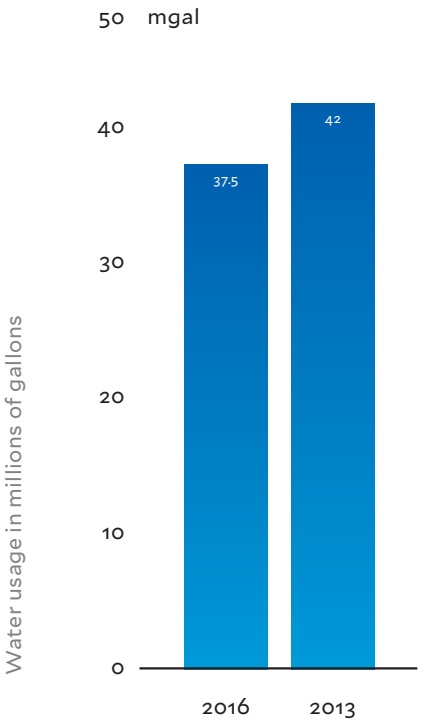
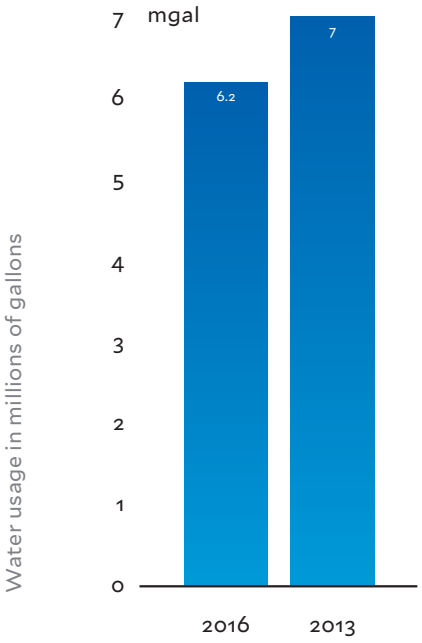
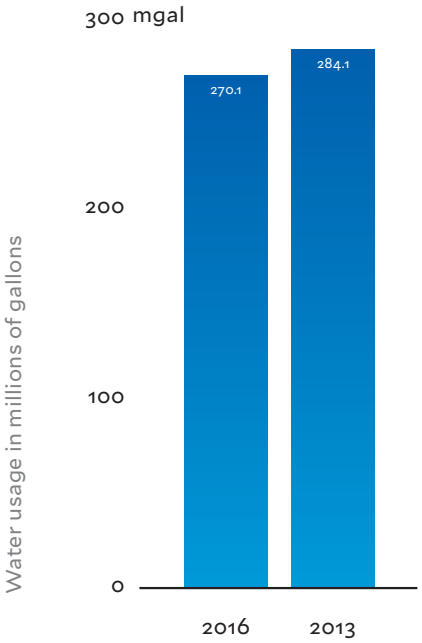


Chart 5 Annual Total Water Use at Payne Whitney Gym



Another initiative involved various strategies to minimize cooling tower water demand during peak cooling months. Water use data shows that the overall annual total water use at power plants decreased by 5% between FY2013 and FY2016 (Chart 6).

Chart 6 Annual Total Water Use at Power Plants



While data demonstrates the success of these initiatives, it is assumed that these reductions were counterbalanced by general campus growth and maintenance issues.

Moving Forward

The following section describes strategies toward the University's immediate water conservation goals and longer-term vision for active and adaptive water stewardship. These strategies build on the progress and analyses made since the Water Management Plan 2013–2016 and provide a coherent and flexible framework for future activities.

Strategy 1 Maintain commitment to water metering and analysis

Maintain current metering infrastructure and quarterly data collection processes, while preparing to convert to Advanced Metering Infrastructure (AMI) in partnership with RWA. Analyze and publish data at the campus level on an annual basis.

For the past three years, we have continued to log and monitor water-use data as it is provided on our quarterly and monthly bills from RWA. We have also reported this water use annually. We have found that the time and resources needed to collect, validate, analyze, and share water-use data from RWA and Yale's internal submeters on a more frequent basis are too high. In addition, inconsistent data quality does not allow actionable conclusions to be drawn about water-use trends across campus.

We are hoping to significantly improve our metering and analysis capabilities moving forward in conjunction with RWA's AMI project. Yale has been selected as a participant in the "pilot testing program," which is the first phase of AMI deployment that began in January 2017. 10 meters on priority buildings have been upgraded to advanced meters, allowing hourly data to be viewed using a web-based interface. Yale agreed to provide technical support to install the devices and to give administrative feedback to RWA. Ultimately, this water-use data will be highly valuable because it will be available through a directly accessible web portal in real time, offering an unprecedented opportunity to learn about campus and building water dynamics, and to inform proactive and innovative operations.

Water-use data will continue to be reported annually in Sustainability Progress Reports.

Strategy 2 Align design standards and planning documents

Update existing design standards and planning documents to reflect the most current requirements for water metering, water efficiency, and reclaimed water strategies.

Yale has piloted a number of water conservation and metering systems over the past several years, particularly within LEED-certified buildings, and has reviewed the performance of many of these pilots to intentionally inform future direction on campus.

Future projects, including those designated as Comprehensive, Small Scope, and Limited Scope, will be executed in accordance with design standards and planning documents updated with water management goals. Sections of Division 15 of Yale Design Standards for Capital Projects were updated in spring 2016 and will continue to be updated to reflect requirements for water-efficient plumbing fixtures and water metering as they evolve. Guidelines in support of building-level reclaimed water and irrigation systems will also be developed.

Yale intends to incorporate all lessons learned to date, standards, and guidelines in the update and adoption of High Performance Design Standards by 2019 in accordance with the Yale Sustainability Plan 2025.

Strategy 3 Implement water conservation projects and activities

Implement projects and activities to reduce annual potable water use on campus 5% below FY2013 levels by June 2020.

Three years ago, Yale committed to an assertive water conservation goal within the Sustainability Strategic Plan 2013–2016 and the corresponding Water Management Plan 2013–2016. While this goal was not achieved, several successful projects were implemented, including:

- Retrofit of all existing showerheads in the residential colleges and Payne Whitney Gym. Following pilot of various showerheads, a high-performance 1.5 gpm model was selected and installed over a period of three months.
- Decommissioning of underutilized washing equipment serving critical research areas at the Medical Campus; implementation of a "warm water wash" cycle within critical research areas that saves steam and quench water.
- Pilot of high-performance irrigation systems and moisture monitoring at select irrigation locations to inform future use; investigation and resolution of underground irrigation leaks.
- Active monitoring and scheduling of academic spaces during the summer months to reduce chilled water demand during peak cooling months and avoid use of potable water as cooling tower makeup.

In addition, Yale Facilities has completed feasibility studies and preliminary permitting reviews to develop a campus-level reclaimed water system to

supply nonpotable water to the Sterling power plant. A system of this scale could provide approximately 100M gallons of nonpotable water annually, while offering new teaching and research opportunities associated with urban water infrastructure.

Moving forward, in alignment with Yale Sustainability Plan 2025, Yale will continue to seek opportunities within buildings and the central power plants. Concerted efforts toward more effective identification and resolution of maintenance issues will be made. Opportunities that increase the resiliency of systems and are focused on both water and energy savings, addressing the campus-level energy/water nexus, will be prioritized.

Strategy 4 Adapt management plan goals

Identify progressive water conservation goals by 2020 in alignment with municipal, regional, and state priorities.

The Water Management Plan is presented to support an adaptive and iterative process to promote water conservation at Yale. In the initial plan, we intended to garner a more robust water-use data set to complement a portfolio of projects implemented for water conservation. However, inconsistent data quality has prevented a comprehensive assessment of all the projects completed between 2013 and 2016. We are hoping that AMI data at the building level will allow a more precise evaluation of specific water conservation activities.

Yale will set the next water conservation goal by 2020 in explicit alignment with municipal, regional, and state priorities. Currently, several significant and related plans are being developed, including:

- New Haven Climate & Sustainability Framework
- CT State Water Management Council Plan
- RWA Strategic Plan

Yale intends to identify ways to contribute to the forthcoming priorities of these plans, which will likely include specific goals related to stormwater reduction, water quality, and drought response. As an example, while water supply is relatively abundant across our region, the Connecticut Interagency Drought Workgroup tracked persistent dry weather and issued the first ever Drought Watch in October 2016. It is critical that the University develop strategies to conserve water in response to regional conservation needs as they arise.

More broadly, the University intends to address water management priorities as a critical component of the Campus Resilience Plan as part of the Yale Sustainability Plan 2025. This document will comprehensively address campus issues with and preparation for climate change adaptation, including extreme weather events.

Conclusion

Yale is continuing its commitment to reduce its potable water usage by 5% from 2013 levels by the end of 2020 and making efforts for more robust and actionable water-use data. Yale recognizes the value of water beyond its utility costs and the necessity of active and adaptive water management for long-term resilience.

Appendix

Table 1 Water Meter and Building Account Priorities

Location	Meter name	Meter number	FY2016, gallons	%
Sterling Power Plant	305 CONGRESS RMT BX LT SIDE 309 CONGRESS AVENUE 184 LIBERTY ST–YPI (*0.66)	31909803 70030356 8702700	154,588,644	27.25
Central Power Plant	18 ASHMUN ST. 18 ASHMUN STREET MNSACHEM RMT PST TREE (*0.6) RMT LT FT 205 PROSPECT Sage Bowers Sci Hill SW SN 18 ASHMUN ST.	31904141 1633286 30780133 12702042 31952679	51,415,276	9.06
West Campus Power Plant	400 Morgan Lane Fire Pit 1 (*0.07) 0 Heffernan Rd York Cooling Tow 0 Heffernan B-45 Water Pit 4 (*0.96) 0 Heffernan Rd Water Pit 3 (*0.07)	54890340 1587444 1568651 7704335	40,423,005	7.13
Hunter Building	Hunter Bldg.–15 York	8702604	34,504,492	6.08
10 Amistad Building	10 Amistad St	59293682	27,353,612	4.82
Central Chiller Power Plant	CCCP		23,691,217	4.18
Anlyan Center	350 CONGRESS AVE. 300 CEDAR ST.	7701653 1577905	23,098,921	4.07
Outdoor Tennis Center	CENTRAL AVENUE WH ATHLT FLD RMT PST	12700045 7707394	11,233,464	1.98
Yale Bowl	150 Yale Ave SOCCER FIELD 150 Yale Ave Yale Bowl 150 Yale Ave Yale Bowl	8805702503 1633237 6703756 5702503	10,360,548	1.83
Morse College	MORSE COLLEGE TOWER PKWY MORSE COLLEGE TOWER PKWY MORSE COLLEGE TOWER PKWY	8702677 10702113 10702116	6,763,416	1.19
Boyer Center for Molecular Medicine	295 CONGRESS AVE	6702526	6,591,376	1.16
Payne Whitney Gym	Payne Whitney Gym 68 Lake PL 70 TOWER PKY	14703098 31952680	6,177,096	1.09
344 Winchester	344 Winchester 344 Winchester	11701534 31931549	5,458,418	0.96

Location	Meter name	Meter number	FY2016, gallons	%
Yale Health Center	55 Lock St 55 Lock St	9708524 8700516	5,318,280	0.94
Hall of Graduate Studies	RMTBX INSIDE WALL TWR	1577988	5,304,442	0.94
Silliman College	354 Temple St / Silliman 344 TEMPLE RM 327RMTWNDFR 505 College St Yale Block#622	7701522 9702497 6708213 6702517	5,155,964	0.91
Dewitt Cuyler Track Complex	DERBY AVE	10704214	4,157,010	0.73
Yale Golf Course	200 CONRAD DR. 200 CONRAD DR.	56221770 1588076	4,069,142	0.72
Hopper College	CALHOUN COLLEGE 189 ELM ST RMT RT BSMT DOR 434 COLLEGE	8705900 12702185	4,041,968	0.71
Ezra Stiles College	STILES COLLEGE BROADWAY 19 Tower Pkway RMT RTFRT ON BRDWY SID RMT RTFRT	10702123 8703269	3,682,030	0.65
Becton Lab	BECTIN LAB PROSPECT ST	10704175	3,510,738	0.62
West Campus B24 research building	0 Heffernan Rd—West Campus (*0.66)	1578216	3,505,128	0.62
Timothy Dwight College	TIMOTHY DWIGHT COL 116 GROVE Timothy Dwight Col 65 Wall	1554430 1588568	3,337,950	0.59
Branford College	HIGHT ST BFD CLG-RNW BRANFORD COLLEGE 98 HIGH ST (*0.5)	1554448 1554449	3,296,810	0.58
Kline Biology Tower	MNSACHEM RMT PST TREE (*0.4)	30780133	3,267,264	0.58
Davenport College	PIERSON COLLEGE 221 PARK ST (*0.5) 240 YRKDVNPTRMTLTFTDRST (*0.5)	1554437 10700001	3,233,604	0.57
Pierson College	PIERSON COLLEGE 221 PARK ST (*0.5) 240 YRKDVNPTRMTLTFTDRST (*0.5)	1554437 10700001	3,233,604	0.57

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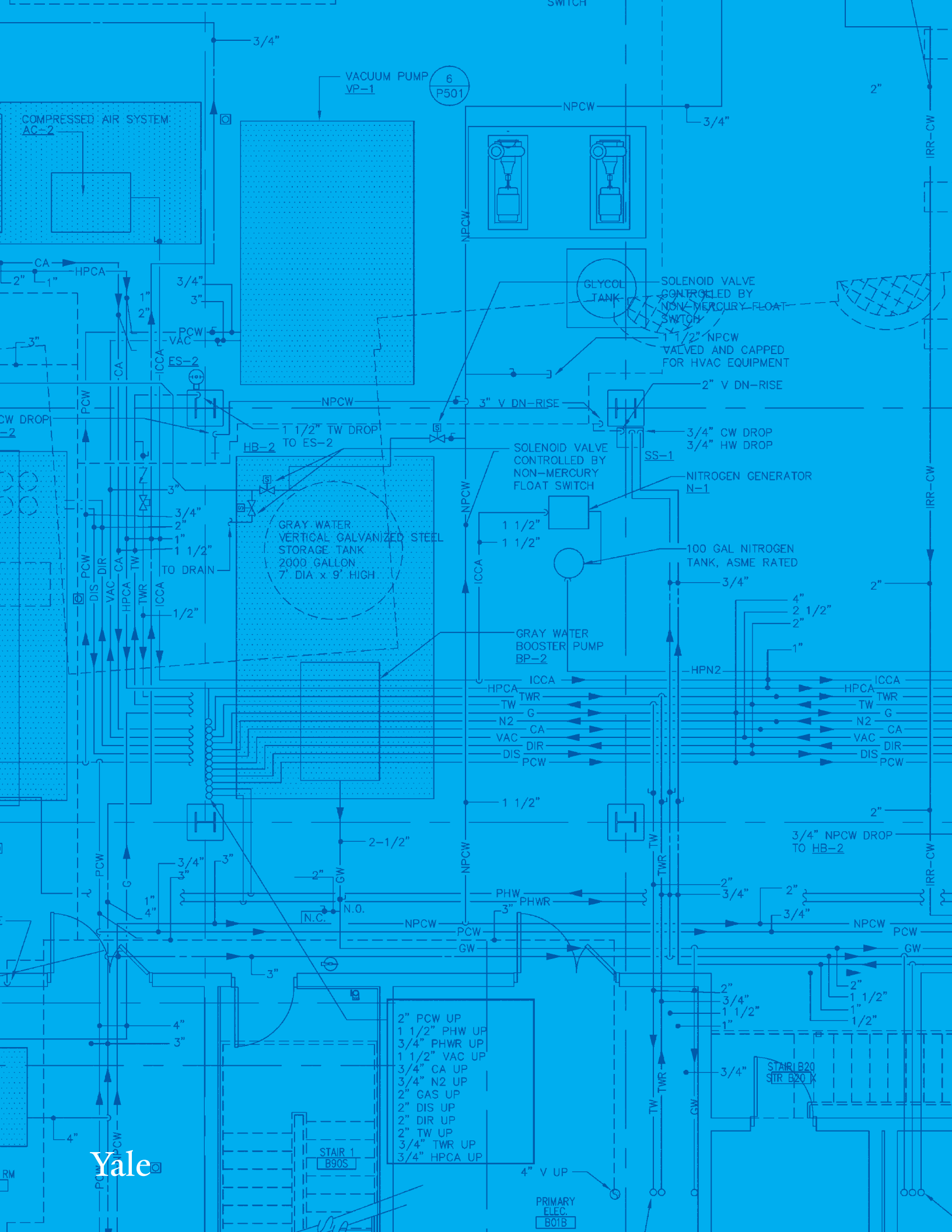
COMPRESSED AIR SYSTEM
AC-2
VACUUM PUMP
VP-1
6
P501
NPCW
3/4"
2"
IRR-CW
GLYCOL TANK
SOLENOID VALVE CONTROLLED BY NON-MERCURY FLOAT SWITCH
1 1/2" NPCW VALVED AND CAPPED FOR HVAC EQUIPMENT
2" V DN-RISE
3" V DN-RISE
3/4" CW DROP
3/4" HW DROP
SS-1
NITROGEN GENERATOR
N-1
100 GAL NITROGEN TANK, ASME RATED
ES-2
1 1/2" TW DROP TO ES-2
HB-2
GRAY WATER VERTICAL GALVANIZED STEEL STORAGE TANK 2000 GALLON 7' DIA x 9' HIGH
TO DRAIN
GRAY WATER BOOSTER PUMP
BP-2
HPN2
ICCA
HPCA
TWR
TW
G
N2
CA
VAC
DIR
DIS
PCW
3/4" NPCW DROP TO HB-2
2-1/2"
GW
PHW
PHWR
N.O.
N.C.
2" PCW UP
1 1/2" PHW UP
3/4" PHWR UP
1 1/2" VAC UP
3/4" CA UP
3/4" N2 UP
2" GAS UP
2" DIS UP
2" DIR UP
2" TW UP
3/4" TWR UP
3/4" HPCA UP
4" V UP
STAIR 1
B90S
STAIR B20
STR B20
PRIMARY ELEC.
B01B
Yale