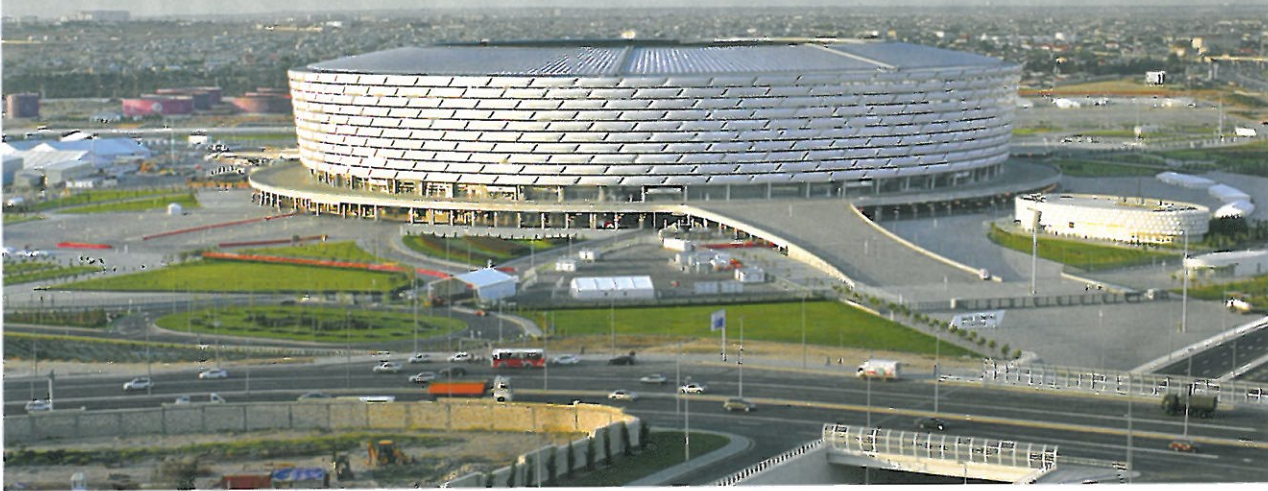


WIND LOADS IN BAKU ARE SIMILAR TO THOSE IN THE COASTAL REGIONS OF ALASKA, WITH A 50-YEAR RETURN PERIOD AND 3-SECOND GUST WIND SPEEDS OF 53 M/S.



Designing the braced frames as a conventional chevron system would have resulted in very large horizontal tubes. The tubes would have had to be custom fabricated from plate and would have carried a proportion that was not architecturally acceptable. To reduce the horizontal tube sizes, a zipper column was provided in the chevron frame. A zipper column is a tension element that starts at the top of the lowest chevron bay—at the central brace node—and extends up to the brace node at the top of the highest chevron bay. It collects the unbalanced vertical seismic load component at each frame level and delivers it to the top chevron frame. With the loads collected, the top chevron frame is designed to remain elastic under the applied unbalanced load plus those determined from structural analysis.

As in the radial trusses between the tie-down column and the megacolumn, the chevron braces terminate at the uppermost concourse in each quadrant of the stadium. The seismic loads are then transferred into the concrete moment-resisting frame system. With the inclusion of the zipper column, all of the horizontal tubes in the brace bays are of hollow steel and have a diameter of 711 mm. The zipper columns are hollow steel tubes 355 mm in diameter. The typical diagonals have a diameter of 368 mm, and in the topmost bay of chevron diagonals the diameter is 508 mm. The connections of steel elements in the braced frame system and the connections to the megacolumns were detailed to be similar to the radial trusses, that is, fork and knife plates with clevis pins and significant embeds cast into the megacolumns.

The foundation system selected for the project was a piled raft. The raft slab was typically 1,500 mm thick under the inner $\frac{3}{4}$ of the stadium and 2,500 mm thick under the outer $\frac{1}{4}$ of the stadium, where the cantilever roof megacolumns and perimeter braced frames would be located. The piles were drilled reinforced-concrete caissons 1,200 mm in diameter,

The site selected for the stadium is on the shore of Lake Boyuk Shor approximately 10 km from the city center and near Heydar Aliyev International Airport.

each with a capacity of approximately 600 metric tons. The groupings ranged from just a single pile at the front of the lower bowl to six piles beneath each canopy megacolumn. The foundation work, which included a total of 1,720 piles and the 1,500 to 2,500 mm

thick raft, was completed in May 2013, a mere six months after the commencement of the project.

THE FLAME at the Ateshgah temple, which is near Baku, burned on its own for centuries, fed by the land's underground energy riches. Flames also occurred naturally in fissures nearby, and these natural wonders made the area holy for Zoroastrians, Hindus, and others. The name "Baku" is derived from the old Persian name for the city, which meant "city where the wind pounds." Baku is thus a locale of relatively high seismicity and high winds. Wind loads in Baku are similar to those in the coastal regions of Alaska, with a 50-year return period and 3-second gust wind speeds of 53 m/s. The ground-level wind pressure in Baku is about 3 kPa, which is approximately four times the street-level wind pressure in New York City.

Baku is located on the peninsula of Absheron, which has witnessed many severe seismic events. The seismic zoning of Baku is mainly 8 in the MSK-64 scale (named for S. Medvedev, W. Sponheuer, and V. Kárník). However, the construction site is located near the coast, and the water and loose soil conditions were seen as posing a higher seismic hazard. The MSK-64 rating was thus increased to 9, which is similar to California seismicity. The seismic design category for the project site according to the International Code Council's *International Building Code* is D. Furthermore, the 2010 edition of the local Azerbaijan code stipulated that an importance factor of 1.4 would have to be a minimum with regard to seismic loads. The seismic response coefficient, C_s , for design was (Continued on Page 78)

TREATMENT TRIO

As part of a plan to reduce its dependence on nonrenewable groundwater and diversify its drinking water sources, the Parker Water and Sanitation District, in Parker, Colorado, recently completed the Rueter-Hess Water Purification Facility, an innovative 10 mgd plant that features ballasted sedimentation, recirculated powdered activated carbon, and ceramic membrane filtration. The facility enables the district to treat a blend of source waters, including surface runoff, groundwater, alluvial well water, and reclaimed wastewater.

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By Mike Lutz, P.E., and Alan Pratt, P.E.

THE PARKER WATER and Sanitation District (PWSD), in Parker, Colorado, operates along the Front Range approximately 20 mi southeast of downtown Denver. Once a rural setting for western pioneers and homesteaders, the suburban communities served by the district have experienced rapid growth in recent years. When the district was originally established, in 1962, it served fewer than 300 residents, whereas today its service area is home to nearly 50,000.

The PWSD's service area encompasses a total area of 43 sq mi through which Cherry Creek, a tributary of the South Platte River, flows north toward Denver. Historically, the district has relied on groundwater to meet its customers' needs. In recent years, it has maintained facilities that include a network of 37 deep wells and eight alluvial wells, two wastewater treatment plants, five water storage tanks, lift stations, and pump stations.

Like many communities throughout the western and southern states, those served by the PWSD are experiencing steadily declining groundwater levels. Increased customer demand and the effects of climate change, including drought conditions, have resulted in an unsustainable rate of water extraction from the aquifers, the annual withdrawal rates exceeding the recharge rate. The PWSD's leadership has long recognized the potential for critical water shortages in the district's service area.

In 1985, noting the steadily declining aquifer levels and well production rates, the PWSD initiated a 30-year plan to move from the exclusive use of groundwater to a renewable water supply. With dramatic increases in population forecast, the district began taking steps to address the potential water shortage—at that time still decades away—with an ambitious, multiphase



Selected for their durability and ease of maintenance, the 560 ceramic membrane filter modules included as part of the treatment train of the Rueter-Hess Water Purification Facility represent the first use of the technology for a drinking water system in North America.

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capital improvement program. Ultimately, the PWSO envisioned developing the infrastructure to capture, store, treat, and distribute water from renewable sources by 2015.

The PWSO's forecasts proved accurate: three decades later the population has soared, and groundwater levels have steadily declined. With the completion of the Rueter-Hess Reservoir in 2013 and the new, state-of-the-art Rueter-Hess Water Purification Facility (RHWP), which came onstream last summer, the district's vision for use of a renewable water supply has now been realized. The \$51.5-million, 10 mgd large-scale treatment facility utilizes surface water, groundwater, alluvial well water, and reclaimed wastewater stored in the Rueter-Hess Reservoir to create potable water for its customers. The plant, which can be expanded to treat up to 40 mgd, reduces the district's reliance on groundwater resources while enabling it to meet local water needs well into the future.

In 2007 the PWSO selected the Denver office of Dewberry, which has its headquarters in Fairfax, Virginia, to design the plant. The firm had a long track record of working with the district, having completed the 2 mgd North Water Reclamation Facility, the Regional Pumping Facility, and the Cherry Creek Diversion Dam and Pump Station. All of these facilities now play a key role in supplying alluvial water, reclaimed wastewater, and surface water to the Rueter-Hess Reservoir.

Planning for the plant began in 2007, and at the point construction was just beginning on the reservoir, which was to serve as the raw water supply for the facility. At the time the quality and variability of the planned water supply were unknown. Further complicating this challenge, the anticipated sources of water to the reservoir covered a broad range and included surface runoff from Cherry Creek, water from alluvial wells fed by that creek, and reclaimed wastewater effluent from the district's two water reclamation facilities. Because the blend

Pumps are used to move water from the facility's coagulation chambers to the ceramic membrane filters.

of these waters can vary greatly from season to season, the quality of the water supply for the new treatment plant was difficult to predict.

The facility design was based on an assessment of several alternatives, including magnetic ion exchange, ultraviolet photocatalytic oxidation, the ultraviolet advanced oxidation process, polymeric membrane filters, recirculating powdered activated carbon (PAC), and ceramic membrane microfiltration. Except for the ultraviolet advanced oxidation process, all of the alternatives were tested on a pilot basis. Pilot testing was conducted using stored wastewater effluent from a smaller district-owned reservoir that contained high levels of algae and dissolved organic compounds (DOCs). It was believed that this source would serve as a "worst-case scenario" for the anticipated source water. During testing, the pilot systems were subjected to source water that had experienced large algae blooms and had DOC levels as high as 12 mg/L.

The PWSO's forward-thinking approach to infrastructure development carried over to the design of the RHWP, which showcases state-of-the-art processes and technology as well as the potential for long-term life-cycle value and cost savings. The RHWP is the first plant in the world to incorporate a trio of cutting-edge, sequential technologies that surpass the U.S. Environmental Protection Agency's drinking water standards: ballasted sedimentation, recirculated PAC, and ceramic membrane filtration.

In addition to Dewberry, design consultants for the RHWP included Lintjer + Haywood Architects, of Denver; Integrated Solutions Engineering, of Littleton, Colorado, for electrical engineering; Shaffer • Baucom Engineering & Consulting, of Lakewood, Colorado, for heating, ventilation, air-conditioning, and plumbing engineering; and the Denver office of Norris Design for landscape and irrigation design. The

RUETER-HESS REGIONAL WATER PURIFICATION FACILITY

1 Parker Water and Sanitation District's water rights in Cherry Creek supply a portion of the district's water needs.

A 50 cfs pump station brings water from Cherry Creek to the Rueter-Hess Reservoir. The pump station can capture raw water and reclaimed wastewater from Cherry Creek along with water from the Cherry Creek alluvial wells.

2

3 Water stored in the Rueter-Hess Reservoir flows by gravity to the water purification facility.

The self-cleaning raw water strainer removes such large particles as leaves from the water.

4

Flow to the plant is metered and controlled with a flow control valve.

5

Residuals are removed and stored in a residual pond

Recirculated microsand and sludge

6

In the first ballasted sedimentation chamber, a coagulant chemical is added to the water, causing particles and impurities to collect and form larger particles. The addition of microsand aids in the removal of these impurities during sedimentation.

7

The second ballasted sedimentation chamber, powdered activated carbon (PAC) is used to remove dissolved organic matter from the water. This organic matter may include natural matter from decaying vegetation as well as such man-made or man-derived organics as pesticides, herbicides, caffeine, hormones, and pharmaceutical products.

Residuals are removed and stored in a residual pond

Recirculated microsand, sludge, and PAC

8 Ceramic membrane filters remove any remaining algae, bacteria, or other particles that are larger than 0.1 μm in diameter from the pretreated water.

9 A small dose of chlorine is added to kill any viruses and prevent contamination of the treated water in the distribution piping system.

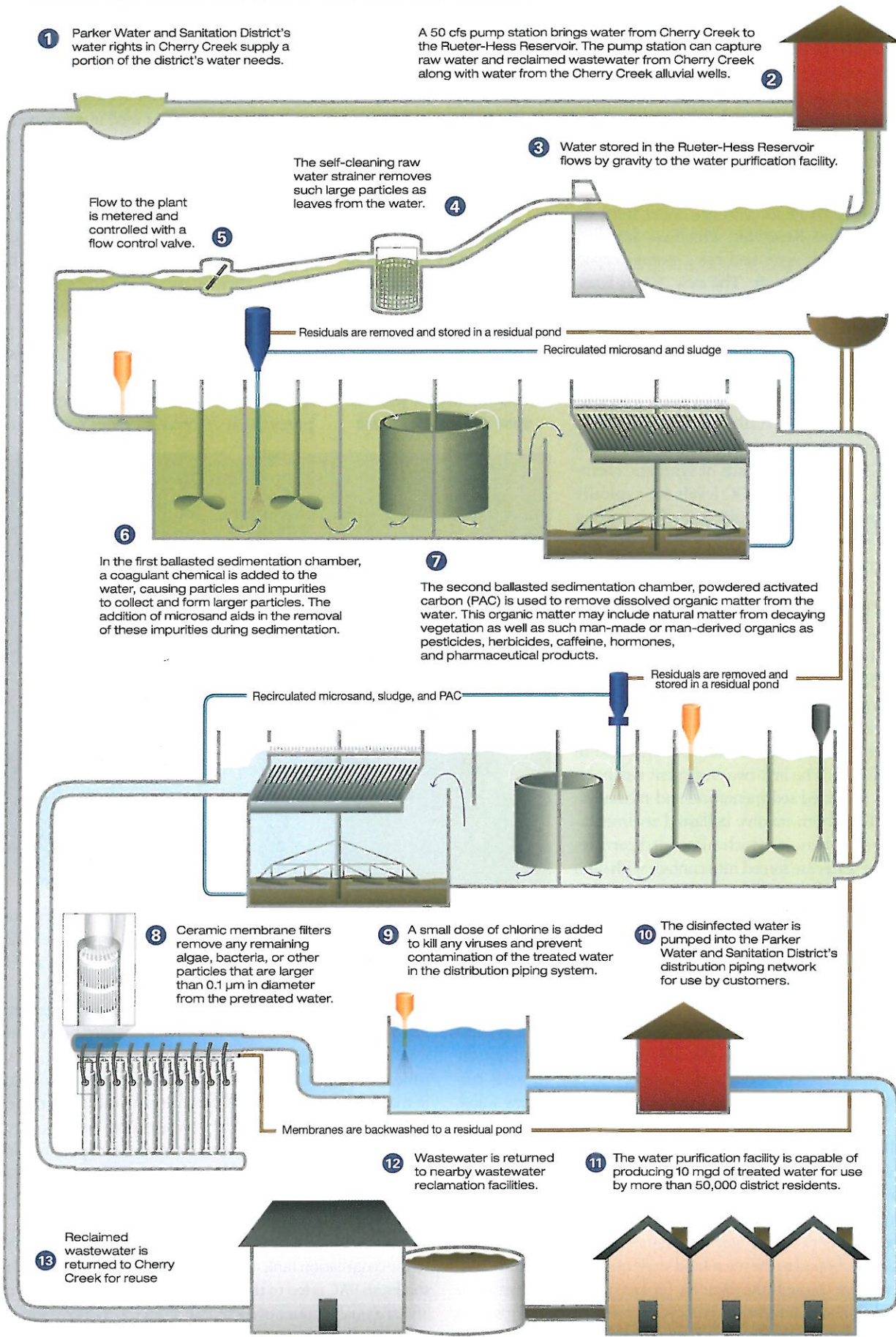
10 The disinfected water is pumped into the Parker Water and Sanitation District's distribution piping network for use by customers.

Membranes are backwashed to a residual pond

12 Wastewater is returned to nearby wastewater reclamation facilities.

11 The water purification facility is capable of producing 10 mgd of treated water for use by more than 50,000 district residents.

13 Reclaimed wastewater is returned to Cherry Creek for reuse



project team included Western Summit Constructors, Inc., of Englewood, Colorado, as the primary contractor, and McDade-Woodcock, Inc., of Albuquerque, New Mexico, as the electrical contractor. Construction management was provided by Weaver Construction Management, Inc. (formerly Weaver General Construction), of Englewood, Colorado, a wholly owned subsidiary of Garney Holding Company. Construction began in the spring of 2012 and was completed by mid-2015.

The RHWPF receives raw water from the Rueter-Hess Reservoir, which encompasses 1,170 surface acres and has a storage capacity of 72,000 acre-ft. The new, 50 cfs Cherry Creek Diversion Dam and Pump Station conveys water approximately 3 mi from Cherry Creek to the reservoir. The reservoir's water sources, namely, Cherry Creek surface water, water from the Cherry Creek alluvial wells, and reclaimed wastewater effluent, contain relatively high concentrations of DOCs and trace amounts of synthetic chemicals. The average DOC levels are typically 6 mg/L or higher. High naturally occurring phosphorus levels in the Cherry Creek basin contribute to algae blooms, further increasing DOC concentrations.

The facility's robust treatment process is designed to remove a high percentage of the DOCs from the raw water to minimize the formation of disinfection by-products, remove such organic chemicals as pharmaceuticals, and facilitate the removal of other organic chemicals that may be regulated in the future. The first two treatment technologies, ballasted sedimentation and recirculating PAC, both involve ballasted sedimentation chambers, in which suspended particles in the water are forced into contact with sand made up of extremely small grains ("microsand"). The particles bind to the sand and quickly settle to the bottom of a settling chamber.

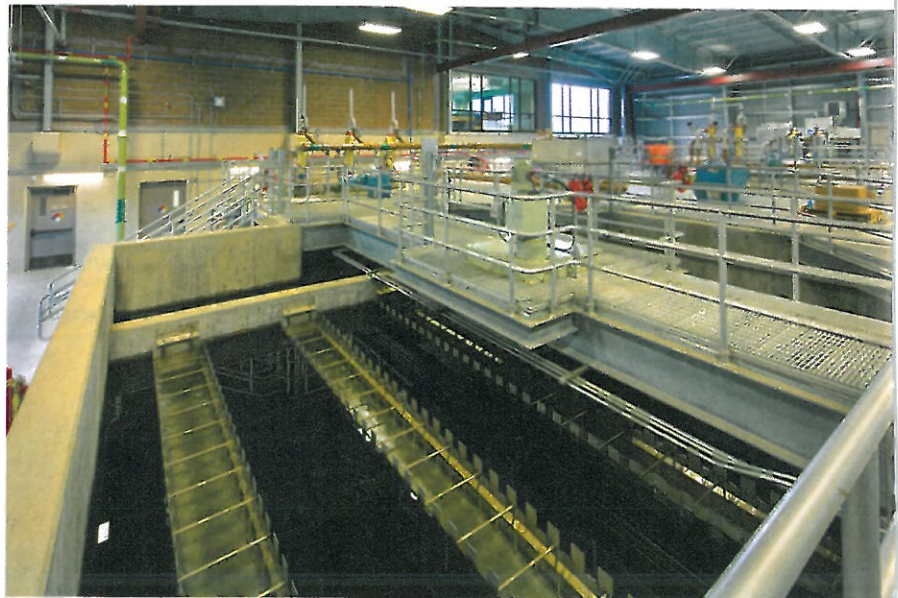
The first stage consists of a ballasted flocculation process combined with a lamella clarifier. The system—which is known as the Actiflo Turbo and was provided by Kruger, Inc., of Cary, North Carolina—consists of a compact chamber in which coagulation, flocculation, and sedimentation are conducted to effect high-rate clarification that removes turbidity, metals, and a portion of the DOCs from the raw water.

Coagulation is achieved using ferric chloride at an optimum pH of approximately 5.5 and rapid mixing to remove turbidity, algae, color, and approximately one-third to one-half of the DOCs. In the flocculation tank, microsand and polymer remove impurities and enhance particle sedimentation while reducing the chamber's surface area requirements. In the settling tank, particles bound to the microsand settle quickly. The clarified water is sent through the plant for further treatment, whereas the settled material is sent to hydrocyclones, where the microsand is separated from the sludge and reinjected into the process.

The second stage relies on the Actiflo CARB process, which features a recirculating PAC chamber that adsorbs most of the remaining organic matter, including natural matter from decaying vegetation, and such man-made or man-derived organic compounds as pesticides, herbicides, caffeine, hormones, and pharmaceuticals. Although PAC is used in many conventional water treatment plants to control taste and odor, the RHWPF is one of the first U.S. applications of the unique recirculating process employed by the Actiflo CARB technology.

The process cuts costs and improves treatment by sending used PAC back through the system, thereby increasing the contact time between PAC particles and DOCs for a more aggressive, efficient treatment. RHWPF pilot tests using 100 percent reclaimed wastewater effluent as the water source showed that an effective dose of 25 mg/L of PAC removed approximately 70 percent of the DOCs, reducing

By sending used powdered activated carbon (PAC) back through the system, the recirculating PAC chamber cuts costs and improves treatment by increasing the contact time between PAC particles and dissolved organic compounds in the water undergoing treatment. Approximately 1,000 mg/L of PAC in the chamber gives the water its black appearance.



DOC levels to the operating target of 2 mg/L. This level minimizes disinfection by-product concentrations in the finished water. If higher PAC doses are used, the facility is capable of reducing DOC levels to just 1 mg/L.

At the start of the second stage, clarified raw water enters a PAC reactor chamber in which the PAC concentration is approximately 1,000 mg/L. The high PAC concentration, the contact time, and the PAC recirculation maximize the amount of organic matter that is adsorbed. From the reactor chamber, the water flows into a coagulation tank, where a low dose of coagulant is added. The remainder of the treatment comprises ballasted flocculation and settling with microsand in a lamella clarifier similar to that of the Actiflo Turbo process. The settled solids from the clarifier are pumped to a hydrocyclone that separates microsand from the PAC by gravity. The microsand is recycled to the coagulation tank, and the PAC is recycled to the PAC reactor. Fresh PAC is fed to the PAC reactor at a rate of 5 to 30 mg/L, and an equal amount of spent PAC from the hydrocyclone is extracted and discharged from the system. The amount of fresh

PAC metered into the reactor depends on the type of PAC used and the desired percentage of DOC removal.

Next, the treated water is pumped through ceramic membrane filters to remove particles with diameters greater than 0.1 μm , including algae and bacteria, as well as any remaining microsand or PAC. The state-of-the-art ceramic membrane filter technology, which was supplied through a partnership between Kruger and METAWATER Co., Ltd., of Tokyo, relies on monolithic extruded porous ceramic cylinders having parallel tubular channels that extend through the length of the cylinders. The inner surface of each tubular filter channel is coated with a thin ceramic membrane. All of the ceramic material used in the membrane modules is made of an aluminum oxide material that offers different gradations to produce differing degrees of porosity. Water flows from inside the filter channels through the membrane layer and the porous monolithic ceramic material to exit the channels. The filtration cycle typically lasts one hour between normal backwashes.

The RHWPF's 560 ceramic membrane modules were se-

ria and pathogenic protozoans of the genera *Giardia* and *Cryptosporidium*.

- The design flux rate of up to 175 gpd per square foot of membrane surface is about twice that of a polymeric membrane system, meaning that less membrane material is needed to filter the same volume of water.

- Ceramic membrane filters exhibit minimal irreversible fouling or increases in transmembrane pressure. By comparison, polymeric membrane installations typically see a significant increase in transmembrane pressure after two or three years of service because of irreversible fouling. Increases in transmembrane pressure result in higher power costs and shorter membrane life.

- Cleaning can be less frequent. Because ceramic membranes are inorganic and chemically inert, they can handle stronger cleaning agents and require fewer cleaning cycles.

- Because backwashes can be less frequent, ceramic membranes have a higher water recovery efficiency than do polymeric membranes.

- Ceramic membranes result in improved operations and durability, as they are compatible with polymers and in some applications allow direct filtration, eliminating the need for sedimentation.

- Strong chemical oxidants, temperature extremes, and extreme pH levels do not damage the filters, which can withstand pressures of up to 150 psi.

- Ceramic membranes have never failed a membrane integrity test.

- Warranty durations are typically double or triple those of polymeric membrane systems. In the case of the membranes used by the PWSD, the warranties are for 20 years.

Managers at the PWSD weighed these benefits carefully against the increased upfront costs for ceramic membrane filters, which cost about twice as much as polymeric membranes. The decision in favor of the ceramic membrane filters, which represented approximately 20 percent of the total construction cost, was ultimately based on their operational value. The ceramic membranes require fewer chemicals, incur lower power costs, and have a much longer life span. This installation, which required the regulatory ap-

proval of the Colorado Department of Public Health and Environment, represented the first use of ceramic membrane filtration technology for a municipal drinking water system in the United States.

The sequence comprising the ACTIFLO Turbo and ACTIFLO CARB systems and the ceramic membrane filters, together with systems upstream and downstream of these processes that prepare the raw water and provide final treatment, has proved successful in treating source water with highly variable influent quality to a standard higher than that required by regulating agencies. Natural rivers, streams, and groundwater sources all contain trace amounts (Continued on Page 79)

lected because of their ability to resist damage from the abrasive sand and PAC particles used in the upstream processes, as well as their ability to withstand repeated aggressive cleaning cycles, which greatly extends the useful life of the membrane elements. Over the past 15 years, the technology has been used extensively in Japan, where more than 115 ceramic membrane drinking water facilities having an installed capacity of more than 140 mgd exist. The experience with ceramic membrane filters in Japan has shown that the durable microfilters last much longer and can be cleaned to be pristine using stronger, more aggressive chlorine and acid cleaning solutions. While the more common polymeric membranes, which consist of fine, delicate fibers, typically deteriorate during a life of 6 to 10 years and need to be replaced, the ceramic membranes can be expected to last 20 years or more.

The ceramic membranes confer the following additional benefits:

- The 0.1 μm pores are an absolute barrier to bacte-

The initial ballasted flocculation stages include a chamber, located below the grating, in which ferric chloride and microscopic sand particles are added to facilitate coagulation.



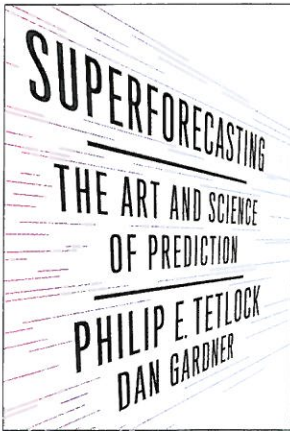
Books

Reviewed by Ray Bert

Superforecasting: The Art and Science of Prediction

By Philip E. Tetlock and Dan Gardner. New York City: Crown Publishers, 2015; 340 pages; hardcover \$28; e-book \$13.99

ANYONE FOLLOWING sports, the stock market, or geopolitical matters is sure to hear forecasts and predictions with regularity. Moreover, whether we think of it this way or not, we are all constantly making forecasts of our own of, for example, our relationships, our purchases large and small, and our careers. We make decisions in sig-



nificant part on the basis of what we think will happen.

Superforecasting will get you caught up on some possibly uncomfortable truths that have been coming to light via significant research projects. It turns out that, in the aggregate, most people simply aren't very good at forecasting, especially in relation to complex matters. As shown in a long, groundbreaking study carried out by one of the authors from 1984 to 2004, with the results published in 2005, even experts' opinions are,

overall, only slightly better than what could be expected from random chance.

What was less reported from the study was that a small percentage of people did show a significant ability for forecasting and thus exhibited true foresight. Philip Tetlock, Ph.D., the author of that study and a professor at the University of Pennsylvania's Wharton School, spent the next decade methodically figuring out how such foresight was possible. Together with journalist and coauthor Dan Gardner, those answers arrive in the form of this book. And the good news, they say, is that the ability in question involves skills and habits that can be learned.

A significant chunk of the methodology discussed comes from something called the Good Judgment Project, an extensive study of tens of thousands of laypeople carefully organized to tease out what makes a small percentage of them "superforecasters."

Without spoiling the entire conclusion, the answers are that certain levels of intelligence, numeracy, and knowledge of the world are essential ingredients. However, being a superforecaster also requires one to be open minded, curious, careful, and, crucially Tetlock says, self-critical.

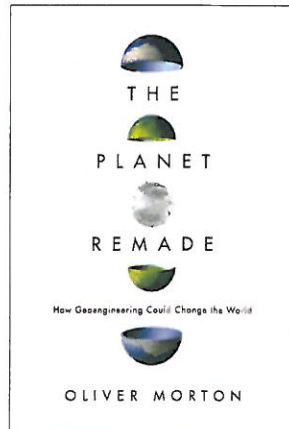
The narrative of *Superforecasting* is learned and occasionally a bit technical (statistics primarily), but the book remains a highly accessible and compelling read. In addition to exploring the qualities that distinguish such people and offer-

ing ways that will enable the reader to emulate them, it provides portraits of a number of these unusual people, who come from all walks of life. You're nearly guaranteed to come out of it wondering how good your own forecasting skills really are, and you may even consider joining the Good Judgment Project yourself to find out.

The Planet Remade: How Geoengineering Could Change the World

By Oliver Morton. Princeton, New Jersey: Princeton University Press, 2015; 428 pages; hardcover \$29.95

YOU MAY HAVE heard the "two questions" framing anyone's stance on climate change: (1) Do the risks of climate change merit serious



action to lessen them? (2) Is reducing an industrial economy's carbon dioxide emissions to near zero very difficult? Oliver Morton, the author of *The Planet Remade*, answers those questions yes and yes, as would many scientists. However, the book notes that, worldwide, this

is a decidedly minority view. Many people do not believe the risks are serious. Others clearly do but appear to minimize the difficulty of the transition from fossil fuels.

According to Morton, the "yes/yes" worldview is characteristic of "people imagining a planet where the earthsystem is manipulated in such a way that climate and carbon emissions are no longer so tightly bound." He concedes that this line of thinking is not without difficulties in that it can be used to justify inaction, can be overly simplistic, and can give rise to implausible ideas. However, it is also a view that warrants deep and careful thought because of the gravity of the risks we face.

And that, ultimately, is the driving force behind *The Planet Remade*: imagining an earth reengineered in a responsible but not excessively cautious way and starting to think about what might be possible if we tried as hard as we should in view of the stakes involved.

These interventions currently include such ideas as photosynthetic plankton, a veil against the sun located in the earth's stratosphere, and massive numbers of unmanned ships seeding the clouds.

Morton, a science writer with a degree from the University of Cambridge in the history and philosophy of science, is an editor for the *Economist*, and his writings have appeared in a variety of both technical and nontechnical publications. Heady at times, carefully researched, and boldly yet intelligently presented, *The Planet Remade*