Case Study: Groundwater Replenishment System

Incentivizing Groundwater Recharge

Case Study #9

Working Draft

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Center for Law, Energy, and the Environment
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This case study is part of a series focusing on incentives for Managed Aquifer Recharge, and the institutional context in which MAR projects are conducted. The series is being produced as part of a larger project examining this topic. A symposium on September 10, 2019 will highlight these and other projects. More information is available at law.berkeley.edu/recharge2019.

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Groundwater Replenishment System (GWRS)

Incentivizing Groundwater Recharge – Case Study #9

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Overview

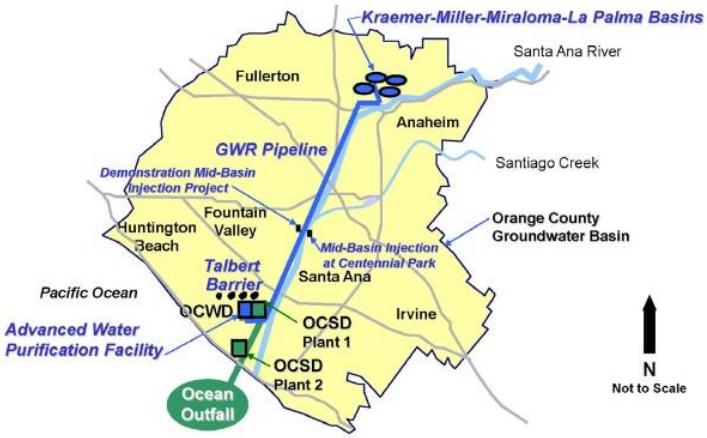

Figure 1: GWRS system. Source:2018 GWRS Annual Report

Location: Orange County, CA
Motivation for MAR: Maximizing use of surface water and treated wastewater; halting seawater intrusion; increasing water supply reliability
Groundwater Challenges: Seawater intrusion and groundwater overdraft
MAR Challenges: fluctuations in surface water availability; maintaining percolation capacity of recharge basins; acquiring sufficient land for recharge basins; public acceptance of recharge with treated wastewater
Project Goals: Maximize use and storage of purified wastewater; halt and reverse further seawater intrusion
Key Actor(s): Orange County Water District (OCWD); Orange County Sanitation District (OCSD)
Water Source: Recycled wastewater and surface water from Santa Ana River
Start Date: 1975-2004 (Water Factory 21); 2008-present (GWRS)
Current Status: First two phases implemented; final expansion online in 2023
Amount recharged from GWRS: 105,621 AF recharged in the 2017-2018 water year[1]
Cost per AF (GWRS): $850/AF (without grants factored in to cost); $525/AF (with grants and OCSD contribution factored in to cost)[2]

1. Motivation and Goals

Orange County, California has a long history of conducting managed aquifer recharge. MAR was initially implemented as a response to falling groundwater levels and the encroachment of seawater into the aquifer. Beginning in the 1970s, Orange County's MAR program introduced recycled water as a source of recharge. Today, a large advanced treatment plant recycles water for recharge through both percolation and injection. The Orange County MAR program has achieved the goals of preventing critical overdraft conditions, controlling seawater intrusion, and maintaining groundwater resources as the most economical and reliable water supply source for overlying communities. As part of this success, the program's broader impacts include helping to normalize the notion of potable water reuse through treated water recharge nationally and internationally.

2. Geographic and Historical Context

Orange County is located in southern California. It is a predominantly urban area, with over 3 million residents. Orange County's climate is arid, and the area receives an average of 14 inches of rain per year. In addition to rainfall, the county receives surface water from the Santa Ana River. However, in recent years, droughts have caused low amounts of rainfall and reduced the supply in the Santa Anta River. To meet its water demands, Orange County relies upon water imported from the Colorado River and Northern California as well as local surface and groundwater supplies. A large groundwater basin underlies the northern half of the county, which is also where the majority of the population and economic activity is located.

Groundwater overdraft in the northern half of the county was first observed as early as 1930 and worsened thereafter with increased development.[3] In response to requests from local leaders, the California Legislature created the Orange County Water District (OCWD) as a special act district in 1933 to manage surface and groundwater and to represent the interests of the county relative to the upstream areas of the Santa Ana River watershed.[4] OCWD immediately began experimenting with MAR, conducting in-stream recharge of Santa Ana River water. With the success of this program, OCWD purchased six miles of the Santa Ana riverbed.[5, 6] In 1948, OCWD expanded its MAR activities to include using Colorado River water imported by the Metropolitan Water District of Southern California (MWD).[7]

While these efforts partly alleviated overdraft, it became clear that seawater intrusion was affecting the quality of groundwater in the basin. To address this problem, OCWD financed the construction of an injection barrier along the Pacific coast. The barrier's purpose was to create an groundwater pressure ridge that would block further seawater intrusion into the aquifer; later studies showed that most of the injected water also flowed inland and provided recharge to the basin. This barrier injected a blend of groundwater and highly treated wastewater into a series of wells. The source of the highly treated wastewater was an advanced wastewater treatment facility, "Water Factory 21." Water Factory 21, which came online in 1975,[8] was the first facility in California to treat wastewater using reverse osmosis. Water Factory 21 produced 15 million gallons of water per day and operated for 29 years.[9]

By 2004, OCWD determined that Water Factory 21 needed to be upgraded. Additionally, greater uncertainty in the availability of imported water, increasing cost of imported water from MWD, and the opportunity presented by improvements in wastewater treatment technology and materials provided further motivation for upgrading and expanding the system. Based on technological advancements, it was now feasible to produce water from wastewater that was of higher quality and comparable cost relative to treated imported water. Increasing the use of recycled water would help guard Orange County from interruptions in MWD supplies and continual cost increases of MWD water. Further, an expanded recharge system could save the Orange County Sanitation District (OCSD) hundreds of millions of dollars it would otherwise need to spend on a second ocean outfall for handling its increased wastewater discharge. The updated Groundwater Replenishment System (GWRS) was completed in 2008.[10]

GWRS is an indirect potable reuse system, meaning that the recycled water enters the potable water supply after first being infiltrated into the Orange County groundwater basin, moving through the aquifer before being extracted by wells. GWRS purifies secondary treated wastewater from OCSD and delivers the treated product water to eight different locations, each with distinct but related purposes. Delivery sites include a network of 36 injection wells at the Talbert Seawater Intrusion Barrier (Talbert Barrier), an injection well at the Demonstration Mid-Basin Injection Project site, four infiltration basins farther inland (the Kraemer, Miller, Miraloma, and La Palma Basins), and two non-potable customers (Figure 1).[11]

GWRS initially produced 70 million gallons of treated water per day (MGD), yet was designed to support two expansions during its lifetime. The initial expansion took place in 2015, and increased production of treated water to 100 MGD.[12] The second and final planned expansion, once it occurs, will bring production of treated water up to 130 MGD.[13]

3. Regulatory Setting

The Orange County Water District has authority to manage groundwater resources through a combination of basin recharge projects and assessments (fees) on groundwater pumping. Groundwater quality standards and regulation in Orange County are the responsibility of a state agency, the Santa Ana Regional Water Quality Control Board (Regional Water Quality Control Board). OCWD and other local governments overlying the groundwater basin are required to conduct monitoring and reporting according to protocols established by the Regional Water Quality Control Board.

4. Managed Aquifer Recharge in Orange County and the Groundwater Replenishment System (GWRS)

Although OCWD continues to implement several MAR projects that make use of Santa Ana River water and imported water (in years when MWD has adequate supply), this section focuses on the GWRS.

4.1. Recharge

The Orange County Sanitation District (OCSD) supplies the GWRS water from the wastewater flows OCSD collects and treats and would otherwise discharge to the ocean. OCSD provides effluent from wastewater that has undergone primary and secondary treatment to GWRS.[14,15,16] Once in GWRS, the effluent is tertiary treated by microfiltration and reverse osmosis. The resulting purified water is then exposed to ultraviolet light and hydrogen peroxide (advanced oxidization) for further disinfection. Finally, water is blended with calcium hydroxide and cationic polymers to improve settling of any remaining undissolved particles, and pH is verified to avoid corrosion or scaling of pipes. At this point, water is ready for use in MAR.[17]

The purified water then follows two paths. Approximately 35 MGD is sent to injection wells along the Talbert Barrier. The total amount of water sent to the Talbert Barrier varies from year to year, with 20,747 AF of GWRS water injected in 2017-2018.[18,19] The remaining 65 MGD of water produced from GWRS is sent to a demonstration injection well project located in the central part of the basin, and to the Kraemer, Miller, La Palma, and Miraloma infiltration basins

(Figure 1).[20] Recharged groundwater is eventually pumped by local wells where it is chlorinated or treated with another disinfectant before it is introduced into the potable water delivery system.[21]

4.2. Accounting

Basin conditions (supplies, storage, demand, and water quality), the amounts of imported water purchased and recharged to the basin, the amounts of water injected in the seawater intrusion barrier facilities, as well as financial data on the GWRS and for OCWD as a whole are reported annually through a combination of published reports available at the District's website, or by request.[22] The annual Engineer's Report contains data on basin conditions and operations, and there are separate annual budget reports and GWRS reports. As noted earlier, OCWD also reports water quality data to the Regional Water Quality Control Board.

4.3. Recovery

Stored groundwater is extracted by production wells throughout the basin, primarily for municipal and industrial uses. The largest groundwater producers are overlying cities and water service companies. OCWD itself does not extract groundwater or directly supply water to customers; its responsibility is managing the groundwater basin as a shared resource. In 2017-2018, total groundwater production in the basin amounted to 236,916 AF.[23]

OCWD sets limits for groundwater pumping and charges a pumping fee for groundwater production in the basin. These fees are based on a Basin Pumping Percentage (BPP) set by OCWD. Each year, OCWD determines the BPP for groundwater producers in the basin. The BPP is the limit that producers can pump from the basin, based on their total water needs. For example, in 2019, the BPP was set at 77%, which meant that groundwater producers could supply 77% of their water needs with groundwater pumping. Producers then pay a pumping fee (called a Replenishment Assessment) of $487 per AF extracted, up to the BPP limit. If producers pump over their BPP limit, they then may an additional pumping fee (called a Basin Equity Assessment), which is charged at $542/AF for every AF over the BPP limit that is extracted.[24]

5. Management

5.1. Institutional Structure

OCWD is the sole manager of GWRS, and is governed by a ten-member Board of Directors. OCWD's boundaries contain ten sub-districts, with one Board Member representing each district.[25] The Board of Directors appoints members to the GWRS Steering Committee, which includes three members of the OCWD Board and three members of the OCSD Board.[26] Several other subcommittees handle other aspects of the project, including interagency relations the Municipal Water District of Orange County (MWDOC).[27] The Director of Water Production oversees day-to-day operations of GWRS.[28]

Groundwater producers constitute OCWD's most directly engaged stakeholder group. Groundwater produces mainly include city water departments, local water districts, and private water service companies that supply water to the residents, businesses, and public spaces within OCWD. A producer committee meets regularly with OCWD staff to discuss basin

conditions and recharge operations, and to provide input on proposed basin assessments (pumping fees). Basin assessment comprise the main source of OCWD revenues.

5.2. Storage and Water Recovery Rules

The OCWD Act gives OCWD rights to all the groundwater storage space in the basin.[29] OCWD manages this storage within certain limits to ensure there are supplies available during droughts and to minimizing undesirable effects such as seawater intrusion and subsidence. Storage is managed on behalf of all the producers.

Groundwater quality is closely monitored.[30] Thirty chemists and lab technicians, and twelve water quality monitoring personnel are employed for the quality assurance and testing of both final GWRS product water and of the nearly 200 large-capacity drinking water wells within OCWD's boundaries. An advanced water quality assurance laboratory is located on the Fountain Valley campus, and performs over 400,000 analyses of 20,000 water sample each year.[31]

The California State Water Resources Control Board's Division of Drinking Water and the Santa Ana Regional Water Quality Control Board have provided permits and authorization for GWRS. These permits are conditional, and require regular quality testing and sampling of the final product water. If any of the samples or tests does not pass the quality standards, there will be an immediate and full shutdown of the GWRS plant.[32] An Independent Advisory Panel also provides ongoing scientific peer review by analyzing the data of the plant operations and checking water quality data. The National Water Research Institute appoints the scientists who serve on the IAP, including chemists, microbiologists, hydrogeologists, environmental engineers, and water treatment technicians. They write and publish scientific and technical reports on the results of their tests that are written for health and regulatory communities to read, understand, and evaluate.[33]

5.3. Costs and Financing

The GWRS system is a multi-million dollar operation that depends on funding from several different sources, including grants, usage fees and government support. Construction of the plant was a joint partnership between OCWD and OCSD. The two organizations shared the cost of building the plant. Construction began in 2002 and cost $481 million.[34] The project was supported by $92.5 million of grant funding from various government agencies[35] including: $37M from the State Water Board (approved by California voters under Prop 13), $30M from California Department of Water Resources, $20M from the US Bureau of Reclamation (USBR), $5M from the State Water Resources Control Board, and $500,000 from the EPA.[36] In the early years of GWRS plant operation, the MWD provided $7 million a year for twelve years to subsidize operating costs. MWD supported the project because it reduced demand on MWD's imported water supply.

Currently, OCWD has the full financial responsibility for ongoing operation costs and maintenance expenses. Operation costs of GWRS amount to roughly $40M per year, including the costs of electricity, facility maintenance, and O&M staffing.[37] To cover these costs, OCWD

relies on revenues from several different sources. In 2017-2018, the Replenishment Assessment provided $134.4M, and the Basin Equity Assessment provided $1.8M.[38] Additionally, Ad Valorem property taxes provided $24.2M in revenue. Other revenues included $1.5M from investments, $1.5M from water sales, $8.6M from an MWD subsidy to GWRS, $0.6M in annexation fees, and $1.2M rents and leases.[39] OCWD has also received significant grant funding for studies related to GWRS, which enables them to continue to innovate on treatment and potable reuse strategies.[40]

6. Analysis and Summary

The MAR program in Orange County is extremely successful and has become internationally recognized.[41] Since the 1960s, the negative consequences of groundwater overuse have been offset through MAR and managing groundwater pumping. Groundwater levels in most of the basin have been maintained above sea level, the inward intrusion of seawater has been largely arrested, and overlying communities have been able to continue their reliance on groundwater supplies in ways that would not have been sustainable in the absence of MAR.

6.1. Key Elements

The institutional foundation of the GWRS is an established local government agency that has been specifically charged with working towards a goal of sustainable water supply for decades. Orange County's MAR program, including GWRS, has been built in stages over 70 years. The program starting with in-stream recharge of river flows, expanding to include use of adjacent off-stream recharge basins and injection wells. OCWD is now in a position to shift among three potential sources of recharge water for the basin – local surface water, imported surface water, and treated wastewater, according to changes in their relative availability and costs. GWRS, and its predecessor Water Factory 21, are essential ingredients in OCWD's MAR portfolio because provide OCWD with a source of water for recharge that is stable and primarily under its control. Access to this water offsets risks associated with the variability of the river flows and with reliance on imported supplies that are subject to decisions and actions by other agencies and communities. Additionally, OCWD benefits from years of research and technological development. Finally, the successful operation of Water Factory 21 for many years build up trust with the public to support its replacement with GWRS.

Another strength comes from OCWD's narrow mandate from the legislature. OCWD has one primary responsibility – the management of the groundwater basin. As Special Act District, not a general-purpose local government such as a city of county, OCWD does not have to juggle water resource management responsibilities with other essential services such as public safety, public health services, street maintenance, etc. OCWD and its directors and personnel pursue multiple programs, projects, and activities but share the mission of keeping the basin full and safe from various threats. Further, GWRS management has a clear chain of command and leadership in discussing decisions or changes relevant to the operation. OCWD also benefits from high levels of interagency cooperation and coordination with the entities connected to it via contracts, partnerships, and collaborations.

Finally, GWRS maintains a favorable image with the public and in local news media coverage. Part of this positive public opinion is due to the fact that OCWD staff are proactive about effectively engaging with the public and providing public information. OCWD's recognition of the need to garner public support is attributed to their learning from obstacles that San Diego and Los Angeles Counties could not overcome when attempting to establish similar water recycling projects in the early 2000s. Indeed, the accepted success of GWRS in Orange County has been seen as playing a role in increasing public acceptance of water reuse in other communities in California and beyond.

6.2 Incentives and Benefits

Orange County's MAR program benefits its primary participants OCWD and OCSD, both of which have received significant incentives to undertake the GWRS. In addition to the grants and subsidies mentioned above, OCSD and OCWD have received approval from U.S. EPA the Santa Ana Regional Water Quality Control Board to operate the GWRS and the extensive multiple-barrier treatment methods of the GWRS receive pathogen reduction credits that allow the project to maintain that approval.

The principal benefit to the OCSD and OCWD comes in the form of avoided costs and increased water reliability. By finding an outlet for its treated wastewater flows that were still growing in the 1990s and early 2000s, OCSD saved hundreds of millions of dollars by not having to construct a second ocean outfall for disposal of the area's treated sewage. OCWD receives the flow from OCSD at no cost. In light of the expense associated with the additional treatment provided through the GWRS (microfiltration, reverse osmosis, and ultraviolet disinfection), it is unclear whether OCWD would have been willing or able to build and operate the GWRS if OCWD also had to pay for the source water. With the GWRS, OCWD insulates its recharge program somewhat from the uncertainties associated with imported water through MWD and the variability of Santa Ana River flows.

Groundwater producers and end users of water benefit also, because GWRS and Orange County's MAR program have sustained the local groundwater supply. Pumping groundwater, even with the OCWD Replenishment Assessment, remains a superior alternative to complete dependence on local rainfall and imported water. The current population and economy of the northern half of Orange County might not have been possible in the first place, or sustainable in the long run, without an effective MAR program to preserve and protect the groundwater basin. For groundwater producers in the area, the estimated cost of using groundwater, inclusive of pumping costs and OCWD's assessment fee amounts to roughly $754/AF. This is in sharp contrast to the estimated cost of treated, non-interruptible supplemental water (non-groundwater), which is estimated at $1,144/AF.[42] Additionally, MWD benefits from the existence of GWRS because a more reliable groundwater supply means that MWD will face less demand on its water supply.

6.3 *Challenges and Future Considerations*

GWRS, in large part, depends on OCSD for water. Expansion of GWRS relies on the ability of OCSD to supply increased amounts of treated wastewater, and functioning of GWRS relies on

OCSD flow rates remaining stable enough to support the GWRS infrastructure. When GWRS and its predecessor Water Factory 21 were designed and built, it seemed inevitable that wastewater flows would remain stable or increase forever. Instead, the effectiveness of water conservation over the last two decades has lowered water consumption per capita and per household so successfully that wastewater flows have declined too. It seems likely that the second expansion of the GWRS will be the last one for the foreseeable future. If OCSD water volumes continue to decrease, other sources of water for GWRS may be needed.

Acknowledgements
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References

[1] 2017-2018 Engineer's Report (p. 21)
[2] https://www.ocwd.com/gwrs/frequently-asked-questions/ (FAQ)
[3] (California Division of Water Resources 1930: 109); (Weschler 1968).
[4] During the 20th century there were three lawsuits by the downstream area of the Santa Ana River watershed (i.e., Orange County) against the upstream area (mostly in Riverside and San Bernardino counties) over reduced inflow to Orange County as a consequence of increased water use upstream. After the first litigation, OCWD was created and it took the lead as plaintiff on behalf of the lower watershed area in the subsequent two lawsuits.
[5] https://www.cwea.org/conferences/2016/E&R/CWEAHutchinson3-17-16.pdf ; CITE – history of OCWD that discusses the demand by local gw agencies, etc.
[6] *Id.;* (Hutchinson 2003).
[7] (Weschler 1968; Hutchinson 2003).
[8] Other water produced by Water Factory 21 was used for nonpotable purposes such as landscape irrigation and, in buildings with retrofitted plumbing, indoor flushing.
[9] (Hutchinson 2003).
[10] (Herndon).
[11] https://www.ocwd.com/media/7934/2018-gwrs-annual-report.pdf at ES-1. The non-potable customers are the Anaheim Canyon Power Plant and the Anaheim Regional transportation Intermodal Center.
[12] (Technical Brochure).
[13] (Technical Brochure).
[14] (Technical Brochure).
[15] (Technical Brochure).
[16] (Technical Brochure).
[17] (Technical Brochure)
[18] In 2015-2016, 47,524 acre feet was sent to the seawater barrier (2015-2016 ENGINEER'S REPORT). In comparison, only 24,848 acre feet was sent to the seawater barrier in 2017-2018. (2017-2018 ENGINEER'S REPORT).
[19] (2017-2018 ENGINEER'S REPORT) (p. 21, Table 4)
[20] www.ocwd.com/gwrs/the-process/process-steps/water-delivery/
[21] www.ocwd.com/gwrs/the-process/process-steps/water-delivery/
[22] www.ocwd.org
[23] 2017-2018 Engineer's Report; p. 39, Appendix 5.

[24] https://www.ocwd.com/news-events/newsletter/2019/april-2019/ocwd-establishes-2019-ra-price-and-quantity-of-basin-pumping/
[25] Each December following an election for the OCWD Board, the newly elected Board of Directors and Current Board of Directors all meet together to hold position elections. They elect a President, First Vice President, and Second Vice President. The President and both Vice Presidents must be members of the Board of Directors. The Board also appoints a Treasurer, Auditor, General Counsel, and District Secretary, and Assistant District Secretary. These individuals may be, but are not required to be, appointed from existing OCWD Staff (Orange County Water District Act, 18). The Board also appoints county-specific roles as needed, and can employ attorneys and engineers and other specialized positions as needed (Orange County Water District Act, 18). The Board is in charge of specific hiring and firing of employees, work requests, and communicating instruction to the appointed individuals (2015 OCWD Policy Manual, 9).
[26] Transparency is required for OCWD actions and decisions under the Orange County Water District Act and a variety of other California statues that collectively require public hearings and records availability for a range of its actions. Due to its status as a Special District, OCWD operates under the Orange County Water District Act and is subject to the Brown Act of 1953. The OCWD Act requires all public notices be published in the local newspaper. The Brown Act protects the public's right to attend and participate in local legislative body meetings. Public hearings are required for a variety of Board actions, including approval of Engineer's Reports on groundwater conditions, water supply, basin utilization, investigation and report on water supplies; the levy, modification, exclusion, or exemption of groundwater pumping fees; petition for inclusion of land in the OCWD boundaries; and approval of any annual reports. OCWD also complies with the California Public Records Act. The Public Records Act states that all government records with regard to conduct of public business must be about government agencies in California, both local and state. This means that any person can receive a copy of the OCWD public records with a written request.
[27] Those committees include Administration and Finance, Communications and Legislative Liaison, OCWD/MWDOC Joint Planning, Property Management, and the Water Issues Committee. Ad hoc committees are also appointed by the President for limited timer periods, and serve as an advisory capacity only. (2015 OCWD Board of Directors Policy Manual, p. 6).
[28] Including change orders and hiring staff; Board approval required for moving $ between funds, etc.
[29] OCWD District Act, Section 2.6.c. Available at https://www.ocwd.com/media/5749/2017-ocwd-district-act.pdf.
[30] (*2015-2016 ENGINEER'S REPORT*).
[31] (*2015-2016 ENGINEER'S REPORT*).
[32] (Frequently Asked Questions).
[33] (Frequently Asked Questions).
[34] (Herndon).
[35] ("White Paper: Cost of GWRS").
[36] ("White Paper: Cost of GWRS").
[37] (2, Annual Budget Report); FAQ - https://www.ocwd.com/gwrs/frequently-asked-questions/
[38] (5, Annual Budget Report).
[39] (5, Annual Budget Report).
[40] For example, during the 2017-2018 Annual Budget: the Santa Ana Watershed Project Authority funded the Middle Santa Ana River Pathogen Total Maximum Daily Load Study; the California Energy Commission (CEC) funded a study on Improving Membrane Treatment Energy Efficiency through monitoring and removal of colloidal particle foulants; Water Environment & Reuse Foundation (WE&RF) funded the evaluation of Post-Treatment Challenges for Potable Reuse Applications, the utility validation of NDMA Analysis Alternative Methods, and the Characterization of Microbiome of State of the Art Water Reuse System to Enhance Treatment Performance (funding for this last study was supplemented by the USBR). *See* (106, Annual Budget Report).
[41] (Endo 2018).
[42] (2017-2018 Engineer's Report, p. 28-30).