WRF 4973 Fact Sheet: ID 2001

Strategy: Nutrient Reduction Outside WRRF

Manage Nutrients Outside the WRRF

Directing Effluent to Reuse Can Reduce Nutrient Discharge.
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Horizontal Levee Provides Nutrient Reduction and Sea-Level Rise Protection.
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This fact sheet is an overview of strategies that reduce the amount of nutrients discharged into receiving waters without modifying the water resource recovery facility (WRRF) process directly. These typically reduce nutrient loads to receiving waters by either (1) redirecting or further reducing nutrients once the water leaves the WRRF or (2) reducing the source of nutrients and the nutrient load that enters the WRRF.

Redirecting WRRF effluent for reuse in applications such as irrigation, industries, groundwater replenishment, and potable reuse also reduces the amount of nutrients entering receiving waters. Water reuse practices are well established and provide an outlet for WRRFs during warm, dry periods, but they often do not provide much relief during peak flows. The practice of replenishing groundwater and potable water supplies through WRRF effluent reuse has continued to gain traction in the United States and has proved to be a resilient and reliable source of water.

Strategies that focus on nutrient source reduction can be used for both point and diffuse sources. Even though these two source types are both difficult to control and reduce, some cases of successful nutrient reduction have been achieved and demonstrated. The phosphorus (P) ban on soap and detergents, for example, resulted in a reduction of phosphorus entering WRRFs from 6–10 milligrams (mg) P per liter (L) to 4–7 mg P/L and lower. Some states have also started to ban dishwasher detergents with phosphorus, causing a shift in manufacturing and further reduction of phosphorus in WRRF influent. Urine separation devices have also been used effectively in closely controlled systems (such as hotels, campuses, etc.) and allow a system to separate the nutrient-heavy urine from the rest of the wastewater to be treated or processed separately. Nutrient loads from industrial discharges have also been reduced because of changes in industry operation.

Regulatory "trading" has been a successful strategy when it comes to diverting nutrients. The Chesapeake Bay, San Francisco Bay, Long Island Sound, and other watersheds have implemented or are considering bubble nutrient permits where dischargers can trade nutrients to remain under a long-term, permitted nutrient load.

This fact sheet provides a high-level overview of strategies that reduce the nutrient load to a WRRF before entering and/or after leaving the WRRF. Related fact sheets provide some additional information about these strategies.

Fact Sheet Application Checklist

R = fact sheet relevant to item
PR = fact sheet is potentially relevant to item depending on application, existing conditions, etc.

Category		Intensification
		Chemical addition
		Carbon management
		I&C strategies
		Sidestream mgmt.
		Energy savings
		Chemical savings
		Operational savings
	R	Other means of NutRem
Nutrient	R	Ammonia
	R	NOx
	R	TN
	R	Ortho-P
	R	TP
Scale (design flow)	R	Small (<1 mgd)
	R	Medium (1–10 mgd)
	R	Large (>10 mgd)

Goal		Improve reliability
	R	Reduce nutrient
		Reduce O&M cost
Group	R	Optimize existing CNR
	R	Optimize existing TNR
	R	NutRem in secondary plant
Process	R	Small
	R	Pond
	R	Fixed film (secondary)
	R	Conventional act. sludge (CAS)
	R	Nitrifying act. sludge (NAS)
	R	Conventional NutRem (CNR)
	R	Tertiary NutRem (TNR)
		Other

CAS = conventional activated sludge (BOD only)
NAS = nitrifying activated sludge (without denitrification)
CNR = conventional nutrient removal no chemical/no filter, etc.
TNR = tertiary nutrient removal with chemical, filter, etc.

Technology Summary Evaluation

Footprint	5	Compared to conventional (1 = much smaller; 3 = conventional; 5 = much larger)
Development status*	2–5	Technology ranking based (LIFT) see below*
Energy use	1	Compared to conventional (1 = much less; 3 = conventional; 5 = much more)
O&M impact	1–3	Compared to conventional (1 = much less; 3 = conventional; 5 = much more)
Material/consumables	1–2	Scale 1–3: minimal = 1; some = 2; significant = 3 (e.g., UV lamps/membranes)
Chemical use	1	Scale 1–3: minimal/none = 1; some = 2; significant = 3 (e.g., chemical process)

* Technology ranking based on Leaders Innovation Forum for Technology (LIFT) Water Research Foundation (WRF) Technology Development Level (TDL) definitions:
1 = bench research and development
2 = small-scale pilot

3 = full-scale pilot (demonstration)
4 = pioneer stage (production and implementation)
5 = conventional

Descriptions/Evaluation

Strategy	Manage nutrients outside WRRF
Description	These strategies reduce the amount of nutrients discharged by a WRRF using means outside of WRRF treatment. There are two classifications: reducing nutrient loads entering the WRRF and diverting/removing nutrients from discharges to receiving waters. These strategies include the following: • Send treated effluent to reuse, specifically consumptive uses such as agricultural or landscape irrigation. • Send treated effluent to industrial users for applications that return flows to the WRRF. Some reuse opportunities may reduce nutrients partially and return the remaining nutrients back to the WRRF. • Indirect potable reuse (IPR) or direct potable reuse (DPR). • Nature-based solutions (NbS), including horizontal levees, groundwater recharge, wetlands, etc. • Implement source control for nutrients in the collection system. • Gain nutrient credit by eliminating other sources of nutrients reaching the receiving water, such as septic tanks or small community systems.
Application	Opportunities for other means of nutrient reduction are highly site-specific and can be identified by considering the entire water cycle within a community's or service area's watershed. A water balance can be developed to determine the potential for nutrient diversion within the watershed. Nutrient reduction outside the WRRF is attractive in the following scenarios: • Nutrient reduction is required during the summer only. This allows seasonal irrigation to redirect nutrients away from the WRRF's effluent. • Local demand for water is high. • Limited potable water sources available or unreliable (drought sensitive) making DPR and IPR attractive. • WRRF already achieves tertiary nutrient removal (TNR) quality, which meets most unrestricted non-potable reuse requirements. • Strategies with multiple benefits make a strategy attractive. An example of this could be public wetlands, which may also help with controlling the impacts of rising sea levels.
Constituents removed	Nitrogen and phosphorus and other constituents in diverted WRRF effluent
Development status*	Varies depending on technology (e.g., reuse = 5, industrial reuse = 5; DPR = 3).
O&M considerations	See Table 1 below for more information.
Benefits	Strategies outside the WRRF are generally environmentally friendly, low-energy solutions. Treatment efficiency is dictated by the environment and can be highly effective with biological uptake and the transformation of nutrients. Resource recovery is achieved by water reuse or by WRRF nutrient uptake. Water reuse can augment existing water and make water supply more robust and drought-proof. Some options can improve sea-level rise resilience and provide public open-area recreation.
Limitations	NbS require a large footprint that could be a limitation for highly populated areas. In those cases, it may provide a partial solution to stretch water supplies or provide a partial reduction in nutrients.

Design considerations	Some specific strategies will require agreements with other agencies or entities. These entities may have special water quality restrictions for accepting reuse water. NbS may require special permits.
Potential fatal flaws	A site-specific assessment is required to determine the feasibility of these strategies. There are many potential stumbling blocks, such as public acceptance, permitting, funding, water quality requirements (for reuse), available footprint, and many others.
Footprint requirements	Footprint requirements range from none (e.g., source control) to large (NbS). Irrigation with reclaimed water requires a large footprint of land available, but the irrigation may offset water demands and provide sufficient economic stimulus to be attractive (e.g., golf course irrigation).
Residuals	Some strategies produce little or no residuals (e.g., irrigation or IRP/DPR) except for the residuals associated with treating the water to meet use requirements. Other strategies (including NbS) grow biomass/vegetation then needs to be managed and disposed of or beneficially use (such as algae recovery for energy production).
Cost considerations	Investment is required for most strategies to convey the WRRF effluent. Effluent from TNR and some conventional nutrient removal (CNR) processes can often meet reuse requirements. Some strategies may require additional treatment.
Past experience	Satellite WRRFs constructed upstream in collection system to produce reuse quality water for local consumption; e.g., Irvine Ranch Water District (IRWD) (Irvine, California), Los Angeles County Sanitation District (LACSD), Martin Way/Cities of Lacey, Olympia, and Tumwater and Thurston County (LOTT) Clean Water Alliance (Olympia, Washington), etc. Groundwater replenishment; e.g., Orange County Water District (OCWD) (Fountain Valley, California), Sustainable Water Initiative for Tomorrow (SWIFT) (Hampton Roads Sanitation District [HRSD], Virginia), etc. Industrial reuse; e.g., Delta Diablo, Pittsburg, California (power plant cooling), botanical gardens (Silverton, Oregon), etc. Horizontal levee demonstration project; e.g., Oro Loma Sanitary District, California, etc.
Publications	Bell, M., E. Lozon, H. Netto, T. Haug, K. Redd, S. Hammond, and W. Hartnett. 2010. "Nutrient Removal Treatment Practices Implemented at the City of Los Angeles Upstream Water Reclamation Plants." WEF's 83rd Annual Technical Exhibition and Conference. New Orleans, Louisiana: WEFTEC. California Code of Regulations (CCR). 2022. "Title 22, Division 4, Chapter 3 Water Recycling Criteria." Thomson Reuters Westlaw. https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=IE8ADB4F0D4B911DE8879F88E8B0DAAAE&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default). Accessed February 14, 2022. California State Water Resources Control Board. 2021. "Volumetric Annual Report of Wastewater and Recycled Water: Help Guide for Volumetric Annual Report in GeoTracker." February 8, 2021. https://www.waterboards.ca.gov/water_issues/programs/recycled_water/docs/2020/var_helpguide.pdf. Frantzeskaki, N., T. McPhearson, M.J. Collier, D. Kendal, H. Bulkeley, A. Dumitru, C. Walsh, K. Noble, E. van Wyk, C. Ordóñez, C. Oke, and L. Pintér. 2019. "Nature-Based Solutions for Urban Climate Change Adaptation: Linking Science, Policy, and Practice Communities for Evidence-Based Decision-Making." BioScience. 69(6):455–466 https://doi.org/10.1093/biosci/biz042 Hughes, J., K. Williamson, and D. Austin. 2015. "Low-Energy Nitrogen Removal in Intensified Wetlands." WEF's 88th Annual Technical Exhibition and Conference. Chicago, Illinois: WEFTEC. Kadlek, R. and S. Wallace. 2008. "Treatment Wetlands, 2nd ed." CRC Press: Boca Raton, Florida http://dx.doi.org/10.1201/9781420012514. Olson, D., I. Venner, and D. Ornelas. 2016. "Upstream Biological Treatment for Total Nitrogen Removal in a Direct Potable Reuse Application." WEF's 89th Annual Technical Exhibition and Conference. New Orleans, Louisiana: WEFTEC.

	U.S. EPA. 2011. "Principles of Design and Operations of Wastewater Treatment Pond Systems for Plant Operators, Engineers, and Managers." EPA/600/R-11/088; U.S. EPA Office of Research and Development National Risk Management.
Related fact sheets	2010: Water Reuse 2020: Nature-Based Solutions
Date updated	9/10/2022
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Note

* Technology ranking based on LIFT WRF TDL definitions:
1 = bench research and development
2 = small-scale pilot
3 = full-scale pilot (demonstration)
4 = pioneer stage (production and implementation)
5 = conventional (https://www.waterrf.org/sites/default/files/file/2019-07/LIFT%20Scan%20Application-LIFT%20Link%2BHub_0.pdf : accessed September 2020)

Additional Information

Several strategies can reduce the amount of nutrients in a WRRF's effluent by redirecting flows elsewhere. Table 1 below has an application checklist for some strategies for nutrient reduction outside the WRRF. Table 2 contains a summary description of the strategies and potential situations where this strategy would be applicable for nutrient reduction. See the related fact sheets for more information on these strategies.

Most WRRFs produce an effluent that can meet the criteria for some reuse applications. Despite this, some additional redundancy and monitoring may be required. Reuse water quality criteria, which are set by individual states, vary considerably from state to state. Many states, such as California, have a well-developed program outlining treatment, monitoring, and application requirements for reusing secondary effluent, as well as requirements for filtration and disinfection. Beyond disinfected secondary effluent, the effluent from many CNR and TNR WRRFs will also meet the water quality criteria for unrestricted water reuse in many states.

Table 1. Technology Application Checklist.

Feature	Reuse: Irrigation	Reuse: Industrial	IPR	DPR	Horizontal Levee	Ground-water Recharge	Wetlands	Source Control	Nutrient Credits
GOAL									
Improve reliability									
Reduce nutrient	✓	P	✓	✓	✓	✓	✓	✓	✓
Reduce O&M cost									
GROUP									
Optimize existing CNR	✓	✓	✓	✓	✓	✓	✓	✓	✓
Optimize existing TNR	✓	✓	✓	✓	✓	✓	✓	✓	✓
NutRem in secondary plant	✓	✓	✓	✓	✓	✓	✓	✓	✓
PROCESS									
Small	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pond	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fixed film (secondary)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Conventional act. sludge (CAS)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nitrifying act. sludge (NAS)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Conventional NutRem (CNR)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tertiary NutRem (TNR)	✓	✓	✓	✓	✓	✓	✓	✓	✓
CATEGORY									
Intensification									
Chemical addition									
Carbon management									
I&C strategies									
Sidestream mgmt.									
Energy savings									
Chemical savings									
Operational savings									

Feature	Reuse: Irrigation	Reuse: Industrial	IPR	DPR	Horizontal Levee	Ground-water Recharge	Wetlands	Source Control	Nutrient Credits
Other means of NutRem	✓	✓	✓	✓	✓	✓	✓	✓	✓
NUTRIENT									
Ammonia	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO_x	✓	✓	✓	✓	✓	✓	✓	✓	✓
TN	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ortho-P	✓	✓	✓	✓	✓	✓	✓	✓	✓
TP	✓	✓	✓	✓	✓	✓	✓	✓	✓
OVERVIEW									
Footprint (scale 1–5)	5	2	2	2	5	3	5	1	1
Development (scale 1–5)	5	5	4	3	3	5	5	5	4
Energy use (scale 1–5)	1	1	3	5	1	4	1	1	1
O&M impact (scale 1–5)	1	1	3	5	1	4	1	1	1
Material/consum-ables (scale 1–3)	1	1	3	4	1	2	1	1	1
Chemical use (scale 1–3)	1	1	2	3	1	3	1	1	1

✓ = applies; P = partially applies

Scale definitions

Footprint	Compared to conventional (1 = much smaller; 3 = conventional; 5 = much larger)
Development status*	Technology ranking based (LIFT) see below*
Energy use	Scale 1–5: 1 = use much less; 3 = use similar to conventional; 5 = use much more
O&M cost	Scale 1–5: 1 = cost much less; 3 = cost similar to conventional; 5 = cost much more
Material/consumables	Scale 1–3: minimal = 1; some = 2; significant = 3 (e.g., UV lamps/membranes)
Chemical use	Scale 1–3: minimal/none = 1; some = 2; significant = 3 (e.g., chemical process)

Table 2. Technology Summaries.

Nutrient Reduction outside WRRF	Brief description	Application
Reuse: irrigation [a]	Water sent to unrestricted irrigation typically requires tertiary filtration and disinfection to meet the 2-nephelometric turbidity unit (NTU) and 2.2 most probable number (MPN) total coliform water quality requirements. Infrastructure (distribution pipes and storage) is required to convey water to the application points. This strategy is often used seasonally during the summer.	Three categories [a]: • *Agricultural irrigation:* pasture or crop irrigation • *Landscape irrigation:* irrigation of parks, greenbelts, and playgrounds; school yards; athletic fields; cemeteries; residential landscaping, common areas; commercial landscaping; industrial landscaping; and freeway, highway, and street landscaping • *Golf course irrigation:* irrigation of golf courses, including water used to maintain aesthetic impoundments within golf courses
Reuse: commercial	Water sent to non-industrial businesses. The water treatment requirements are dependent on the application. Some applications align with unrestricted irrigation requirements, whereas others treatment requirements align more with those typical for industrial applications.	*Commercial application* [a]*:* commercial facilities, businesses (such as laundries and office buildings), car washes, retail nurseries, and appurtenant landscaping that is not separately metered
Reuse: industrial	Industrial reuse typically requires tertiary filtered and disinfected reclaimed water. Additional, industry-specific requirements may also affect the water quality requirements. These additional requirements could be for nutrient reduction, total dissolved solids (TDS) limits, or other specific compounds.	*Industrial application* [a]*:* manufacturing facilities, cooling towers, process water, and appurtenant landscaping that is not separately metered
Reuse: other non-potable uses	This grouping for non-potable applications covers other applications that do not fall within one of the identified reuse categories.	*Other non-potable uses* [a]*:* including but not limited to dust control, flushing sewers, fire protection, fill stations, snow making, and recreational impoundments

Nutrient Reduction outside WRRF	Brief description	Application
Potable reuse: indirect	States regulate IPR requirements. These typically require advanced water treatment (AWT) to achieve additional virus removal, reduction in contaminants of emerging concern (CECs), and an environmental buffer (storage and dilution with natural water).	Intentional IPR is growing because of water scarcity and of interest to water suppliers to have a more sustainable water supply source. The two applications addressed in most regulations across the country are as follows[a]: • *Groundwater recharge:* Highly treated effluent is injected into the ground to be recovered at a later time. Water quality requirements are site-specific and depend on the aquifer that water is injected into. In many cases, groundwater injection requires AWT with reverse-osmosis (RO) treatment. Application of groundwater injection is dictated by the aquifer characteristics. Some applications include: o Storage for future extraction o Creating a water barrier to prevent ocean water intrusion o Replenishing aquifers that were overdrawn in past years • *Surface water augmentation:* Highly treated effluent is augmented to a raw surface water reservoir used as a source of domestic drinking water. The water requirements are regional and site-specific based on regulatory requirements. A typical requirement, besides additional treatment, is a 6-month hydraulic retention time (HRT) for the augmented water in the surface water.
Potable reuse: direct	States regulate DPR requirements. DPR applications do not require the environmental buffer. Consequently, DPR requires additional engineered barriers, reliability and monitoring requirements, and redundancy requirements.	DPR has gained interest in the U.S. because of drought conditions in western states such as Texas, California, and others. It remains an emerging strategy.

Nutrient Reduction outside WRRF	Brief description	Application
Nature-based solutions	NbS are typically referred to as nature-based forms of wastewater treatment, such as treatment wetlands. The NbS term encompasses treatment wetlands and other treatment innovations incorporating natural elements and technology-based or engineered solutions (Frantzeskaki et al. 2019).	There are various NbS technologies, such as but not limited to (1) free water constructed wetlands, (2) unit-cell open water wetlands, (3) denitrifying bioreactor beds, and (4) horizontal levees. Of those listed, all but horizontal levees are well-documented with design criteria (e.g., Kadlek and Wallace 2008; USEPA 2011, etc.), A horizontal levee is a gradually sloped levee that offers various benefits, such as (1) sea-level rise protection (if needed), (2) habitat restoration (if desired), and (3) nutrient management based on the fundamentals of natural systems treatment.
Source control	Eliminates nutrient addition to the sewer system by regulatory initiatives. An example is the reduction in phosphate associated with limiting the disposal of detergents through the wastewater system. Another example is local limitations on the disposal of grease and other nuisance compounds.	Imposing local regulations on discharges is a long and difficult path but not impossible.
Nutrient credits	Many watersheds allow nutrient trading (e.g., Long Island Sound) that allows dischargers to sell nutrient load credits to other utilities. A discharger can create nutrient credits by eliminating a nonpoint source discharge to the watershed. An example is in Spokane County, Washington, where septic systems were incorporated into a new WRRF to obtain P credits, which were then used to obtain a discharge permit for a new WRRF.	Trading programs provide opportunities for multiple dischargers to collaborate and maintain the health of the watershed by trading nutrients discharged by their individual systems. Utilities that discharge to the Chesapeake Bay share a common annual nutrient load allocation and some trading between dischargers exists. San Francisco Bay and Puget Sound are considering a similar approach. The City of Las Vegas, Clark County, City of Henderson, and North Las Vegas collaborate to manage their combined P discharge into the Las Vegas watershed.

a. California State Water Resources Control Board. 2021. “Volumetric Annual Report of Wastewater and Recycled Water: Help Guide for Volumetric Annual Report in GeoTracker.” February 8, 2021. https://www.waterboards.ca.gov/water_issues/programs/recycled_water/docs/2020/var_helpguide.pdf.

Abbreviations

AWT	Advanced water treatment: to produce IPR and DPR water
BOD	Biochemical oxygen demand
CAS	Conventional activated sludge: BOD removal only
CEC	Contaminant of emerging concern
CNR	Conventional nutrient removal
DPR	Direct potable reuse
EBPR	Enhanced biological phosphorus removal
HRSD	Hampton Roads Sanitation District
HRT	Hydraulic retention time
I&C	Instrumentation and controls
IPR	Indirect potable reuse
IRWD	Irvine Ranch Water District
kW	Kilowatt
L	Liter(s)
LACSD	Los Angeles County Sanitation District
LIFT	Leaders Innovation Forum for Technology (now RIC and RISE)
LOTT	Cities of Lacey, Olympia, and Tumwater and Thurston County (Clean Water Alliance)
mg	Milligram(s)
mgd	Million gallons per day
MPN	Most probable number
NAS	Nitrifying activated sludge
NO_x	Oxidized nitrogen (nitrate + nitrite)
NTU	Nephelometric turbidity unit(s)
NutRem	Nutrient removal
OCWD	Orange County Water District
O&M	Operations and maintenance
P	Phosphorus
RIC	Research & Innovation Committee
RISE	Research and Innovation for Strengthening Engagement
RO	Reverse osmosis
SWIFT	Sustainable Water Initiative for Tomorrow
TDL	Technology Development Level
TDS	Total dissolved solids
TN	Total nitrogen
TNR	Tertiary nutrient removal

TP	Total phosphorus
TSS	Total suspended solids
UV	Ultraviolet
WRF	The Water Research Foundation
WRRF	Water resource recovery facility