The Water Environment & Reuse Foundation (WE&RF) is a 501c3 nonprofit research institute that identifies, supports, and disseminates research that enhances the quality and reliability of water for natural systems and communities with an integrated approach to water management, resource recovery, and reuse. WE&RF also facilitates interaction among practitioners, regulators, educators, researchers, decision makers, and the public.

WE&RF was formed through the merger of the Water Environment Research Foundation and the WateReuse Research Foundation. The new organization brings together a broad portfolio of research in water, wastewater, and stormwater, valued at more than $200 million. The merger strengthens the industry movement toward One Water, which focuses on integrated approaches to water, wastewater, and stormwater management and use.

WE&RF is supported by more than 350 utilities, businesses, industrial and commercial enterprises, educational institutions, and government agencies. The utilities combined represent more than 50 million residential and small business water consumers across the country.

WE&RF serves as a research hub for organizations interested in water research and integrated water management. WE&RF partners with diverse set of stakeholders to define critical research needs, develop research questions and sponsors peer-reviewed projects to address these needs. WE&RF has engaged with the agricultural community for over a decade. In 2012, WE&RF began to partner with agricultural organizations to jointly understand the nutrient contributions of point and non-point sources and to provide peer-reviewed tools to minimize nutrient runoff into receiving waters. This effort has recently expanded into the areas of agricultural reuse, nutrient recovery and codigestion.

Several featured WE&RF agricultural research projects are provided below, organized into three areas of study: economics and policy, sustainable practices, and management approaches.

**Economics and Policy**

**Evaluating Economic and Environmental Benefits of Water Reuse for Agriculture (Reuse-16-06)**

In many studies assessing the economic impacts of drought, the focus is often on the resilience and vulnerabilities to drought in the agricultural sector. This study will build upon current WE&RF project “State of Irrigated Agricultural Water Reuse – Impediments and Incentives (WRRF-15-08)” which is evaluating the financial benefits of water reuse for agricultural uses. The expected kickoff for this study is summer 2017.

This study will address the following questions:

- What are the potential economic impacts of water reuse of domestic wastewater, produced water from oil and gas production, agricultural return flows, and other nontraditional water sources in agriculture?
- To what extent can water reuse protect agricultural communities from irrigation water supply shortages faced during drought?
- Does the availability of water reuse change the types and value of crops that can be grown?
- What are the indirect economic benefits of water reuse for agricultural communities?
- How can onsite reuse (i.e., developing water reuse facilities of wastewater generated onsite) on agricultural lands provide an economic and environmental benefit and make farmland more productive?

- What opportunities are available for monitoring on agricultural lands to characterize water quality, improve knowledge, and improve water quality for the environment?

**FDA Food Safety Modernization Act (FSMA) Produce Safety rule: Opportunities and Impacts on Water Reuse for Agricultural Irrigation (Reuse-16-07)**

The U.S. Food & Drug Administration (FDA) Food Safety Modernization Act (FSMA) Produce Safety rule has been finalized and establishes science-based minimum standards for the safe growing, harvesting, packing, and holding of fruits and vegetables grown for human consumption. Farms are required to be compliant with the rule in the near future, with compliance dates ranging from two to four years. Three categories of water sources are discussed – public water supply, groundwater, and surface water- with mandatory testing standards for each cate-
The rule outlines criteria standards which need to be met for the use of agricultural water. There is a need to navigate the impacts and potential opportunities for utilizing recycled water for agricultural irrigation presented by the rule. As implementation guidelines are drafted and determined, states need to be informed of these opportunities for reuse. This well-timed White Paper will provide an explanation of the rule and how it will relate to reuse in terms of testing and water quality requirements, and present potential opportunities for reuse for states to consider. This project is expected to begin in summer 2017.

**State of Irrigated Agricultural Water Reuse – Impediments and Incentives (WRRF-15-08)**

Potential for use of recycled water for agricultural irrigation is especially promising in the arid and semi-arid regions of the world where groundwater depletion is a critical issue. However, this potential remains unrealized due to a number of challenges and impediments. To address this need, this research effort, led by Dr. Bahman Sheikh and a team of experts, will explore and recommend ways to overcome the challenges facing agricultural water reuse.

The research approach includes assembly of a global inventory of successes, delays, and set-backs in the process of switching from various traditional sources of irrigation water to recycled water. For each successful case, the incentives that gave rise to adoption of recycled water will be identified. For each case of a set-back, the reasons will be identified and catalogued. Any failures of offered incentives will also be identified.

This project began in March 2016. Publication of the final report is expected in Summer 2018. Potential future research opportunities include:

- Explore landscape and/or golf irrigation. Turf grass irrigation can account for 50% of a municipality’s water use during summer months.
- Examine what kind of uptake of CECs is present in recycled water for agricultural reuse.
- Investigate the energy and economic issues associated with different levels of treatment for agricultural reuse.

**White Paper on Groundwater Replenishment with Recycled Water on Agricultural Lands (WRRF-16-03)**

This White Paper, funded by WE&RF through the Tailored Collaboration Research Program, will create opportunities in areas that have been obstacles in the past, resulting in benefits to stakeholders in the agricultural setting. Successful implementation of groundwater recharge with recycled water on agricultural land makes more efficient use of two resources – off-peak recycled water and dormant agricultural land – and would provide significant groundwater sustainability, agricultural sustainability, and habitat benefits where the worst impacts of the recent drought are being felt in the region.

The objective of the White Paper is to assimilate the relevant current knowledge from three similar types of practices: groundwater recharge on agricultural land with surface water, urban groundwater recharge with recycled water, and Agricultural Reuse projects, and to develop a regulatory and operational “roadmap” for groundwater recharge with recycled water on agricultural land. The document will investigate various aspects of existing regulatory frameworks as they may be applied to recycled water groundwater recharge on agricultural land and consider alternative methods to meet the intent of those regulations; the paper will also define operational challenges that are likely to be faced by farmers and propose ways to resolve or mitigate those challenges. To accomplish this, the project team, led by Dave Richardson of RMC Water and Environment and Dr. Bahman Sheikh as Co-Principal Investigator, will utilize a series of workshops, combined with Case Studies and focused Issue Papers, to work toward a comprehensive set of potential solutions.

This project is currently underway. Potential future research opportunities include an increased number of case studies in California and additional states included in the case studies.
Sustainable Practices

Manure Resource Recovery (STAR_N3R14)
This U.S. EPA STAR grant project is a collaboration between the Center for Sustaining Agriculture and Natural Resources, Washington State University, and Dr. David Stensel, University of Washington. It is one in a suite of six projects funded by the STAR Grant awarded to WE&RF’s National Center for Resource Recovery and Nutrient Management.

Adoption of anaerobic digestion (AD) projects for energy production on both farms and the municipal sector is currently hampered by poor economics. Co-digestion of organic wastes, with its ability to harness extra energy as well as provide tipping fees, improves AD project viability. However, imported wastes exacerbate nitrogen accumulation. Ammonia stripping is a known technology for removal of nitrogen (N) from high ammonia streams resulting from AD; however, to date, adoption of ammonia stripping for recovery purposes has been slow due to high costs.

The objectives of this study led by the University of Washington, are to demonstrate the performance and economic link between co-digestion and low-input (i.e., reduced pH and temperature), ammonia stripping N recovery, and to reduce ammonia concentrations in, and emissions from, animal and municipal wastewater. Collected N will be stabilized as ammonia salts either as a single product or blended with biosolids. AD performance will be offset by reducing capital/operating costs, and incorporating the operation within a total system approach (i.e., using co-digestion for enhanced biogas as well as ammonia concentration), and producing more-valued bio-fertilizers. The project started in May 2014 and will be completed by June 2017.

Towards a Renewable Future: Assessing Resource Recovery as a Viable Treatment Alternative (NTRY1R12)
Though the recovery of biosolids for land application has been practiced for years, water resource recovery facilities (WRRFs) are looking at extractive nutrient recovery, defined as the production of chemical nutrient products devoid of significant organic matter. This practice complements existing nutrient removal efforts at WRRFs which have to deal with stringent regulatory requirements that dictate remediation of nutrient loads. During extractive nutrient recovery, energy and resources are used to accumulate and produce a chemical nutrient product that is recyclable and has a resale value that can help offset operating costs while reducing nutrient production from raw materials for agricultural or other uses.

The main objectives of this project were to 1) characterize factors influencing the adoption of extractive resource recovery systems; 2) provide guidance on the implementation of extractive resource recovery technologies at WRRFs with a special emphasis on phosphorus; and 3) experimentally evaluate innovative extractive nutrient removal technologies with an emphasis on P-recovery. For the first objective, the project team performed an extensive literature review regarding extractive nutrient recovery. They also surveyed commercial technology providers to supplement the peer reviewed data. An assessment of the data collected led to the development of a State of the Science and Market Assessment Reports (NTRY1R12a) and an electronic interactive technology matrix (NTRY1R12m). For the second objective, the project team interviewed 20 utilities which are either doing or considering extractive nutrient recovery at their facilities. The compilation of operating data for pilot and full-scale testing is documented in a Case Studies report (NTRY1R12b) and, along with the matrix, was the basis of the development of the Tool for Evaluating Resource Recovery (TERRY-Phosphorus, NTRY1R12t) – but only for phosphorus in the form of struvite crystallization. The research conducted for the third objective focused on enhancing nutrient recovery at WRRFs via crystallization, multi-cell electrodialysis, and the impact of varying potassium concentrations in the influent.

Incorporating Forestry into Stormwater Management Programs: State of the Science and Business Model Evaluation for Nutrient Reduction and Volume Control (SIWM12C15)
In collaboration with the U.S. Endowment for Communities and Forestry, WE&RF is funding a study on Incorporating Forestry into Stormwater Management Programs. The research is expected to consider five key questions: to what extent are trees/forests an effective, affordable, desirable, and practical way to meet stormwater regulatory requirements and at what scale. The 12-18 month project will advance our understanding of how forest systems impact nutrient reduction and volume control, with a particular attention to economic considerations. Cost comparisons to other stormwater infrastructure (other green and grey alternatives), as well as a quantification of ancillary benefits will provide useful information for utilities considering or pursuing trees/forests for stormwater controls.
Management Approaches

Agricultural BMP Database
A current regulatory focus is implementing strict nutrient runoff requirements for the agricultural community. While many conservation practices and pollutant reduction measures (i.e., BMPs) are being voluntarily adopted by farmers, the effectiveness of these BMPs is not well characterized due to limited availability of comparable BMP performance, site characterization, and design data.

To address this gap, WE&RF, the National Corn Growers Association, and the Missouri Corn Growers Association partnered in 2012 to develop the Agricultural BMP Database (AgBMPDB, www.bmpdatabase.org/agBMP.html). United Soybean Board joined in 2015. The database provides a tool that can be used to evaluate agricultural BMP performance for row crops and support scientifically sound approaches to selecting appropriate BMPs for specific site characteristics. The AgBMPDB includes 44 peer-reviewed studies focused on row crops that characterize pollutant loading and/or concentrations in 192 study plots and allows entry of BMP performance data for 14 types of BMPs (see Table). Results from the current analysis have found that tillage practices and edge-of-field practices can have a significant effect on unit area loading rates. There is a need to expand the database to better characterize BMP performance, influence of different geographies, impact on crop yield, and additional crop types. Additional support will allow the team to:

- Increase the number of BMP performance studies for multiple crop types.
- Standardize analysis procedures and reporting metrics to enable consistent comparisons of BMP performance to provide better, customized recommendations for BMPs based on site characteristics.
- Conduct an analysis of the data in the AgBMPDB and prepare BMP performance summary reports for different BMP types and pollutants of concern.

Recycled Water Use in Zoo and Wildlife Facility Settings (WRRF-07-06)
Although much attention has been paid to recycled water use for irrigation and industrial uses, for toilet and urinal flushing, and in cooling towers and water features, little research has been conducted on its use in zoo and wildlife facility settings. This 2013 WaterReuse Research Foundation study surveyed 23 zoos and wildlife facilities in the U.S. and overseas and one animal shelter to evaluate their current recycled water practices. The findings present initial research on the current status of recycled water use by these facilities and examine water quality, treatment technology, potential animal health effects, and regulatory issues.

<table>
<thead>
<tr>
<th>BMP Types Included in the Agricultural BMP Database</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riparian Buffers</td>
</tr>
<tr>
<td>Filter Strips</td>
</tr>
<tr>
<td>Grasses Waterways</td>
</tr>
<tr>
<td>Water and Sediment Control Basins (Ponds)</td>
</tr>
<tr>
<td>Constructed Wetlands</td>
</tr>
<tr>
<td>Controlled Drainage</td>
</tr>
<tr>
<td>Terraces</td>
</tr>
</tbody>
</table>

Attenuation of PPCPs through Golf Courses Using Recycled Water (WRRF-08-02/WERF1C08)
The scarcity of water supplies in portions of the U.S. makes landscape irrigation with recycled water a highly viable and beneficial practice. An increasing number of studies show that some pharmaceuticals and personal care product chemicals (PPCPs) are resistant to chemical or biological treatment processes and are found in recycled water. A multi-year, collaborative research project was conducted to investigate the fate and transport of pharmaceuticals and personal care product chemicals in turfgrass/soil systems irrigated with recycled water. The results of this 2012 study Water Environment Research Foundation study support the use of recycled water for irrigation purposes, as long as sound, science-based irrigation management practices (e.g., cycle and soak irrigation) are implemented.

Risk Assessment Study of Pharmaceuticals and Personal Care Products in Nonpotable Recycled Water to Support Public Review (WRRF-09-07)
Discussions of human health risk during nonpotable water reuse project reviews have focused on the presence of residual chemicals in highly technical terms. However, the actual effects of these chemicals on human health, if one considers likely exposure pathways and concentrations, have largely been subject to speculation in the absence of empirical data, raising concerns with the public and hindering project acceptance. The 2012 WaterReuse Research Foundation research project provides quantitative human health risk assessment results for a small group of selected pharmaceuticals and personal care products in recycled water for a representative set of nonpotable use cases. The tools developed use language that the general public can more easily comprehend, enabling water reuse agencies to better address public opposition to recycled water projects arising from perceived health risks.