RIVER REFUGIUM PROJECT

Watershed-Scale Nutrient Recovery Infrastructure

APPENDIX D

Master Glossary

Plain-language definitions for every term used in the series

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ABSTRACT

This glossary defines the terms, processes, and concepts used throughout the River Refugium Project documentation. It is written to be understood by a reader with a high school education and no background in water treatment, chemistry, agriculture, or finance.

The whitepaper itself is written at a college reading level. That is a deliberate choice — it has to survive review by engineers, regulators, and lenders. This glossary exists so that the reading level of the whitepaper is not a barrier to understanding what the project actually does. Nothing here is simplified to the point of being wrong. Where a term has a precise technical meaning, that meaning is given, and then explained again in ordinary language.

Version 3.0 expands the glossary substantially. It adds every term introduced by the production configurations in Section 7.4 of the whitepaper, the growing systems in Section 7.3, and the verification and containment vocabulary in Sections 7.5 and 10.

Audience: community members, policymakers, tribal officials, investors, students, farmers, and anyone encountering this framework for the first time.

How to Use This Glossary

Terms are grouped by subject rather than listed alphabetically, because most of them make more sense next to related terms than they do on their own. Sections A through I move roughly in the order water travels through the facility.

Where a definition refers to another defined term, that term appears in the same glossary. Where a definition includes a number, that number is an estimate unless stated otherwise — see Provisional in Section I.

A. The Basics

River Refugium Project (RRP) — The whole framework described in this documentation. It is a design for a type of industrial facility that takes polluted water out of a river, removes the pollution by growing plants in it, converts those plants into fuel and other products, and returns cleaner water to the river. The goal is that the products pay for the operation, so the cleanup does not depend on grants or donations to continue.

Refugium — In biology, a place where a species survives conditions that have become too harsh elsewhere. In this framework, it is a specific piece of equipment: a calm, managed body of water where river water is stabilized and biologically prepared before it goes into production. Its job is not to make water clean. Its job is to make water ready.

Node — One complete RRP facility, typically built on about 100 acres. A node contains everything needed to take in water, treat it, grow crops in it, process the harvest, and return the water.

Grow unit — The building block of a node. One grow unit is thirteen production greenhouses plus one evaporation greenhouse, a water intake, a storage tank, the treatment tanks, the pipe network that routes

water, and a harvest preparation area. It covers roughly seven to eight acres. A 100-acre node holds twelve to fifteen grow units.

Pilot — A single grow unit built first, before any full node. Its purpose is not to make money and not to look impressive. Its purpose is to measure things nobody has measured before, so that the numbers used to plan every later facility come from a real system instead of from published research on other systems.

Model A and Model B — Two versions of a node. A Model A node has its own thermochemical plant on site. A Model B node does not — it uses that space for more growing area and ships its harvest to a nearby Model A. Model B is cheaper to build; Model A can process its own material.

Hub-and-spoke cluster — The standard operating arrangement: one Model A node (the hub) receiving harvested material from five to ten Model B nodes (the spokes). This exists because the thermochemical reactor works best running continuously, and one node's harvest is seasonal while eight nodes' harvests together are steady.

Watershed — All the land that drains into a particular river system. Rain falling anywhere in the Mississippi watershed eventually reaches the Mississippi River, which is why farming practice in Iowa affects the Gulf of Mexico.

Confluence — The point where two rivers join. Confluences carry the combined pollution of both rivers, which makes them efficient places to put a facility.

B. The Problem

Nutrient — In this context, nitrogen and phosphorus — the two main ingredients in fertilizer. They are called nutrients because plants need them to grow. They become pollution when they end up in water instead of in a crop.

Nutrient load — How much nitrogen, phosphorus, and organic material a river is carrying. A high nutrient load is bad for the river and good for this facility, because the pollution is the raw material.

Runoff — Water that flows off the land instead of soaking into it, carrying whatever was on the surface — fertilizer, manure, soil, chemicals — into ditches, streams, and eventually rivers.

Non-point source pollution — Pollution that does not come out of a single identifiable pipe. Fertilizer washing off a hundred thousand separate farm fields is non-point source. It is much harder to regulate than a factory discharge, because there is no one place to point at.

Algal bloom — A population explosion of algae in water, caused by too much nitrogen and phosphorus. The algae grow fast, die, and decompose. The decomposition consumes oxygen.

Hypoxia and the dead zone — Hypoxia means not enough oxygen in the water for animals to breathe. The Gulf of Mexico dead zone is a hypoxic area that forms every summer where the Mississippi empties, caused by decomposing algal blooms. Fish leave if they can. Anything that cannot leave dies. It has repeatedly reached the size of a small state.

Acid mine drainage — Water that has flowed through old mine workings and picked up acid and dissolved metals — iron, manganese, aluminum, sometimes rare earth elements. It is the defining water problem across much of Appalachia and the interior coal basins.

Micropollutant — A contaminant present in very small amounts that still causes harm — pharmaceutical residue, hormones, pesticide breakdown products. Standard municipal water treatment was not designed to remove these and mostly does not.

PFAS — A family of manufactured chemicals used in nonstick coatings, firefighting foam, and stain resistance. They are called forever chemicals because the carbon-fluorine bond holding them together is extremely difficult to break, so they persist in water and in bodies for a very long time.

C. Water and Flow

Forebay — The first pool water enters at the facility. It slows the water down so heavy sediment settles out, screens out debris and fish, and evens out changes in river level.

Cistern — A large holding tank, in this design holding about three times what the facility processes in a day. It smooths out the difference between what the river is doing and what the plant needs, and it is the main place where water chemistry is measured before treatment begins.

Suspended solids (TSS) — Particles floating in water — soil, silt, bits of organic matter. Measured as total suspended solids. In this facility they are captured and used rather than disposed of.

Hydraulic residence time (HRT) — How long, on average, water stays in a given stage. Longer residence time generally means more complete treatment, and also means a bigger tank.

Prepared water — This framework's term for what comes out of the biological treatment stage. It is not clean water. It is water whose chemistry has been balanced, whose biology has been stabilized, and which has been measured — so that the crops downstream receive a known input rather than whatever the river sent that day.

Discharge — Water returned to the river after treatment. Roughly fifty-five percent of what the facility takes in is discharged; the rest is either inside the crops or evaporated.

D. Biology and Treatment

Biofiltration — Using living bacteria to clean water. The bacteria are not added as a chemical; they colonize surfaces in the treatment tanks and do the work as part of living there.

The nitrogen cycle — The natural sequence by which nitrogen changes chemical form. In this facility it matters in three steps: ammonia becomes nitrite, nitrite becomes nitrate, and nitrate can either feed a plant or be converted to harmless nitrogen gas that returns to the air.

Nitrification — The first two steps above — ammonia to nitrite to nitrate — performed by bacteria that need oxygen. This happens in the four aerated tanks.

Denitrification — Converting nitrate into nitrogen gas, performed by different bacteria that work only where oxygen is scarce. This happens in the two low-oxygen tanks and is how nitrogen leaves the system entirely rather than moving somewhere else.

Aerobic and anaerobic — Aerobic means with oxygen. Anaerobic means without. Different bacteria need different conditions, which is why the treatment train has separate tanks rather than one big one.

Dissolved oxygen (DO) — How much oxygen is available in the water for organisms to use. It is one of the most important measurements in the facility and one of the easiest to get wrong, because the sensors foul.

Redox — Short for reduction-oxidation. A measure of whether conditions in a body of water favor adding oxygen to substances or taking it away. Different chemical reactions need different redox conditions, which is why some treatment designs establish a sequence of zones rather than one uniform condition.

Biological oxygen demand (BOD) — How much oxygen would be consumed by bacteria breaking down the organic material in a water sample. High BOD means a lot of decomposable material, which means the water will go low on oxygen on its own.

Polishing — A final cleaning stage after the main treatment, catching whatever the earlier stages missed. In this facility the polishing beds are also where the final water quality measurement is taken.

E. Plants and Growing Systems

Biomass — Any organic material grown in the facility — algae, floating plants, grasses, fiber crops, willow rods. It is the physical form the captured pollution takes once it has been pulled out of the water.

Duckweed — A very small floating plant, common on ponds. It absorbs nitrogen and phosphorus rapidly and can double its weight in two to four days in warm conditions. It is roughly ninety-two to ninety-five percent water when harvested.

Azolla — A small floating fern with similar properties to duckweed, notable for also fixing nitrogen from the air and for absorbing dissolved metals.

Algae — Simple aquatic organisms ranging from single cells to visible mats. High-lipid algae — varieties that store a lot of oil — are the preferred feedstock for making biocrude.

Vetiver — A deep-rooted grass used worldwide for erosion control and for pulling contaminants out of soil and water.

Hyperaccumulator — A plant that concentrates a substance in its tissue far above the level present in its surroundings. Duckweed and algae are hyperaccumulators of metals, which is exactly why they are useful for cleanup and exactly why their harvest cannot automatically be used as food or feed.

Phytoremediation — Using plants to clean contaminated soil or water. The plants take the contaminant into themselves; the cleanup is only complete when the plants are harvested and dealt with.

Coppice — An ancient way of growing wood. Certain trees — willow especially — regrow from the stump when cut, so a single planting produces poles and rods on a repeating cycle for decades without replanting.

Bast fiber — Fiber that comes from the inner bark or stem of a plant rather than from a seed pod. Hemp, flax, jute, and nettle are bast fiber crops. Cotton is not — cotton is a seed fiber.

Retting — The process of soaking plant stems so that bacteria break down the material binding the fibers together, allowing the fibers to be separated. Water retting produces the best fiber and was largely abandoned because the leftover water is heavily polluting. That leftover water is the exact type of input this facility is built to process.

Deep water culture and raceway — Growing methods where plants float on or in moving water with no soil. Simple, cheap, and suited to fast aquatic species.

Compost pot culture — This framework's method of growing plants in containers of living compost set into the water flow, rather than bare-rooted in inert material. The compost creates a small pocket of slightly

acidic, fungally active conditions right at the roots, which keeps iron and trace minerals available to that plant regardless of what the surrounding water chemistry is doing.

Mycorrhizal fungi — Fungi that live in partnership with plant roots. They extend far beyond the root itself, gather minerals the root cannot reach, and trade them to the plant for sugars. They are a major reason a plant grown in living compost outperforms one grown in sterile material.

Chelation — Chemically wrapping a mineral — usually iron — so that it stays dissolved and available to a plant instead of locking into a form the plant cannot absorb. It can be bought as a product. Fungi and compost do it for free.

River rock channel — A growing bed filled with rounded, water-worn stone. The rounded shape leaves large connected gaps that carry water and air and resist packing down. The gaps are simultaneously the water path, the air supply, and an enormous surface for beneficial bacteria.

Fixed datum — A constant water level held in a channel. Each plant container is then set at its own height above that level, so plants that want wet roots sit low and plants that want dry crowns sit high — letting different species share one channel without any of them being in the wrong conditions.

Behavioral containment — Stopping roots from spreading by giving them a material they do not want to enter, rather than by building a barrier. Roots avoid coarse rock because it offers no moisture, no organic matter, and no fungal partners. A barrier can crack; a material roots decline to enter cannot.

F. The Production Complex

Configuration — What a production greenhouse is set up to produce. A greenhouse is just a building with a water loop and climate control; the configuration is the combination of species, water grade, growing system, and harvest rules that makes it a feed house or a fiber house. Configurations can be changed without rebuilding anything.

Segmentation — Keeping each production greenhouse separate — its own water, its own species, its own harvest — rather than running everything together in one mixed system.

Polyculture — Growing many species together in one system, each occupying a different niche. It is generally the most efficient and most resilient way to build a small biological system. This framework keeps polyculture at the level of the whole facility while separating individual production cells, for reasons explained in Section 7.1 of the whitepaper.

Routing grid — The computer-controlled network of pipes and valves that sends different water chemistries to the greenhouses best able to use them. It is what makes segmentation practical, because it means the facility can run several different water conditions at the same time.

Source water tier — A grade assigned to where the water came from, not to any individual harvest. A cleaner source is a higher tier and may produce feed; a degraded source is a lower tier and may not, regardless of what a single test result says on a given day. This exists because contamination is intermittent and one clean sample proves very little.

Nitrate accumulation — Grass grown on water very high in nitrate stores that nitrate in its leaves. Cattle and other ruminants convert stored nitrate into nitrite, and nitrite interferes with the blood's ability to carry oxygen. Poisoning can be rapid and fatal, and the crop looks perfectly healthy. This is why feed production is placed late in the treatment sequence.

Sequestration — Capturing something and holding it in a controlled form. In this framework it refers to the configuration that captures metals and micropollutants from badly degraded water.

Biosorption — Contaminants sticking to the surface of biological material rather than being absorbed into living tissue. Beds of such material can be used as a filter and later stripped and reused.

Methylmercury — A form of mercury created by certain bacteria under low-oxygen, sulfate-reducing conditions. It is far more dangerous than the mercury it forms from because it builds up in the food chain. This is why any treatment design using sulfate-reducing conditions is ruled out entirely where mercury is present.

Kesterson — A reservoir in California where agricultural drainage water was collected in ponds during the 1980s. Selenium concentrated in the pond ecosystem and caused severe deformities and deaths in waterfowl. It is the reference case for why a facility that concentrates contaminants must physically exclude wildlife, not merely prevent the water from escaping.

Containment doctrine — The set of rules in this framework governing what may not leave the site: no water path to any natural water body, no organism stocked without confirmed legal status, no release of biomass when a system shuts down, and physical exclusion of wildlife from cells concentrating contaminants.

Clean-in / clean-out (CICO) — A standard industrial practice of taking one production unit fully offline, emptying and cleaning it, and returning it to service, while the rest of the facility keeps running.

G. Concentration and Conversion

Evaporation greenhouse — A greenhouse used to concentrate the nutrient stream rather than to grow anything. Water sits in shallow beds, sunlight evaporates part of it, and what remains is denser and richer. It produces no crop at all.

Reverse osmosis (RO) — The standard industrial method of separating dissolved substances from water by forcing the water through a membrane under high pressure. The evaporation greenhouse achieves a similar separation using sunlight instead of a pump and a membrane, at much lower purity and much lower cost.

Condensation netting — Fine mesh that catches water vapor from the air and channels it down into a trough. The same technology is used to harvest drinking water from fog in dry regions. Here it recovers the water that evaporates inside the evaporation greenhouse.

Thermochemical conversion — Using heat and pressure to break organic material down into simpler chemical products. It is not burning, because there is no oxygen involved.

Hydrothermal — Meaning with hot water. Hydrothermal processes work on wet material and use the water itself as part of the reaction, which is why the harvest does not have to be dried first. Drying wet plants uses more energy than the plants contain, and that fact ended two decades of algae fuel ventures.

Supercritical water — Water held above about 705°F and 218 atmospheres of pressure, where it stops behaving as either a liquid or a gas. It dissolves oils, rejects salts, and attacks chemical bonds it would never touch under normal conditions.

HTC — hydrothermal carbonization — The lower-temperature setting, roughly 350 to 480°F for a few hours. Material does not liquefy; it condenses into a carbon-rich solid. It is the coal-forming process run in an afternoon instead of over geological time.

HTL — hydrothermal liquefaction — The higher-temperature setting, roughly 570 to 700°F for minutes. Material liquefies into an oil. Used for soft, wet, oily material such as algae and duckweed.

Hydrochar — The solid carbon product of HTC. Used as a growing medium, a filter material, and a habitat for beneficial microbes, and salable as a carbon product.

Biocrude — The oil product of HTL. Chemically similar enough to petroleum that refineries can process it alongside crude oil, though it needs treatment first to remove nitrogen and oxygen.

Hydrotreating — A refinery process that removes nitrogen, oxygen, and sulfur from an oil so it can be made into diesel or jet fuel. It is not something a farm can do; it happens at a refinery.

Aqueous phase — The water layer left after thermochemical processing. It carries dissolved acids, sugars, ammonia, and potassium. It is usually treated as waste and is, in this framework, treated as a product stream.

Lignin — The stiff material that makes wood woody. It resists liquefaction and converts well to char, which is why woody material goes to HTC and soft material goes to HTL.

Struvite — A mineral containing phosphorus that can be recovered from waste streams and used directly as fertilizer. It is one of the routes by which phosphorus caught in this facility gets sold rather than buried.

Thermal loop — Reusing waste heat from the reactors to warm the greenhouses and preheat incoming material, so the facility buys little or no outside heating energy.

H. Measurement, Control, and Verification

SCADA — Supervisory Control and Data Acquisition. The computer system that watches every pump, valve, sensor, and reactor in the facility and records what they are doing.

PLC — Programmable Logic Controller. An industrial computer that runs a specific automated process and its safety rules. SCADA watches; PLCs act.

Boundary-first testing — Measuring water quality at the points where water enters and leaves a stage, before measuring anything inside it. The difference between the two is the stage's actual performance, and it is a more trustworthy number than any internal reading.

A/B testing — Changing one thing in one production cell while leaving an identical cell unchanged, then comparing. It is the only reliable way to know whether a change caused an improvement, and it is impossible in a system where everything shares one water.

Duplicate measurement — Every measured value in the facility exists twice — once as an automatic sensor reading and once as a manual reading taken independently by a person. A single instrument reporting a value is treated as unverified.

Sensor drift and fouling — Instruments left in nutrient-rich water accumulate growth on their sensing surfaces and gradually report wrong values. Nothing about this failure looks like a failure: the display is steady, the control system responds correctly, and the reading is simply false.

Retained disagreement — The rule that when the automatic and manual readings differ, both values stay in the record, the disagreement is timestamped, and any resolution is added as a new entry rather than replacing either original. Correcting the disputed value would return the facility to a single unverified source of truth.

Performance receipt — The documented difference between water quality entering and leaving the final polishing stage. It is the evidence behind every nutrient reduction claim the facility makes.

Open data — The commitment to publish operating data rather than only summary results, including data that is unflattering. The purpose is to let people qualified to find errors find them.

I. Money and Policy

Infrastructure — A capital asset with a long design life, a stated capacity, a maintenance schedule, and a revenue basis — a water plant, a rail line, a port. The central argument of this framework is that nutrient recovery belongs in this category and has been funded as something else.

Capital expenditure (CapEx) — The one-time cost of building something. Operating expenditure, or OpEx, is what it costs to run it afterward.

EBITDA — Earnings Before Interest, Taxes, Depreciation, and Amortization. A measure of whether an operation makes money from its actual operations, before accounting for how it was financed.

Payback period — How long it takes for an investment to return what was put in.

Nutrient credits — A payment made for removing a measured quantity of nitrogen or phosphorus from a watershed. Markets for these exist in some regions and are thin or absent in most of the deployment geography, which is one of the framework's identified risks.

Carbon credits — A payment for keeping carbon out of the atmosphere. This facility can generate them because hydrochar is a stable solid form of carbon that does not readily decompose.

Revenue class — A grouping of products the facility sells. Version 3.0 uses eight classes rather than a fixed list of products, because which products a given node makes depends on which configurations its water permits.

Diversification — Earning from many sources so that no single price collapse takes down the operation. It is a design requirement here rather than a preference, because a single-product facility on a bad market year stops running and a stopped facility stops cleaning water.

Clean Water Act — The primary federal law governing discharges into United States waters. Any facility that takes water, changes it, and returns it operates under this law.

Tribal sovereignty — The legal authority of tribal nations to govern their own territory, including permitting and water rights. In this framework it is treated as a jurisdictional fact that changes how and with whom a project is developed, not as an optional consultation step.

Provisional (⚑) — Any number in this documentation marked with this symbol is an estimate taken from published research on similar systems, not a measurement from an RRP facility. No RRP facility has operated yet. Every such figure is expected to change once the pilot produces real values, and the financial model is built to update when they do.

Terms Retained From Earlier Versions

The following terms appeared in Version 2.0 documentation and are recorded here for readers working from earlier documents. They are no longer used in Version 3.0.

Retired Term	Status in Version 3.0
Pathway	Replaced by Configuration. The production pathways described in the Version 2.0 appendices are configurations of the greenhouse complex, not separate subsystems.
Eight-layer revenue stack	Replaced by revenue classes indexed to configuration. The fixed count did not survive the addition of new configurations.
IP licensing revenue	Withdrawn. Contradicted the project's open-access commitment.
Modular slot framework	Retained in the financial model only. It is a modeling structure, not a physical description, and no longer appears in the technical documents.
Floating treatment platform	Superseded. Version 1.0 described refugia as floating or anchored platforms in open water. The current design uses fixed land-based channels and greenhouses.

Notes

Citations follow Chicago Notes-Bibliography style. Internal Cernunnos Foundation and Bright Meadow Group documents are cited by title and year. Figures marked ⚑ are provisional academic proxies pending replacement by measured pilot values.

1. *Bright Meadow Group, "RRP0003 — Consolidated Technical Whitepaper," Version 3.0. CF/BMG, August 2026. Primary source for all definitions.*

2. *Bright Meadow Group, "Master Glossary for Policymakers and Non-Engineers." RRP Document Series, Version 1.0, 2025.*

3. *Standard Methods for the Examination of Water and Wastewater (APHA/AWWA/WEF). Source for analytical parameter definitions in Section H.*

4. *Ohlendorf, H.M. et al., Kesterson Reservoir selenium literature. Source for the Kesterson entry in Section F.*

5. *Kadlec, R.H. and Wallace, S.D., Treatment Wetlands, 2nd ed. CRC Press, 2009. Source for treatment terminology in Section D.*