WERC 2025 Final Technical Report

Team Name: *Renewable Energy Solution for Water & Environmental Restoration*

Institution: New Mexico State University

Team Members:

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I. Executive Summary

Wildfires dramatically degrade soil and water systems, often requiring decades for natural recovery. Our system accelerates the recovery process to 3–5 years using a wind-powered filtration system built from natural materials and monitored in real time via low-cost electronics. The project emphasizes sustainable materials, off-grid operation, and affordability for use in vulnerable communities.

II. Problem Definition

Wildfires introduce ash, debris, herbicides, and heavy metals into water and soil systems. Traditional remediation is costly, slow, and requires electricity. Our task was to engineer a low-cost, off-grid system to filter runoff and accelerate soil regeneration while monitoring the effectiveness of the process.

III. Engineering Requirements & Metrics

Requirement	Metric/Goal
Filtration Efficiency	≥ 90% solids removal
Energy Source	Wind-only power (no solar/battery in prototype)
Flow Rate	≥ 3.0 L/min (20L in ~6.5 min)
Soil Hydration	>15% moisture gain post-filtration
Component Lifespan	≥ 3 years minimum (pump, wind, sensors)
Budget Constraint	≤ $2,000 for prototype
Safety	Fully insulated, grounded, and water-shielded
Replicability	Manual tools and locally available materials

IV. System Overview

A. Water Filtration System

Filtration occurs in a column using gravity-fed water, driven by a wind-powered pump through layers of:

- Gravel and sand – sediment removal
- Lava rock – mineral filtration
- Coconut activated charcoal – chemical adsorption
- Cotton – fine particle capture

B. Wind-Powered Delivery

A vertical-axis wind turbine (~2.3 m tall) powers a Seaflo 42 Series diaphragm pump, which pushes 20L of water in ~6.5 minutes through the filter and soil box.

C. Monitoring System

Sensors connected to an ESP8266 microcontroller track:

- Soil moisture and temperature
- pH and conductivity (Separated testing module)
- Data logged daily and correlated with filter performance.

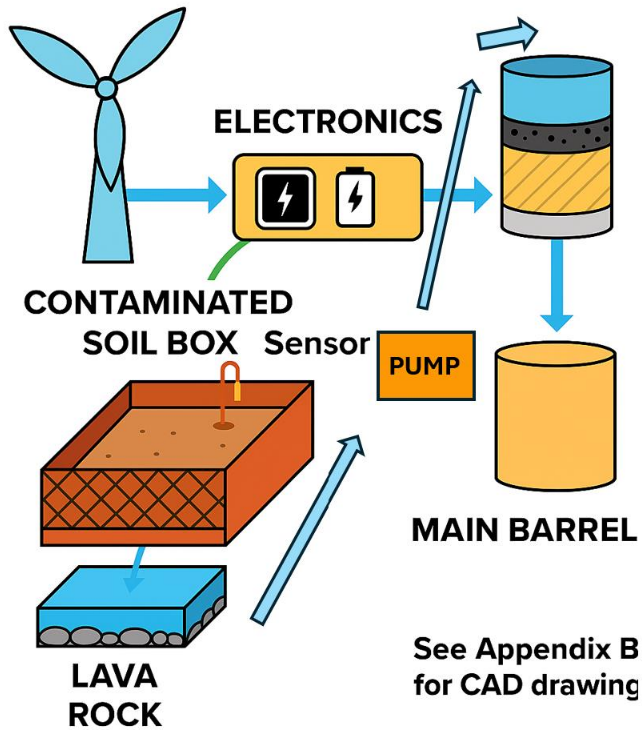


Figure 1
Flow diagram showing the complete system architecture from wind turbine to water collection, filtration, and sensor data collection. See Appendix B for CAD and additional visuals.

V. Testing Protocol

Simulated wildfire contamination was created using:

- Ash-charred soil
- Glyphosate herbicide
- Nitrogen fertilizer
- Garden lime (pH control)

Procedure:

- Each day: Add 20L of water → record flow time and volume
- Measure water quality pre- and post-filter
- Track soil moisture and pH daily using sensors
- Visual clarity and physical signs observed

VI. Results

Metric	Before	After	Observation
Flow Rate	–	3.06 L/min	Met target flow rate
Turbidity	75.1 NTU	8.27 NTU	~89% solids removal
Conductivity	1403 µS	889 µS	Lower ionic presence
Soil Moisture	Dry	+15–20%	Moisture retention improved
Lead Presence	Detected (Day 1)	Lower (Day 3)	Initial leach from charcoal reduced

VII. Financial Assessment

Source	Cost (USD)
Amazon & Lowe's Orders	$1,468.99
In-Store Receipts	$325.86
Total Project Cost	**$1,794.85**

B. Scalability Estimate

- Estimated cost per deployable unit: $4,500–$6,000
- Designed to cover ~1-acre post-fire zone
- Scalable through bulk purchase, grant support, and simplified framing

C. Lifespan of Major Components

Component	Estimated Lifespan
Wind Turbine	8–10 years
Pump	5 years
Sensors (ESP8266)	3–5 years
Filtration Media	Replace each season
Soil Box Frame	5 years (treated)

VIII. Stakeholder Relevance

Stakeholder Group	Relevance
WERC Judges	Innovation, real-world application, data-driven
NGOs	Scalable for disaster relief, low-tech repairable
Government Agencies	Integrates with post-fire recovery programs
Tribal/Rural Communities	Affordable, self-reliant recovery tool

IX. Future Recommendations

- Replace coconut charcoal with pre-treated carbon to avoid early leach
- Expand data logging and remote access capabilities
- Explore battery integration with charge controller for hybrid use
- Extend soil trials to 4–8 weeks for long-term data

X. Conclusion

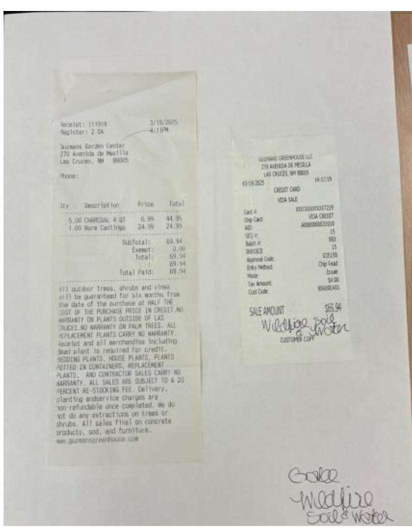
This project provides a low-cost, sustainable solution for soil and water restoration in wildfire-affected areas. By using wind energy and natural filtration media, we offer a system that is affordable, effective, and replicable in regions most at risk. With continued testing and scaling, this design could become part of national post-fire recovery efforts.

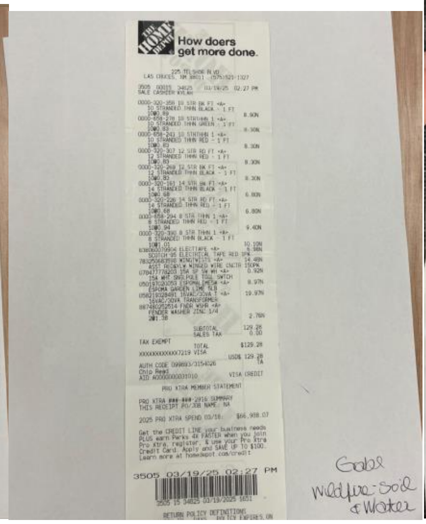
Appendix A – Financials

Item	Qty	Price (USD)	Total (USD)
Mini Wind Turbine (50W)	1	$269.99	$269.99
Charge Controller for Mini Turbines	1	$19.99	$19.99
12V 20Ah Lithium LiFePO4 Battery	1	$169.99	$169.99
Fuse Block (12V)	1	$17.59	$17.59
Voltage Regulator (12V to 5V)	1	$14.99	$14.99
Seaflo 42 Series Diaphragm Pump	1	$64.99	$64.99
Water Tanks (10 liters each)	2	$27.99	$55.98
Coconut Shell Granular Activated Carbon	1	$30.00	$30.00
Capacitive Soil Moisture Sensors	2	$8.68	$17.36
Arduino Nano	2	$15.00	$30.00
ESP8266 Wi-Fi Module	1	$8.00	$8.00
Sper Scientific Turbidity Meter	1	$369.00	$369.00
Apera Instruments AI316 pH Tester	1	$168.75	$168.75
Water Testing Kit	1	$32.99	$32.99
Heavy Metal Testing Strips	1	$15.99	$15.99
Coliform Bacteria Test Kit	2	$22.69	$45.38
50-Gallon ECO Rain Barrel	1	$79.00	$79.00
		TOTAL	$1,409.99

Vendor	Item(s)	Total (USD)

Walmart	Cotton Balls (x2)	$5.96
Ace Hardware	Killer Weed Remuda GT (Herbicide)	$29.99
Home Depot	Tab Tape, Electrical Tape, Wire, Washers, etc.	$233.39
Guzman's Garden	Charcoal (5 units), Worm Castings	$69.94
Lowes	Tubing, tape, screen, hose clamps	$224.20
Harbor Freight	Mixing drill	$64.99
O'Reilly Auto	Connector	$15.99
	TOTAL	$644.46






How doers get more done.

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LAS CRUCES, NM 88011 (575)521-1327

3505 00015 38115 03/21/25 12:37 PM
SALE CASHIER DESTINY

761542204126 2X4-12 GDF <A>
2X4-12FT PREMIUM FIR
2@8.12 16.24N
769887148242 2X4-96 KD-HT <A>
2X4-96" PREMIUM WHITEWOOD KD-HT STUD
2@3.75 7.50N
032076912550 CLIP MASONAR <A> 3.98N
1/2" WHITE PLSTC MSNRY STAPLES 25PK
0000-166-103 3/4 RTD SHTG <A> 40.00N
23/32 4X8 RTD PLYWOOD

SUBTOTAL 67.72
SALES TAX 0.00
TAX EXEMPT
TOTAL $67.72
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TA
AUTH CODE 010785/1154179
Chip Read
AID A0000000031010 VISA CREDIT

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Invoice	2801-291047
Sale Type	CHG. CARD SALE
Date	03/21/2025 1:14 PM
Ship Via	
PO Number	

Bill To

NEW MEXICO STATE UNIV
340 S ESPINA
XX Return Mail 01/28/2013
LAS CRUCES, NM 88001
(575) 527-7588

Counter #	Customer Account	Ordered By	Special Instructions
678393	386073		

Qty	Line	Item Number	Description	Warr	Unit	Tax	List	Net	Extended
1	CTI	81442	CONNECTOR	LT	EA	N	27.18	15.99	15.99

1 Item

Select Super Start Batteries come with Roadside Assistance. Ask for details

Sub-Total	15.99
Sales Tax	0.00
Total	**15.99**
VISA #7219	15.99

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SALE CASHIER JONATHAN

010306011068 PROMIXER <A> 17.37N
QEP XL SPIRAL PRO MIXING PADDLE 30"
048834000063 RED LAVA 5CU <A> 6.57N
VIGORO RED LAVA ROCK .5CU FT
048834000261 PEA PEBBLES <A> 5.47N
VIGORO PEA PEBBLES .5CU FT

SUBTOTAL 29.41
SALES TAX 0.00
TAX EXEMPT
TOTAL $29.41
XXXXXXXXXXXX7219 VISA
USD$ 29.41
AUTH CODE 040894/8154400 TA
Chip Read
AID A0000000031010 VISA CREDIT

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RETURN POLICY DEFINITIONS

	POLICY ID	DAYS	POLICY EXPIRES ON
A	1	90	06/22/2025

HARBOR FREIGHT

LAS CRUCES NM #00236
150 W. Picacho Avenue
Las Cruces, NM 88005
Telephone: (575) 541-0676

SALE

Customer Name: nmsu central purchasing
Customer Number: 888002295755

65179 1/2IN LOW SPEED VSR DRILL $64.99E
Item Tax Exempt No. 197810

Subtotal $64.99
DEFAULT TAX RULE 0.000% $0.00
Total $64.99

Visa $64.99

SALE

***********7219 VISA
Entry Method: Chip Read Contact
Appr Code: 047912
Payment Type: CREDIT
Cardholder: GARCIA/GABE V
Application Pan:************7219
Invoice: 001187839131601
Voice:Issuer
Result:CAPTURED
Ref: 250324121602
Response: Approved
Approved: Online
CID Code:0x80 (ARQC)
VISA CREDIT
SEQUENCE: 00000046
AID: A0000000031010
TVR: 8000008000
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8F1FFF3593449620
: 06011203A08000
ARC: 00

Customer Copy

Please Retain for records.

Store: 00236 Reg: 01 Tran: 187839
Date: 3/24/2025 1:16:08 PM Assoc: XXXXXX
Ticket: 01187839

Item(s) Sold: 1
Item(s) Returned: 0

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LAS CRUCES NM #00236

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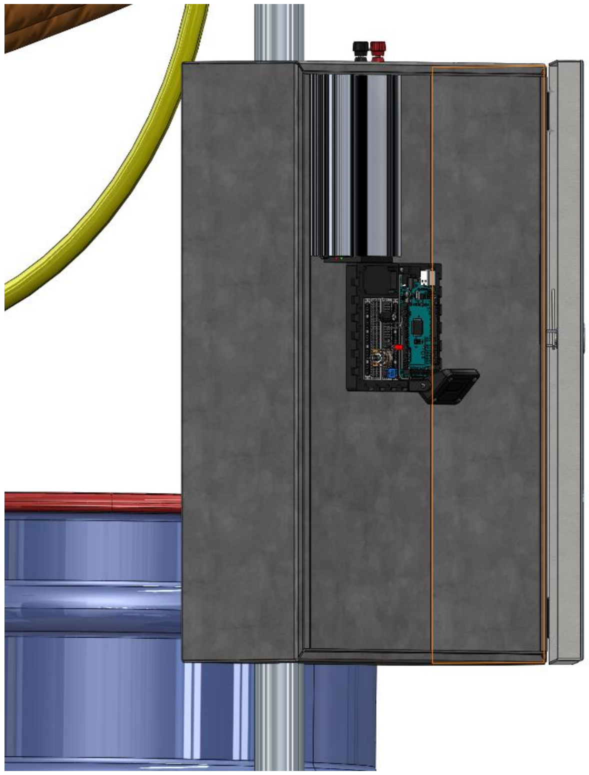
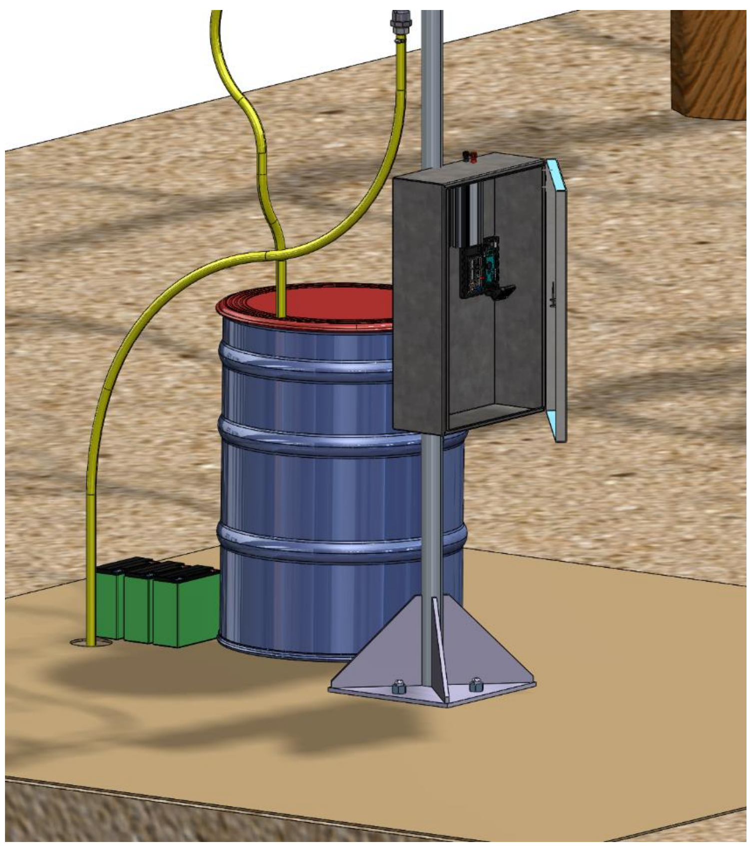
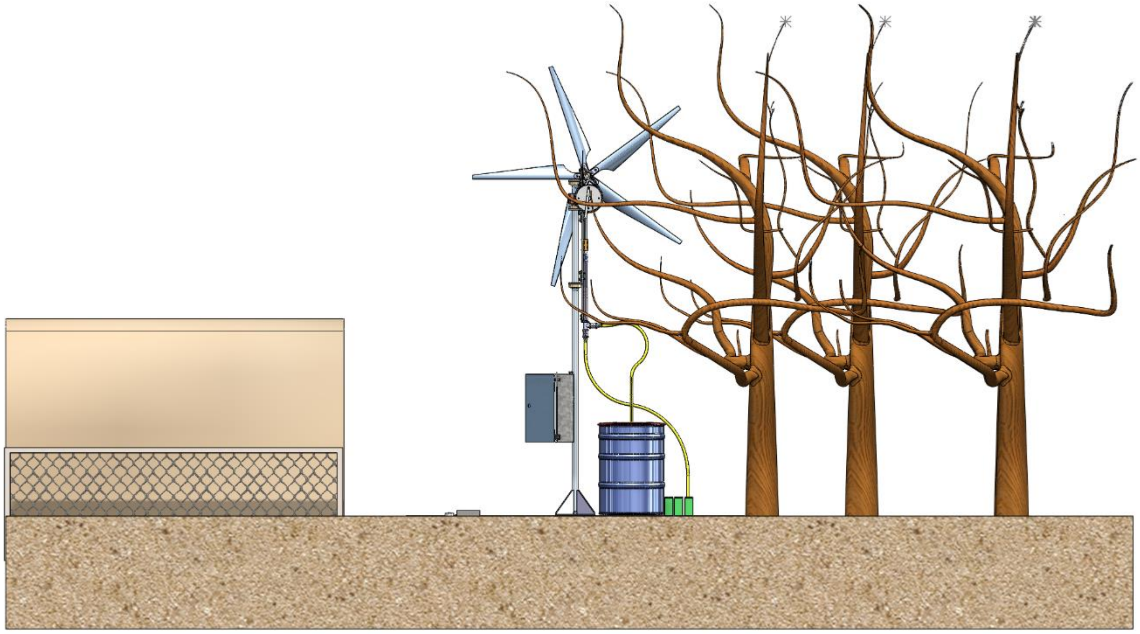
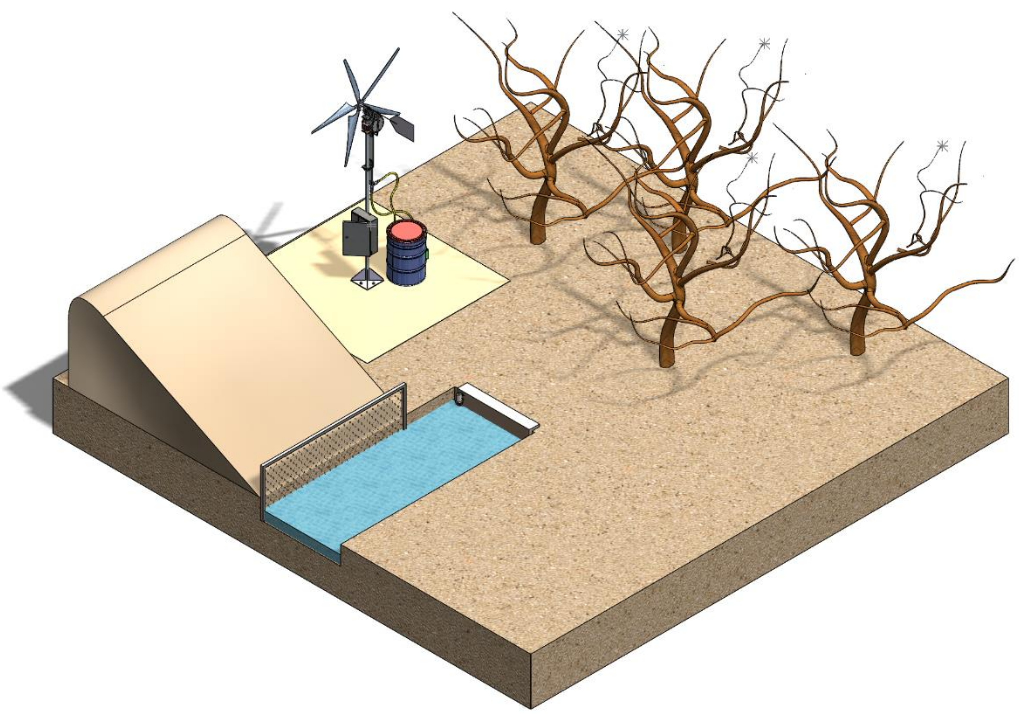
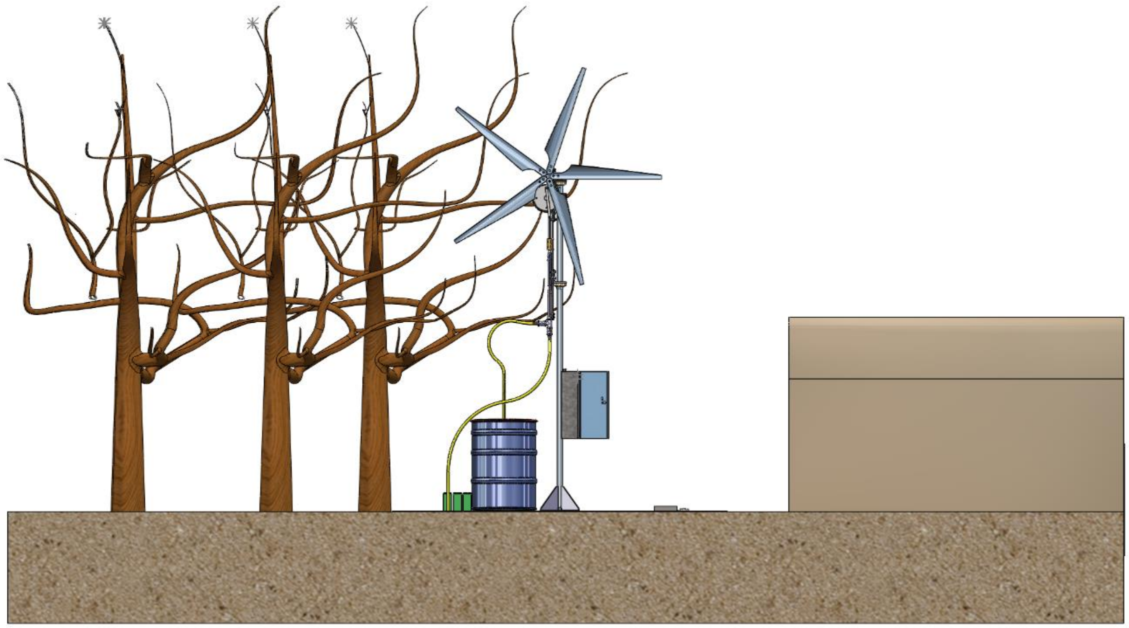
Appendix B – Technical Drawings & CAD Models

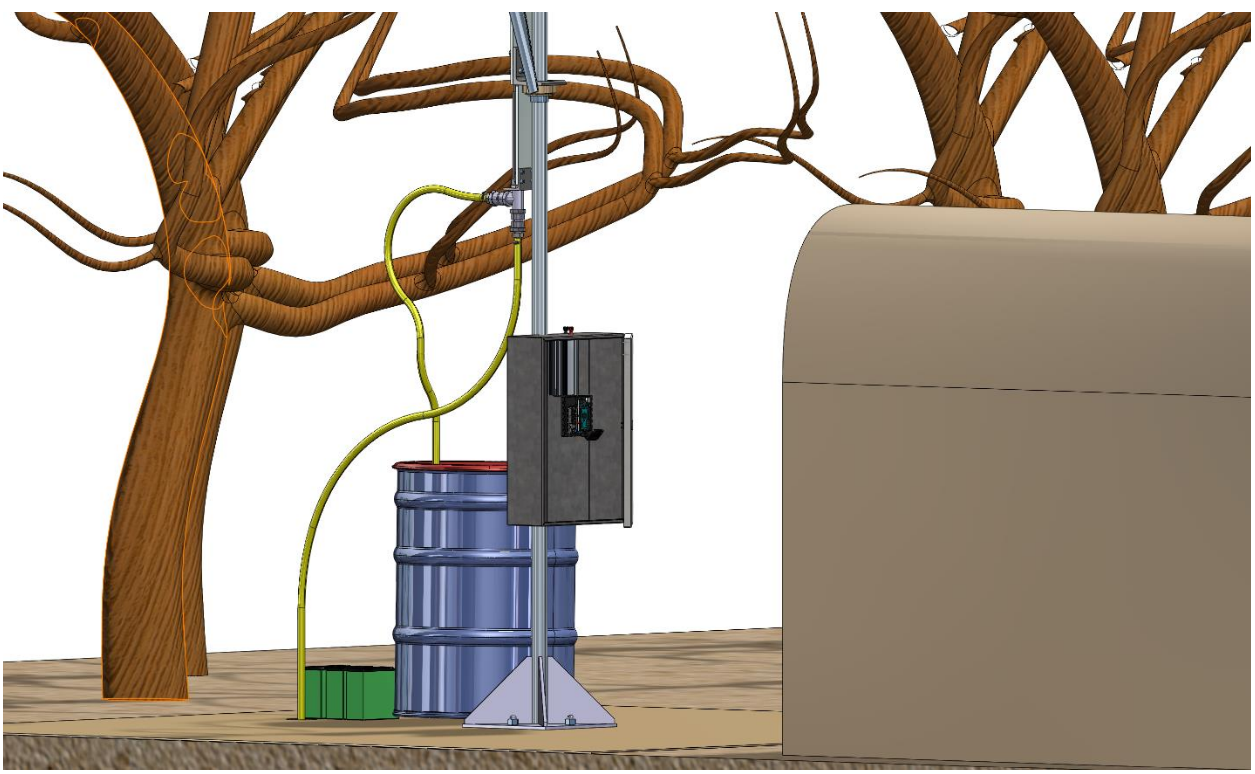












Appendix C – Testing Data & Logs

Sample #	Turbidity (Before)	Turbidity (After)	pH (Before)	pH (After)	Conductivity (Before)	Conductivity (After)	Heavy Metal Strips Photo	Notes
1	731 NTU	27.3 NTU	8.24	9.25	1,084 (µS)	7.15 (mS)		
2	747 NTU	1.37 NTU	8.16	8.89	999 (µS)	1300 (µS)		
3	751 NTU	8.27 NTU	8.24	8.84	1,206 (µS)	1403 (µS)		
4 test 1	712 NTU	4.76 NTU	8.25	8.7	943 (µS)	1053 (µS)	tj	
4 test 2	764 NTU	5.59 NTU	8.28	8.37	946 (µS)	1975 (µS)	tj	
5	623 NTU	5.32 NTU	8.21	8.28	929 (µS)	1633 (µS)	tj	

Table 2 *Water quality results across six sample tests before and after filtration through the renewable remediation system. Parameters measured include turbidity (NTU), pH, and electrical conductivity (µS or mS), as well as qualitative observations using heavy metal test strips. Samples 4 and 5 include a second filtration cycle for comparative analysis.*

Trial #	Volume Collected (L)	Time (min)	Flow Rate (L/min)	Notes
1	20	6.54	3.06	
2	20	6.54	3.06	
3	20	6.54	3.06	
4	20	6.54	3.06	
5	20	6.54	3.06	
Average	20	6.54	3.06	

Table 3 Flow Rate Calculation Summary for Five Trials
Each trial involved collecting 20 liters of water over 6.54 minutes. The average flow rate was consistently measured at 3.06 L/min across all trials. These values indicate the system's reliability and steady performance during multiple filtration cycles.

Figure 2. *Heavy metal test strip results before and after filtration on Day 1 and Day 2. The strips indicate visual changes in lead (Pb) and other metal concentrations. A noticeable increase in lead presence was observed on Day 1 after filtration, likely due to leaching from the coconut-based activated charcoal. No detectable heavy metals were observed after system stabilization on Day 2.*

Appendix D – Arduino & Python Code

Arduino Code

```
#include <Wire.h>
#include <rgb_lcd.h>

// Initialize Grove RGB LCD
rgb_lcd lcd;

// Moisture sensor settings
const int sensorPin = A0;
const int dryValue = 300;
const int wetValue = 650;
const int thresholdLow = 30;
const int thresholdMed = 60;

void setup() {
  Serial.begin(9600);
  lcd.begin(16, 2); // 16 columns, 2 rows
}

void loop() {
  // Read sensor value
  int sensorValue = analogRead(sensorPin);
  int moisture = map(sensorValue, dryValue, wetValue, 0, 100);
  moisture = constrain(moisture, 0, 100);

  // Print to Serial Monitor
  Serial.print("Soil Moisture: ");
  Serial.print(moisture);
  Serial.println("%");

  // Show percentage and status
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Moisture: ");
  lcd.print(moisture);
  lcd.print("%");

  lcd.setCursor(0, 1);

  if (moisture < thresholdLow) {
    lcd.setRGB(255, 0, 0);  // Red
    lcd.print("💧 WATER NOW!");
  } else if (moisture < thresholdMed) {
    lcd.setRGB(255, 255, 0); // Yellow
    lcd.print("⚠ Soil Dry");
  } else {
    lcd.setRGB(0, 255, 0);  // Green
```

```
    lcd.print("🌱 Soil OK");
  }

  delay(2000);

  // Display progress bar
  int blocks = map(moisture, 0, 100, 0, 16); // Max 16 columns

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Moisture Level:");

  lcd.setCursor(0, 1);
  for (int i = 0; i < 16; i++) {
    if (i < blocks) {
      lcd.print((char)255); // Solid block
    } else {
      lcd.print(" ");
    }
  }

  delay(2000); // Wait before next reading
}
```

PHYTHON CODING FOR TEMPERATURE READINGS AND HUMIDITY SENSOR READING AND AUTOMATED .CVS FILING

import serial import csv import time import requests from datetime import datetime
=== CONFIG ===
arduino_port = 'COM3' # 🛠️ Replace with your actual Arduino port if needed baud_rate = 9600 filename = "moisture_temp_log.csv" API_KEY = '16b2757c444b4da4e8f561afa075f604' CITY = 'Las Cruces,US' temperature_fetch_hours = [8, 14, 20] # Fetch temperature at 8 AM, 2 PM, 8 PM
=== Weather API Function ===
def fetch_temperature(): try: url = f'https://api.openweathermap.org/data/2.5/weather?q={CITY}&appid={API_KEY}&units=metric' response = requests.get(url) if response.status_code == 200: data = response.json() temperature = round(data['main']['temp'], 1) print(f"🌡️ Las Cruces Temp Fetched: {temperature}°C") return temperature else: print(f"🌐 API error: {response.status_code}") return "N/A" except Exception as e: print("🌐 Weather fetch error:", e) return "N/A"
=== Connect to Arduino ===
ser = serial.Serial(arduino_port, baud_rate) time.sleep(2) # Wait for Arduino to reset
=== Initialize temp value ===
current_temperature = fetch_temperature() last_checked_hour = datetime.now().hour
=== Start Logging ===
with open(filename, mode="w", newline="") as file: writer = csv.writer(file) writer.writerow(["Timestamp", "Soil Moisture (%)", "Las Cruces Temp (°C)"]) print("🌱 Logging started... Press Ctrl+C to stop.\n")

```
try:
    while True:
        line = ser.readline().decode("utf-8").strip()
        now = datetime.now()
        current_hour = now.hour

        # Check if it's time to fetch temperature again
        if current_hour in temperature_fetch_hours and current_hour != last_checked_hour:
            current_temperature = fetch_temperature()
            last_checked_hour = current_hour

        if "Moisture" in line:
            try:
                moisture = line.split(":")[1].strip().replace("%", "")
                timestamp = now.strftime("%Y-%m-%d %H:%M:%S")
                writer.writerow([timestamp, moisture, current_temperature])
                print(f"💾 {timestamp} | Moisture: {moisture}% | Temp: {current_temperature}°C")
            except Exception as e:
                print("⚠️ Error saving row:", e)

except KeyboardInterrupt:
    print("\n🛑 Logging stopped.")
    ser.close()
```

Appendix E – Photos

Figure 1(Below): Prototype Assembly in its Entirety

Figure 2 (Above): Filter housing with open top for filter maintenance. The top layer of the filter is visible.

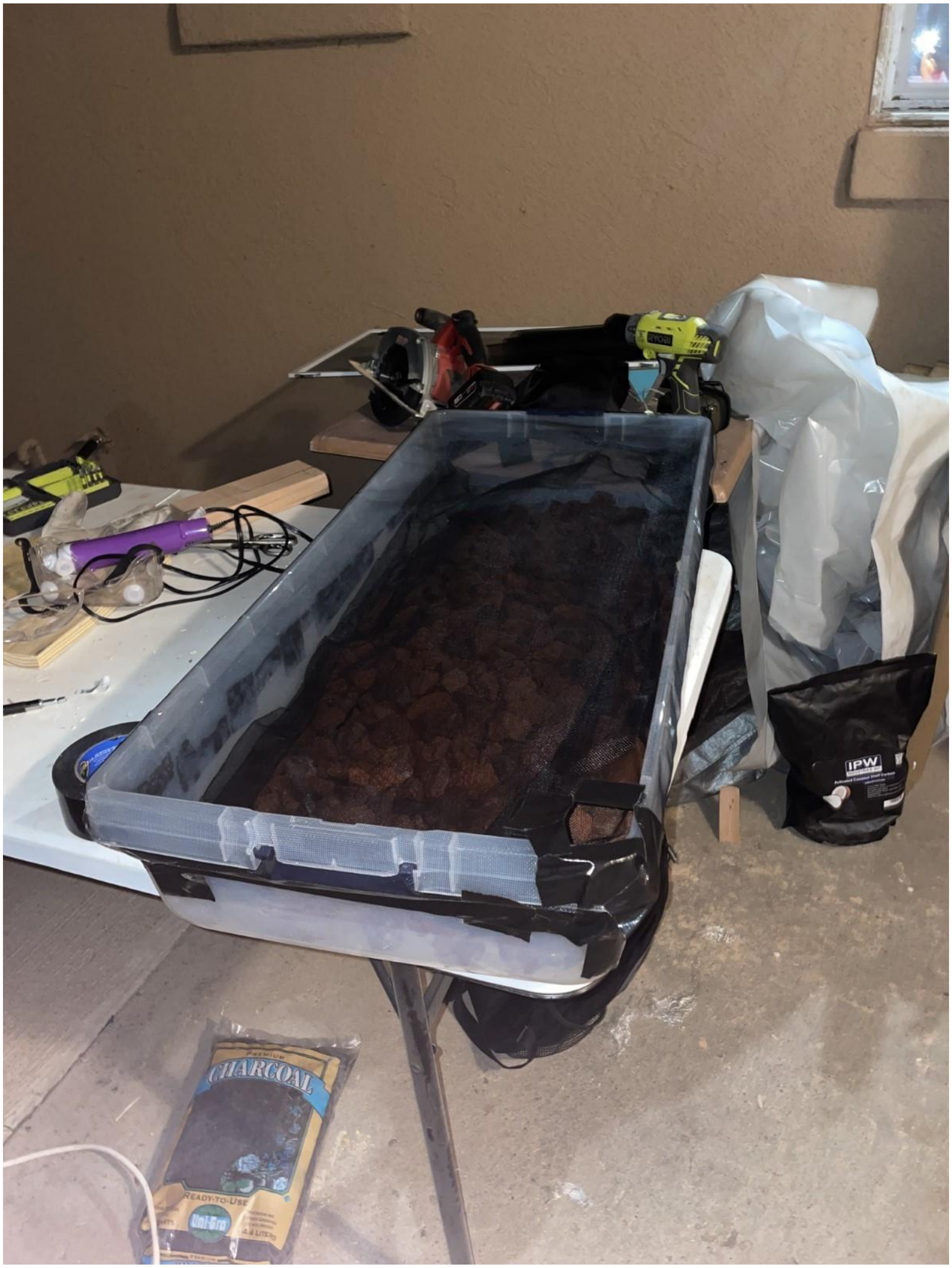


Figure 3 (Above): Close-up of the pre-filter water collection tu

Appendix F – MSDS Sheets

MSDS Reference Table

Material	Description	MSDS Link
Activated Charcoal (Carbon)	Used in water filtration	https://www.parchem.com/siteimages/attachment/activated%20carbon%20msds.pdf
Coconut Activated Carbon	Natural charcoal filtration media	https://sds.aquaphoenixsci.com/SDS/180103_Charcoal%20Activated%20Carbon%20%28S25246%29%20_CanadaSDS_English_2018_8_20.pdf
Sand and Gravel	Filtration and drainage layers	https://www.lgeverist.com/safeDatasheets/Sand%20%26%20Gravel%20SDS.pdf
Lava Rock	Drainage and mechanical filtration	https://www.martinmarietta.com/products/safety-data-sheets
Garden Lime (Calcium Carbonate)	pH stabilizer in soil	https://fscimage.fishersci.com/msds/89308.htm
Clay Soil	Soil simulation layer	https://www.missouribotanicalgarden.org/portals/0/Soil_MSDS_Example.pdf
Organic Compost	Nutrient recovery media	https://www.recology.com/wp-content/uploads/2016/01/Compost-Material-Safety-Data-Sheet.pdf

Nitrogen Fertilizer	Soil nutrient for testing plant growth	https://www.sigmaaldrich.com/US/en/sds/sial/221244
Herbicide (Glyphosate-based)	Simulated contaminant	https://sds.agrian.com/labelcenter/sds_10743_466.pdf
Cotton	Organic filtration layer	Use general caution; no specific SDS required for untreated cotton

All MSDS were retrieved from official manufacturer and chemical safety sources. Materials were selected based on safety, environmental compatibility, and project effectiveness.

Appendix G – Third-Party Audits (To Be Collected)