The Redirt Project: Creating Fabricated Soil from Waste River Silt for Urban Brownfield Regeneration at the ALMONO Site in Hazelwood, Pittsburgh, Pennsylvania

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Abstract

In 2009 the Fabricated Soil Research Team and GTECH Strategies, Inc. agreed to work together on a Green Product Innovation Grant awarded by the Pittsburgh Green Building Alliance to investigate the potential to recycle river silt, a waste product derived in the process of turning river water into drinking water, as an essential component in fabricated soil (fs); an artificial soil made of a mix of low cost, recycled materials. The development of the concept of fs over the last 15 years has been pioneered by members of the Fabricated Soil Research Team at several locations including the Jennings Environmental Education Center, the Robert A. Macoskey Center for Sustainable Systems Education and Research at Slippery Rock University, and the Center for Building Performance and Diagnostics at Carnegie Mellon University. The Fabricated Soil Research Team filled twelve 4'x4'x1'4" test plots (wooden raised beds) with a fabricated soil mix consisting of a proprietary combination of nutrient sources, including Monongahela River Silt, a by-product supplied by the Pennsylvania American Water Company. The beds were unlined, allowing the fabricated soil to sit directly on top of the existing soil. The soil components were tested for nutrients and contaminants. None of the components, including the river silt and the existing site material, were significantly contaminated by any toxic materials.

The beds were sown with annual ryegrass (Lolium multiflorum). The grass germinated within the first week. It was a favorite spot for Canada geese who kept the tender growth trimmed for the first month, adding a nitrogen source to the plots. Other plant material, including culinary, medicinal, ornamental, woody, and ground cover plants, were sown in the midst of the grass. The ryegrass seed and other plants were watered at the time of planting and once a week for the following two weeks. After that, the plots were watered by rainfall alone. There was rain at least once a week, every week but one. Overall, the grass and both woody and perennial plants have thrived in the fabricated soil. The inclusion of the work of the Fabricated Soil Research Team along with GTECH's work at the ALMONO Site, validates these concepts on a continuing scale. For instance, the soil mix derived from the GTECH experiments with the river silt provide for an immediate use of a waste material, an opportunity for the creation of jobs, and a viable business venture. At the same time students and a faculty from Slippery Rock University, as well as a student and alumni from Carnegie Mellon University were involved in carrying out this research.

Providing internship opportunities for sustainable systems graduate students, an independent study opportunity for building performance PhD. Research, and generating research results that can be published, illustrates the academic aspects of this project. The work of the Fabricated Soil Research Team extends these benefits of this project to the creation of bio-regenerative soils that can potentially begin the chain of restoration, linking biological cycles with building and landscape cycles, in such a way that can ultimately restore communities and cities to sustainable levels. The primary narrow focus of this research has clearly demonstrated that the river silt generated by the Pennsylvania American Water Company is a suitable material for creating fabricated soil. The soil mixture that was created is called Almono Fabricated Soil (AFS). The tests conducted by our team and the testing labs, shows clearly that the soil components, individually and as a mixture, all support biological activity, do not contain toxic components above acceptable levels, and support the growth of seeds and transplants of a variety of plants. Mushroom compost that was sampled, as well as the commercial compost used in the mixes at the Almono research site, did not support seed germination and was thought to be toxic for reasons that were not known. The AFS layered soil recipe and the mixes of river silt with various percentages of compost utilized in the GTECH research plots, both proved to be effective mixtures to support plant germination and growth over the research period. This indicates there may be some potential to develop various mixes and recipes of the river silt with other ingredients that can be marketed for various commercial green building and sustainable development projects including green roof, living wall, urban agriculture, vacant lot restoration, brownfield reclamation or mine scarred land regeneration.

Research Plot Details

Twelve (12), four foot wide by four foot deep by one foot four inches tall (4'x4'x1'-4") research plots were constructed, identical to those developed by GTECH Strategies, as a simple basis for research comparison. The attached schematic site plan illustrates this layout, including both sets of 12 research plots, set within a fifty foot by one hundred foot (50'x100') overall research area. This size was chosen because it represents a typical urban or suburban sized residential lot and would put our research within an overall context that would be understandable to the average person. Even though the research occurred at a brownfield site, it has ramifications for the restoration of soils on vacant residential lots within the city of Pittsburgh.

The research plots themselves consisted of the following fabricated soil materials in three inch deep layers.

Typical Profile Layers	Total amount of material for all 12 plots	
3" top soil (4'x4'x.25') = 4 Cu. Ft./27 Cu. Ft.= 0.148148 Cu. Yd. x 12 =	1.77 Cu. Yds.	Round up to 2
3" dark river silt	1.77 Cu. Yds.	Round up to 2
3" mushroom compost	1.77 Cu. Yds	Round up to 2
3" light river silt	1.77 Cu. Yds.	Round up to 2
3" straw bale	1.77 Cu. Yds.	Round up to 2
3" wood chips	1.77 Cu. Yds.	Round up to 2

These layers of fabricated soil materials were layered into the research plots with the topsoil on the top and the wood chips on top of existing soil that was plugged with a lawn aerator or otherwise broken up. Our fabricated soil research team coordinated and installed these research plots and soil layers in conjunction with GTECH and volunteers coordinated by GTECH for this project. Research for this project began with the collection of soil samples from the site including samples of the river silt, wood chip piles, compost pile materials, and the existing subsoil surface, among others. The quality of these samples was examined using a simple four species plant germination test to indicate biological activity. The four species used for this germination test were: Black-seeded Simpson lettuce; White-icicle radish; Red medium clover; annual rye grass. This biological test was completed on the individual soil components and on a sample mixture of our proposed fabricated soil mix. These tests were done in sterile dishes in laboratory conditions. The results are attached in the addendum of this paper.

The examination of these soil recipes was done within the holistic approach of connecting the soil to biological cycles, using plants. As part of this approach the fabricated soil (called Almono Fabricated Soil or AFS) mix were tested at the outset for baseline nutrient, bacterial and fungal levels. The twelve research plots were initially planted with rye grass. Germination and growth was documented periodically for 3-4 weeks.

The rye grass was left in place and inter-planted with other transplants. Poplar and willow trees, both transplants and rooted cuttings, will be planted on 6 plots and medicinal herbs will be planted on the remaining 6 plots. The growth of these plants was documented for the remainder of the growing season. At the first week of December 2009 these plants were harvested, weighed and the biomass per unit area calculated.

This cropping regime demonstrated a variety of uses for the river silt based fabricated soil recipe (AFS) including:

Brownfield Reclamation

Mine Scarred Land Reclamation

Urban Agriculture

Green Roofs and Living Walls

As part of this research, leaves from existing 2-3 year old poplar trees, previously planted by GTECH, were harvested and dried. This biomass was then put into small bundles and buried in the AFS for 2-4 week intervals in late fall, to investigate the ability of microbial activity in the fabricated soil to breakdown carbon polymers in the leaves. This breakdown of carbon polymers is the first step in preparing this biomass as a feedstock to create cellulosic butanol and/or ethanol.

Bio-regenerative Cycle for Sustainability

The other purpose and long term goal of the project was to utilize and find various markets for low-cost, fabricated soil that turns waste into sustainable resources. Those uses may include urban agriculture, green roof and living wall installations, biomass production and various land remediation projects. The goal was to prove the regenerative properties of fabricated soil and demonstrate that it can be produced on a commercial level. The focus was to reconnect biological systems, in terms of the regenerative properties of buildings and landscape, using low cost waste materials, simple low cost technologies, and natural cycles and systems, to reduce negative environmental impacts and carbon footprint.

To more effectively illustrate the link between fabricated soil and green buildings, the use of waste river silt as a component for creating fabricated soils to use for ecological restoration was not only researched and demonstrated, but additionally it was shown how fabricated soils can be used to link the built, agricultural and natural environments using biological cycles. Establishing these plots provided an opportunity to continue this investigation beyond the end of the initial grant term, with a long lasting experiment into the transformation of fabricated soil over time, through several seasons. To leverage that opportunity and extend its value towards the larger goal a fixed research area, including the raised plots and a small bio-regenerative research module and demonstration structure, a 5,000 square foot residential lot sized area was established as mentioned above.

The goal of repairing and regenerating soils to repair and regenerate landscapes to repair and regenerate communities was a primary objective in the conceptualization of this investigation. Putting this fabricated soil research within the context of an urban or suburban residential lot, complete with a prototypical dwelling/structure that is itself a catalyst for ecological and urban revitalization by using natural, biological materials and AFS for construction applications, has set the stage for moving to the next level of market commercialization of AFS as a green building project and ecological restoration material.

Finally, additional cuttings of polar and willow trees were planted at the perimeter of the 50x100 foot research area as part of this larger bio-regenerative cycle for sustainability, to differentiate the restoration area within the larger brownfield site. Additionally these cuttings generated biomass for future use as a fabricated soil component, as a building material and for further research into the creation of bio-fuels, specifically cellulosic butanol and/or ethanol, while at the same time conditioning and repairing the soil. Attached in the addendum is the vision for the Almono Site concept sketch which features the highlights of this biological approach to ecological restoration for sustainable development.

Initial Results and General Observations

The Fabricated Soil Research Team filled twelve 4’x4’x1’4” test plots (wooden raised beds) with fabricated soil. The beds were unlined, allowing the fabricated soil to sit directly on top of the existing soil. The soil components were tested for nutrients and contaminants.

Surprisingly, none of the components, including the river silt and the existing site material, were significantly contaminated by any toxic materials. The beds were sown with annual ryegrass (*Lolium multiflorum*). The grass germinated within the first week. It was a favorite spot for Canada geese who kept the tender growth trimmed for the first month, adding a nitrogen source to the plots. The ryegrass grew thick and high after the geese left it alone. Other plant material, including culinary, medicinal, ornamental, woody, and ground cover plants, were sown in the midst of the grass. The plants adaptable to fall seasonal changes began to grow and continued growing throughout November. Poplar and willow one-year plants were planted in addition to poplar and willow cuttings being stuck in some of the plots. The cuttings began to show roots by late spring. In addition to plantings in the beds, a row of one-year willow and poplar plants were planted along the north side of the designated 5,000 sq. ft. lot. The ryegrass seed and other plants were watered at the time of planting and once a week for the following two weeks. After that, the plots were watered by rainfall alone. There was rain at least once a week, every week but one. Overall, the grass and both woody and perennial plants have thrived in the fabricated soil.

Data and Test Results

1. Laboratory investigation of the components of Almono Fabricated Soil (AFS) samples

a. Micro-bac activity

Creation of ALMONO Site Fabricated Soil (ASFS) activated bacterial and fungal cenosis. The amount of bacteria increased 4 times, and fungi 2000 times.

b. Biological activity

ASFS was tested by the four-crop test and showed high biological activity without any toxicity in the mixture of components.

c. Water-retaining activity

River sediments have high water-retaining activity.

2. Field experiments with AFS

a. Propagation of vegetable plants.

Vegetative plants have high growth activity even in November.

b. Propagation of woody plants.

Willow, forsythia and poplar were easily transplanted.

c. Propagation of cover grasses.

Ryegrass, clover, field ivy and other cover grasses were actively growing even in November.

d. Propagation of medicinal plants.

The most actively growing are the mints. Ornamental plants grow even in November.

3. Modeling of the house with the conception of green architecture.

a. Creation of stucco recipes for the stuccoing of straw bale research module.

b. Vertical gardening on the walls.

c. Green roof construction using native plants.

4. Use of ASFS for the composting process of poplar leaves as substrate for bio- fuel production.

Bacterial and Fungal Counts for Fabricated Soil Test Plots

The tests for fungal and bacterial activity were performed at the start of the fabricated soil in order to make comparisons in a year and two years to see how the soil develops. U.S. Micro-Solutions Inc. in Greensburg, PA performed the tests for bacteria and fungal counts in the ALMONO fabricated soil.

Laboratory Report

Bacillus spp. type 3 - Medium sized, dry, flat, off-white.

Bacillus spp. type 4 - Flat, beige.

Gram-positive coryneform bacillus - Many species of corynebacteria are part of the normal flora of the skin & mucous membranes in human & mammals. Several species of corynebacteria have been found in the inanimate environment (e.g.) diary products, plants, soil and activated sludge.

Fusarium spp. - Fusarium species are widespread as a common soil saprophyte and are an important plant pathogen. Some species produce toxins in grains or stored animal feed. On culture media, this rapidly growing fungus appears in pink, yellow, red, or purple shades. *Fusarium* species are usually identified by their characteristic multicellular sickle-shaped macroconidia, but identification may be difficult with some species.

Rhizopus spp. - Rhizopus species are ubiquitous fungi commonly found in the soil. They have been isolated from decaying fruit and vegetables, compost, old bread, and cereals. Some species are plant pathogens. A member of the Order Mucorales of the Zygomycetes, Rhizopus species are rapidly growing fungi on laboratory media and are distinguished from Mucor by its formation of rhizoids (root-like structures). The spores of Rhizopus may become easily airborne by the slightest disruption of the colony on an agar plate or from building materials.
Bacillus spp. type 1 - Large, flat, dry, wrinkled with irregular edges.
Bacillus spp. type 2 - Large, flat, wet, shiny with irregular edges.

Methods

1. Lay out plots with the conception of a 50'x100' city lot.
2. Build twelve 4'x4'x1'4" ((2) 2x8's) wooden raised beds.
3. Fill with fabricated soil in layers.
4. Plant annual ryegrass seed.
5. Plant perennial culinary, medicinal, ground cover, ornamental, and woody plants.
6. Water at planting time and as needed.
7. Photograph growth progress.
8. Harvest poplar poles from three-year-old poplars from earlier restoration work on site.
9. Harvest poplar leaves for composting experiments.
10. Plant a row of one-year willow and poplar trees on north side of lot.
11. Build a straw bale shed as a bio-regenerative research module (building prototype) using poplar poles and river silt for stucco material.
12. Do four-crop test on fabricated soil components and completed mixture to measure biological activity.
13. Test soil components and mixture for bacterial and fungal activity and for contaminants and nutrients.
14. Dry poplar leaves and put them in netted sacks for composting in FS as a pretreatment for cellulosic biofuels.
15. In lab, test leaves of poplar, willow, sumac, and black walnut for biological activity using the four-crop test. This is a preliminary test for studying natural herbicides.
16. Stick willow and poplar cuttings into beds for propagation of new trees.
17. In lab, prepare paper chromatograms to discern the splitting of carbon polymers through the composting of leaves in fabricated soil.
18. Prepare plant materials and boxes for green roof application.

Goals and Objectives

1. To demonstrate a variety of uses for the river silt based fabricated soil recipe called Almono Fabricated Soil (AFS) including:

- Brownfield Reclamation

- Mine Scarred Land Reclamation
- Urban Agriculture
- Green Roofs and Living Walls

2. To harvest and dry leaves from the existing 2-3 year old poplar trees planted by GTECH on the site. This biomass will then be put into small bundles and buried in the AFS for 2-4 week intervals in late fall, to investigate the ability of microbial activity in the AFS to breakdown carbon polymers in the leaves. This breakdown of carbon polymers is the first step in preparing this biomass as a feedstock to create cellulosic butanol and/or ethanol.

3. To utilize and find various markets for low cost fabricated soil that turns waste into sustainable resources. Those uses may include urban agriculture, green roof and living wall installations, biomass production and various land remediation projects. The goal is to demonstrate the regenerative properties of fabricated soil and show that it could be produced on a commercial level. The AFS will be compared to commercial topsoil and compost products. The focus is to reconnect biological systems in terms of the regenerative properties of buildings and landscapes, using low cost waste materials, simple low cost technologies, and natural cycles and systems, to reduce negative environmental impacts and carbon footprint.

4. To show how fabricated soils can be used to link the built, agricultural and natural environments using biological cycles.

5. To continue this investigation beyond the end of the current grant term, with a long lasting experiment into the transformation of fabricated soil over time, through several seasons. This longer term opportunity includes investigation into additional funding to investigate commercialization, various applications, other components, additional recipes and large scale production. To leverage this current opportunity and extend its value towards the larger goals, we propose the continued use of the fixed research area, including the raised plots and the small bio-regenerative research module and demonstration structure. This is the 5,000 plus square foot residential lot sized area mentioned above.

6. To repair and regenerate soils so that we can repair and regenerate landscapes so that we can repair and regenerate communities, is at the heart of this work. Putting this fabricated soil research within the context of an urban or suburban residential lot, complete with a prototypical dwelling/structure that is itself a catalyst for ecological and urban revitalization by using natural, biological materials and AFS for green roof and green wall applications, will set the stage for moving to the next level of market commercialization of AFS as a green building, ecological restoration and sustainable development material.

7. To plant additional cuttings of polar and willow trees at the perimeter of the 50x100 foot research area as part of this larger bio-regenerative cycle for sustainability, to differentiate our restoration area within the larger site. Additionally these cuttings will generate biomass for future use as a fabricated soil component, as a building material and/or for further research into the creation of bio-fuels (specifically cellulosic butanol and/or ethanol) while at the same time conditioning and repairing the soil.

Why Two Projects are Better than One

The inclusion of the work of the Fabricated Soil Research Team along with GTECH's work at the ALMONO Site, validates the concepts on a continuing scale. For instance, if a useful soil mix is derived from the GTECH experiments with the river silt, this may provide an immediate use of a waste material, an opportunity for the creation of jobs, and a viable business venture. At the same time students and a faculty from Slippery Rock University, as well as a student and alumni from Carnegie Mellon University were involved in carrying out this research. Providing internship opportunities for sustainable systems graduate students, an independent study opportunity for building performance PhD. research and generating research results that can be published, illustrates the academic aspects of this project. The work of the Fabricated Soil Research Team extends these benefits of this project to the creation of bio-regenerative soils that can potentially begin the chain of restoration, linking biological cycles with building and landscape cycles, in such a way that we can ultimately restore communities and cities to sustainable levels.

Rationale behind the Choice of Fabricated Soil Materials

The following layers are included in the ALMONO fabricated soil from the top down;

Typical Profile Layers	Total amount of material for all 12 plots	
3” top soil (4’x4’x.25’)=4 Cu. Ft./27 Cu. Ft.=0.148148 Cu. Yd. x 12=	1.77 Cu. Yds.	Round up to 2
3” river silt	1.77 Cu. Yds.	Round up to 2
3” mushroom compost	1.77 Cu. Yds	Round up to 2
3” river silt	1.77 Cu. Yds.	Round up to 2
3” straw bale	1.77 Cu. Yds.	Round up to 2
3” wood chips	1.77 Cu. Yds.	Round up to 2

The materials are chosen for a balance between nitrogen, carbon, and clay substrate sources and between slow and quick carbon sources. The straw is a quick-splitting carbon source, while the wood chips are a slow-splitting carbon source. The mushroom compost provides nitrogen. The river sediments absorb water and provide an alumino-silicate matrix for the formation of humus. Top soil provides bacterial and fungal elements to begin the formation of the fabricated soil.

Conclusion

This research project, undertaken in conjunction with and on behalf of GTECH Strategies, Inc., has been successful on every level. The primary narrow focus of the research has clearly demonstrated that the river silt generated by Pennsylvania American Water Company is a suitable material for creating fabricated soil. The tests conducted, by our team and the testing labs, shows clearly that the soil components, individually and as a mixture all support biological activity, do not contain toxic components above acceptable levels, and support the growth of seeds and transplants of a variety of plants. Mushroom compost that was sampled, as well as the commercial compost used in the mixes at the Almono research site, did not support seed germination and was thought to be toxic for reasons that were not known. The AFS layered soil recipe and the mixes of river silt with various percentages of compost utilized in the GTECH research plots, both proved to be effective mixtures to support plant germination and growth over the research period. This indicates there may be some potential to develop various mixes and recipes of the river silt with other ingredients that can be marketed for various commercial green building and sustainable development projects including green roof, living wall, urban agriculture, vacant lot restoration, brownfield reclamation or mine scarred land regeneration.

Another application for the river silt that was studied, although not a primary goal of the grant, was the use of the riversilt as a component in a natural stucco recipe. The riversilt worked satisfactorily in this application, but more extensive research, utilizing various recipes and other mixtures would be needed to see of the riversilt had the durability, longevity and maintenance characteristics that would be desired in a commercial stucco product.

The ability to put this research into the context of a typical 5,000 square foot residential plot, complete with a small archetypal building, allows for this research into the use of this river silt waste material as a catalyst for ecological restoration to be seen as valuable to the local landowner who wants to better the urban environment at the neighborhood scale. There is a growing market for this kind of sustainable urban transformation that uses waste materials and other by-products of our industrial heritage as the very catalyst for the transformation. To be able to illustrate this simple but challenging concept with 24 productive raised beds and a small building on a vacant lot in a layout the size of someone’s yard, puts this approach within the grasp of everyone. Certainly making the connections between our buildings, our landscapes and the health of our environment obvious to everyone will help to accelerate the momentum of moving to a greener and more sustainable world, in a profitable and responsible way.

References and Resources

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Addendum

The Biological Activities of Some River Sediments, Wood Chips, and Clay August 1, 2009

Experiment #1

In preparation for some fabricated soil experiments at the Almono site, we performed the four-crop test on five components. On June 26, 2009 we gathered from the site, samples of the river sludge that had been deposited. We took two samples from piles with distinctive differences in color which we describe as "river sludge light" and "river sludge dark." We gathered a sample of the wood chips that are in the beginning stages of composting. Also, we collected a sample of some composted material we labeled "garbage compost." In addition, we used some clay material from another site. For the control, we used "Miracle Gro Potting Mix." Each component was weighed and put into the bottom of three Koch dishes in a thin layer. We divided the samples in each dish into four parts and sowed four types of seeds in each dish: Black-seeded Simpson lettuce; White-cicle radishes; Red medium clover; annual rye grass. The dishes were watered and covered. This experiment began on July 2, 2009.

Weight of container empty	Weight of container with soil.	Weight of soil sample.	Amount of water added.
1. Control: Miracle Grow Potting Mix			
1.1. 11.29 g.	54.3 g.	12.31 g.	10 ml.
1.2. 11.4 g.	24.0 g.	12.6 g.	10 ml.
1.3. 11.8 g.	24.0 g.	12.2 g.	10 ml.
2. Garbage Compost			
2.1. 20.3 g.	54.3 g.	34.0 g.	6 ml.
2.2. 11.3 g.	48.2 g.	36.9 g.	6 ml.
2.3. 11.3 g.	45.2 g.	33.9 g.	6 ml.
3. Wood Chips			
3.1. 11.0 g.	34.0 g.	23.0 g.	6 ml.
3.2. 11.4 g.	30.7 g.	19.3 g.	6 ml.
3.3. 11.2 g.	28.7 g.	17.5 g.	6 ml.
4. River Sludge Dark			
4.1. 11.9 g.	39.5 g.	27.6 g.	10 ml.
4.2. 11.5 g.	39.8 g.	28.3 g.	10 ml.
4.3. 11.7 g.	44.1 g.	32.4 g.	10 ml.
5. River Sludge Light			
5.1. 11.8 g.	66.1 g.	54.3 g.	10 ml.
5.2. 12.0 g.	40.0 g.	28.9 g.	10 ml.
5.3. 11.8 g.	53.7 g.	41.5 g.	10 ml.
6. Clay			
6.1. 11.7 g.	39.0 g.	27.3 g.	8 ml.
6.2. 11.2 g.	53.4 g.	42.2 g.	8 ml.
6.3. 10.8 g.	51.1 g.	40.3 g.	8 ml.

Next we filled 20 ml. flasks with each sample type to determine specific weight.

Weights are recorded below.

Component	Weight of vessel	Weight of flask with material	Weight of material	Specific Weight
0.0. Water	13.3 g.	35.9 g.	22.6 g.	1.13
1.0. Potting Soil	13.3 g.	19.7 g.	4.4 g.	.22
2.0.Garbage Compost	13.3 g.	25.0 g.	11.7 g.	.585
3.0.Wood Chips	13.3 g.	20.3 g.	7.0 g.	.35
4.0 River Sludge Dark	13.3 g.	20.1 g.	6.8 g.	.34
5.0.River Sludge Light	13.3 g.	34.2 g.	20.9 g.	1.0
6.0. Clay	13.3 g.	42.8 g.	29.5 g.	1.475

The diameter of the Koch dishes are 9cm; the radius is 4.5 cm. The area of the bottom of the dish is 69.05 cm^2. A thin layer of material was put in the bottom of each dish.

Results for Experiment #1

Results were measured by measuring the length of the longest five shoots in each group. Average length of the five shoots is given in inches.

Material	**Rye Grass**	**Lettuce**	**Radish**	**Clover**
1.Control/Potting Soil				
1.1	6.7	1.95	3.6	2.05
1.2	6.55	1.9	3.6	1.5
1.3	5.0	1.0	2.6	1.35
average	**6.08**	**1.6**	**3.3**	**1.6**
2.Garbage Compost				
2.1	5.65	1.2	2.6	2.05
2.2	5.6	1.05	4.0	1.25
2.3	6.75	1.5	3.2	1.2
average	**6.0**	**1.25**	**3.3**	**1.5**
3. Wood Chips				
3.1	4.0	1.3	1.75	1.3
3.2	3.55	1.1	2.2	1.35
3.3	4.4	1.4	3.6	1.0
average	**4.0**	**1.3**	**2.5**	**1.2**
4. River Sludge Dark	**Rye Grass**	**Lettuce**	**Radish**	**Clover**
4.1	4.85	1.75	2.45	2.5
4.2	5.2	1.75	2.75	1.25
4.3	5.15	1.75	2.85	1.6
average	**5.1**	**1.75**	**2.7**	**1.8**
5. River Sludge Light				
5.1	5.05	2.5	2.8	1.5
5.2	4.15	1.75	2.95	1.5
5.3	5.2	1.75	2.35	1.15
average	**4.8**	**2.0**	**2.7**	**1.4**
6. Clay				
6.1	4.4	0.5	.85	1.0
6.2	3.25	.3	1.4	1.0
6.3	4.65	.65	1.65	1.25
average	**4.1**	**.48**	**1.3**	**1.08**

Experiment #2

On 07.09.09, we performed the four-crop test on potential components for the fabricated soil mix: mushroom compost and saw dust. Again, commercial potting soil was used as the control for comparison. Measurements were taken on 07.18.09 and recorded in inches. See table below for results.

Material	**Rye Grass**	**Lettuce**	**Radish**	**Clover**
Saw Dust 1	3.9	0.7	1.85	1.15
Saw Dust 2	3.6	1.0	1.6	1.1
Mushroom Compost 1	No Germination	No Germination	No Germination	No Germination
Mushroom Compost 2	No Germination	No Germination	Three seeds show root tips only	No Germination
Potting Soil 1 Dried out	1.6	No germination	.9	.75
Potting Soil 2	6.6	1.6	3.6	1.5

Unfortunately, one set of controls dried out. The important thing to note is that seeds germinated and grew well for a week on saw dust alone. The mushroom compost is toxic for seed germination. It may be treated with herbicides.

Experiment #3

Five soil samples were taken from the Almono site where the experimental beds were being built on a 50'X100' research area. The samples are from each quadrant (SE, SW, NE, NW) and from the center of the area. In each Koch dish, 90g of soil were used for the four-crop test. Another batch of mushroom compost from a different source was tested at the same time and commercial potting soil was the control.

Material (90g)	**Water added in ml.**	**Specific Weight**
1a. SE sample	30	1.2
1b.	30	1.2
2a. SW sample	25	1.04
2b.	25	1.04
3a. Center sample	30	1.16
3b.	30	1.16
4a. NW sample	25	1.0
4b.	20	1.0
5a. NE sample	25	1.1
5b.	25	1.1
6a. Mushroom compost	25	.26
6b.	27	.26
7a. Control/potting soil	35	.17
7b.	35	.17

Results for Experiment #3

Length of the five longest shoots in each group is averaged and recorded in inches.
See table below.

Material	Rye Grass	Lettuce	Radish	Clover
1a. SE sample	5.55	1.6	4.55	1.65
1b.	5.1	1.85	3.3	1.6
2a. SW sample	5.1	1.9	3.3	1.25
2b.	4.65	1.75	3.55	1.0
3a. Center sample	5.25	1.75	4.7	1.5
3b.	4.4	0.5	2.7	1.0
4a. NW sample	4.35	1.75	3.4	1.6
4b.	4.1	1.6	3.7	.75 moldy/some dead
5a. NE sample	2.7 moldy/ shriveled	1.5	3.55	1.0 moldy/ shriveled
5b.	4.5	.65	3.95	1.05
6a. Mushroom compost	No germination	No germination	No germination	No germination
6b.	No germination	No germination	No germination	No germination
7a. Control/potting soil	3.1	No germination Not enough water	3.05	1.0
7b.	4.3	.5	3.2	1.15

Experiment #4

On 07.28.09, a fabricated soil (FS) mixture was made and tested with the four-crop test in comparison with the potting soil control. The components of the FS are as follows (measured by volume):

- 50ml mushroom compost
- 50ml soil (sample #3 from Almono site; center of experimental plot)
- 50ml potting soil
- 50ml pond sediment
- 50ml dry leaves
- 50ml wood chips

This mixture was mashed and mixed together with mortar and pestle. We used the mushroom compost to see if it would be less toxic diluted in the mixture.

Material	Weight of material	Weight of added water	Specific weight
FS a.	50g	25ml	0.58
FS b.	50g	25ml	0.58
FS c.	50g	25ml	0.58
Control a.	44g	40ml	0.17
Control b.	44g	40ml	0.17
Control c.	44g	40ml	0.17

Results for Experiment #4

Results were observed on 08.05.09. The five longest shoots are measured and averaged for each group. Measurements are given in inches. See table below.

Material	Rye grass	Lettuce	Radish	Clover
FS a.	6.75	2.3	3.7	1.9
FS b.	6.8	2.0	4.0	2.25
FS c.	6.45	2.25	4.9	1.5
Avg. FS	**6.66**	**2.18**	**4.2**	**1.88**
Control a.	6.8	1.95	3.25	1.5
Control b.	6.6	1.95	3.3	1.5
Control c.	6.65	2.0	4.35	1.5
Avg. Control	**6.68**	**1.97**	**3.6**	**1.5**

In addition to the above four experiments, we did the four-crop test on another sample of compost to be used in the Fabricated Soil mixture at the ALMONO site. Again, only two rye grass seeds germinated growing to about 3cm, and three radish seeds germinated but had almost no growth. No clover seeds germinated. Also no lettuce germinated, and the lettuce seeds were covered with mold.

Discussion and Conclusions

The soil in the research area at the Almono site is capable of supporting plant life to some degree. All four crops germinated and grew on each of the five soil samples from the research area where the plots are being established. Mushroom compost is apparently treated with herbicides and is toxic to the seeds. The fabricated soil (FS) was composed and tested using the four-crop test. The mushroom compost in the FS composition lost its toxicity thanks to dilution, but remains a N (nitrogen) source for the FS. The biological activity of FS was as high as for potting soil (control). However, the advantage of FS is in containing only waste materials. Thus the first step of the experimental block is over, and we will start to change the original composition of FS using river sediments which were non toxic according to our preliminary experiments.

Additional Experiments Using the 4-Crop Test

Experiment #5 and #6

The four-crop test was performed using the compost material purchased as a component for the Fabricated Soil mixtures. Again, four crops were seeded: Rye grass, lettuce, radish, and clover, in Koch dishes with 90g compost and 30ml water. Specific weight was .68. After one week, there was no growth of seeds except for a few seeds that had barely sprouted and then died. As a control for the compost experiments, I used my own home-made compost from my yard. The results were similar to the potting soil mix. Numbers recorded are average of the five longest shoots for each variety in each of two koch dishes labeled A and B in the chart below.

	Rye Grass	**Lettuce**	**Radish**	**Clover**
A	6.05	2.0	3.35	1.75
B	5.9	2.0	3.2	1.75

Experiment #7

The four-crop test was performed on the AFS (ALMONO Fabricate Soil) after it had been in the beds for one week. Each Koch dish contained 90g soil and 30ml water. Specific weight was .55. Germination was sparse and the plants that germinated were affected by mold. The chart below indicates the average of the five longest shoots for each variety in each of three Koch dishes labeled A, B, and C. The average of each variety in all three dishes is given.

	Rye Grass	**Lettuce**	**Radish**	**Clover**
A	0	.25	2.5	0
B	4.65	.15	2.5	.2
C	0	.05	3.2	.5
Average	1.55	.15	2.7	.23

Conclusion for Experiments #5, #6 and #7

Experiment 5 indicates that mushroom compost is toxic for seed germination. The reason is not clear. Compared to homegrown compost from kitchen and yard waste, it is not a healthy growing medium. However, experiment 7 indicates that the mushroom compost is diluted in the fabricated soil mix allowing some germination but less germination and growth than the control of home-made compost. Nevertheless, the mushroom compost is a good nitrogen source for the fabricated soil. We predict that, given time to develop, the fabricated soil with the mushroom compost material will be a healthy and productive soil. However, there may be a better choice for the nitrogen component in the fabricated soil mix.

ALMONO Site

Fabricated Soil Research Team

Shari Mastalski; Chris Leininger; Valentine Kefeli

October 1, 2009

Bacterial and Fungal Counts for Fabricated Soil Test Plots

Soil is an interactive, ever-changing, independent community of diverse interdependent organisms, minerals, systems, and cycles. A fabricated soil is a layered mixture of materials from on and off site sources intended to start the process of soil formation. The soil develops by the interactive processes between organic and inorganic materials, living and dead plant materials, microorganisms, soil biota, animal and human activity.

Dr. Valentine Kefeli (Slippery Rock Watershed Coalition), Dr. Maria V. Kalevitch (Robert Morris University), and their research teams have been studying the bacterial and fungal activity in soils over the past several years. They believe the function of these microorganisms is important because the relationship between plants and soil development is inseparable. In other words, plants work in conjunction with bacteria and fungi to process soil to make nutrients available. These processes also work to replenish the soil to complete the nutrient cycles. Bacteria and fungi participate in the fermentation and splitting processes in soil to produce humus for soil fertility. Bacteria use monomers for their activity while fungi split carbon polymers. As long as plants are converting the sun's energy into biomass, processes between the soil, atmosphere, and plants can ensure continuously healthy productive soils without additional outside resources.

Other reasons for this study include the ability of bacteria and fungi in the soil to degrade contaminants. In addition, certain bacteria fix nitrogen for plant use.

It is important to observe the bacterial and fungal counts in the soil at the beginning of the process and then in a year to see what progress has been made. From past experiments, Drs. Kefeli and Kalevitch noted the activities of bacterial communities changed the growth of trees, increased root growth and biomass formation, and raised the level of potassium, nitrogen, and phosphorus. The fabricated soil was enriched and increasingly fertile. These fabricated soils can be used to restore damaged sites from mines or brownfields.

For further information read:

Kalevitch, M. V.; Kefeli, V. I.; "Bacterial Presence in Manufactured Soils," *Journal of Agricultural, Food, and Environmental Sciences* Vol. 1, Issue 1, 2006.

Or contact:

Valentine Kefeli at vkefeli@embarqmail.net

ALMONO Site Research Plots

Fabricated Soil Research Team

September 30, 2009

Rationale for Choice of Plants in Test Plots 1C&D-6C&D

The plants used in the fabricated soil test plots (Plots C&D on the north side of the site) represent the diversity of an established soil ecosystem. Monocultures naturally become diversified if not tended carefully or controlled chemically. Each plant adds its own unique chemistry to a soil system as it interacts with the biosphere, the soil, other plants, and microorganisms.

After layering the beds with the fabricated soil components, annual rye grass was seeded. This was a quick way to start the process of soil development. The grass could be turned into the soil as a green manure or left to build root systems. Within two weeks, the grass was fairly well established. Geese were attracted to the grassy plots, eating some and leaving another nitrogen source with additional bacteria.

Next, we planted willows and poplars in several beds. The plants were one year old plants that had been started from cuttings from the fabricated soil plots at Jennings Environmental Education Center. These plants will produce poles for regenerative architecture, mulch for beds, leaves for bio-fuel experimentation, additional cuttings to propagate more plants to populate the site and produce biomass. Willows and poplars also have a traditional medicinal value and possibly have value in protecting other plants such as chestnuts from bacterial, fungal, and viral infection. Willows and poplars will root deeply into the beds, interacting with all the material layers. They will be an important part of the diversity of the beds, allowing for more interaction between plants and soil as well as interactions between plant varieties.

Too little is known about plant interactions and which plants can be beneficial when planted together. Natural plant communities grow in beneficial relationships using and supplying an assortment of nutrients. Besides the willow and poplar plants, we then stuck cuttings from each into the beds for rooting. Past experiments in sticking cuttings outdoors in September to October have been very successful with pussy willows, somewhat successful with riverbank willows, and less successful with poplars.

The rest of the plants fall into four categories: culinary, medicinal, ornamental, and ground cover. The ground cover plants are possible plants for green roofs. Most plants in the ground cover group are also ornamentals. The culinary and medicinal plants are useful for human consumption. There is some overlap between what is medicinal and what is culinary. Ornamentals brighten our world and add diversity to the beds. The plants include both natives and non-invasive non-natives.

The variety of plants might be used for green roofs, living walls, and also in urban agriculture. It is a good opportunity to test an assortment of plant materials in the fabricated soil medium. Which plants will be resistant to mutations? Which plants will be the most hardy, drought tolerant, and resistant to pollution? Ideally, plants for living walls and green roofs would be hardy natives that have culinary or medicinal uses as well as beauty. Regardless of the choice of plants, green roofs provide a thermal buffer for the building, oxygen, stormwater runoff control, heat island effect control, pollution control, sound barrier, and urban wilderness.

Culinary and Medicinal

Nettle *Urtica sp.*
Chamomile *Anthemis nobilis*
Catmint *Nepeta sp.*
Sage *Salvia officinalis*
Lemon Balm *Melissa officinalis*
Comfrey *Symphytum officinale*
Yarrow *Achillea millifolium*
Jerusalem Artichoke *Helianthus tuberosis*
Celery *Apium graveolens*
Chives *Allium schoenoprasum*
Chocolate Mint *Mentha piperita*
Horseradish *Armoracia rusticana*
Oregano *Oreganum vulgare*

Ornamentals

Four O'Clock *Mirabilis jalapa*
Aster *Aster sp.*
Rudbeckia *Rudbeckia sp.*
Goldenrod *Solidago sp.*
Daylily *Hemerocallis sp.*
Money Plant *Lunaria annua*
Iris *Iris sp.*
Lily of the Valley *Convalaria majalis*
Hosta *Hosta sp.*
Kniphofia *Kniphofia sp.*

Ground Cover

Yellow Wood Sorrel *Oxallis europaea*
English Ivy *Hedera helix* (non-native)
Fern
Sedum *Sedum sp.*

Lamb's Ears *Stachys byzantina* (non-native)
Ajuga *Ajuga reptans* (Non-native)

Additional Possibilites for Native Green Roof Cover

Violets *Viola sp.*
Wild Strawberry *Fragaria virginiana*
Heal-all *Prunella vulgaris*
Cinquefoil *Potentilla simplex*
Clover *Trifolium sp.*
Common Plantain *Plantago major*
Nodding Onion *Allium cernuum*
Shepherd's Purse *Capsella bursa-pastoris* (This is an annual which readily reseeds)
Purple Deadnettle *Lamium purpureum* (Reseeding annual)
Choose grasses and other plants with positive qualities from the site.
ALMONO Site
Fabricated Soil Research Team
September, 2009

Wild Plants on Site: September 2009

It is important to note the wild plants naturally occurring on the site at the time the test plots begin. As we work at the site, the ecosystem will go through changes. Although the test plots are in raised beds, we expect to see changes in the original soil outside the beds as well as in the naturally occurring plant materials. Humans play an important part in ecosystem development. Sometimes we create negative impacts, while, at other times, we create positive impacts. We are changing the overall ecosystem in our 50 x 100' area of the ALMONO Site by adding a straw bale building, test beds, poplars, willows and other plants. This mimics a diverse community with healthy bioregenerative systems of nutrients cycling and a reliance on present solar income. We will note changes in wild plants on site in a year.

Beggarticks *(Bidens sp.)*
Thistles (*Cirsium sp.*), maybe Bull Thistle (C. vulgare)
Burdock *(Arctium sp.)*
Clotburs (*Xanthium sp.*)
Common Ragweed *(Ambrosia artemisiifolia)*
Common Mugwort (*Artemesia vulagris*)
Nightshade (*Solanum sp.*) maybe Horsenettle (*S. carolinense*)
Queen Anne's Lace (*Daucus carota*)
Common Plantain (*Plantago major*)
Foxtail (*Setaria sp*)
Hairgrass (*Agrostis scabra*)
Sedge (*Cyperus sp.*)
Evening Primrose (*Oenethera sp.*)
Sumac (*Rhus sp.*) maybe *R. glabra*
Asters (*Aster sp.*) Several varieties
Goldenrod (*Solidago sp.*)
Porcelain Vine *(Ampelopsis brevipedunculata)*
Need further identification for possible plants:
Boneset (*Eupatorium sp.*)
White Thoroughwort (*Eupatorium album*)

Horseweed (*Erigeron Canadensis*)
Burnweed/Fireweed (*Erechtites*)
False Boneset (*Kuhnia*

Shari Mastalski and Beth Rihn
Abstract Submissions for the 2009
Student Symposium on the Environment at **Westminster College**
December 3, 2009

Submission #1

Design: Holistic, Ecological, Sustainable
Shari Mastalski; Beth Rihn
Advisors: Valentin Kefeli; Christopher Leininger
Slippery Rock University Master of Science in Sustainable Systems

Everyone is a designer. By applying principles of sustainability and permaculture, we can redesign our environments. These principles apply whether we are designing buildings or landscapes in urban, suburban, rural or agricultural settings. In addition, it is everyone's responsibility to be good stewards of the natural environment, which Eugene Odum calls our "life support system." This study examines the design process in light of Sym Van der Ryn's five ecological principles.

- Solutions grow from place.
- Ecological accounting informs design.
- Design with nature.
- Everyone is a designer.
- Make nature visible.

The Fabricated Soil Research Team participates in ongoing research on fabricated soils, fast growing woody plants for biomass production, bioregenerative architecture, and living on current solar income. These are basic components of the holistic design process because they restore soil and water health and promote the capture of solar energy through biological processes. These biological processes include cycles of carbon, oxygen, and nitrogen, converting these volatile elements in the air into biomass and stored energy. Finally, how shall we begin to make a difference? What one thing could we do today to support healthier lives, environments, communities, and economies?

Submission #2

Using art forms to promote sustainable systems: Presenting "Playing in the Dirt"
Shari Mastalski
Advisors: Christopher Leininger and Dr. Valentin Kefeli
Slippery Rock University Master of Science in Sustainable Systems

Dance, drama and music have always been part of my life, but I have only recently discovered my niche. I call it story dancing. My mother says everyone has a story to tell, and that is so true. The stories I do are about social and environmental justice, and also about faith. This one is about a precious resource: dirt. I call it "Playing in the Dirt." It sums up, in about eight minutes, my past two years of graduate study in Sustainable Systems. Throughout the course of working for my Master of Science degree in Sustainable Systems (MS3) at Slippery Rock University, I have wanted to combine the arts with the science of sustainable systems.

The arts are a powerful, but often disregarded, tool for imparting knowledge that can motivate positive action. As human members of earth's ecological communities, we have the responsibility to right the wrongs we have done and to restore natural systems and processes. We have created some big problems, and it is time to recognize the crucial interplay between the arts and sciences for solving these problems. When the arts and sciences combine forces, the integrity and intellectual power of the human brain is magnified.

For human survival, we need a healthy world with healthy environments, communities, and economies, and we must apply a holistic approach to this endeavor.

The following resources are referenced in "Playing in the Dirt."

- Eugene P. Odum *Ecology and Our Endangered Life Support System*
- William Bryant Logan *Dirt: the Ecstatic Skin of the Earth*
- Genesis; Matthew
- Native American Chief Seattle

Submission #3

Bioregenerative Architecture: Building a Demonstration Straw Bale Unit

Beth Rihn; Shari Mastalski
Advisors: Christopher Leininger; Dr. Valentin Kefeli
Slippery Rock University Master of Science in Sustainable Systems

Bioregenerative architecture is a crucial component of holistic design. All energy comes from the sun. Capturing this energy through biological processes such as photosynthesis makes it possible to live on current solar income rather than relying on a limited supply of fossil fuels. There are three basic interactive environments: natural, domesticated, and fabricated. Building with straw bales, poplar poles, and local clay-sand stucco demonstrates ecological design concepts that could have broad, practical applications.

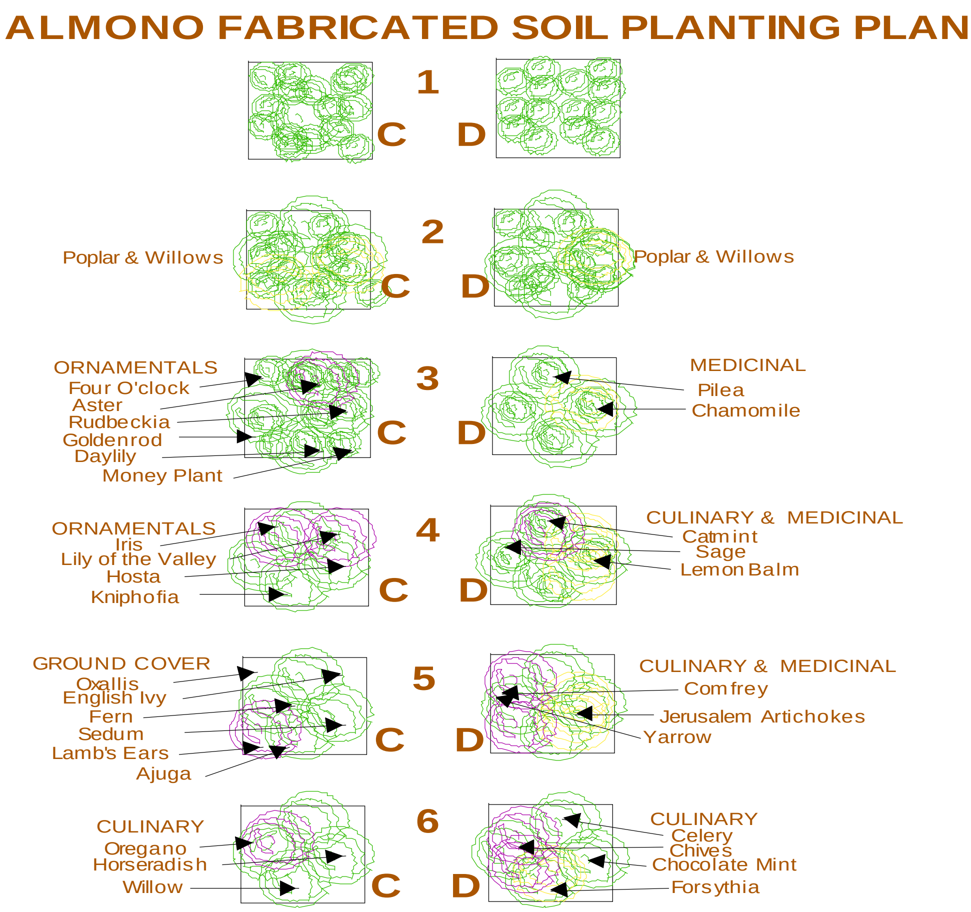
The construction of our straw bale building at the ALMONO site in Hazelwood is part of a demonstration for a sustainable community which begins with soil restoration using fabricated soils and fast-growing woody plant material. The demonstration is based on the concept of using waste materials. The river silt component of the fabricated soil and stucco mixture comes from the Monongahela River and is a byproduct of the Pennsylvania American Water Company. Bioregenerative architecture is also based on the concept of using renewable materials. For example, fast growing poplar and willow trees can be cut down and regrown every year. Products of these trees can be used for architectural elements, new plant production, and biofuel material. The sun's energy is captured by growing plants through photosynthesis, forming carbon polymers for biomass and energy storage.

Submission #4

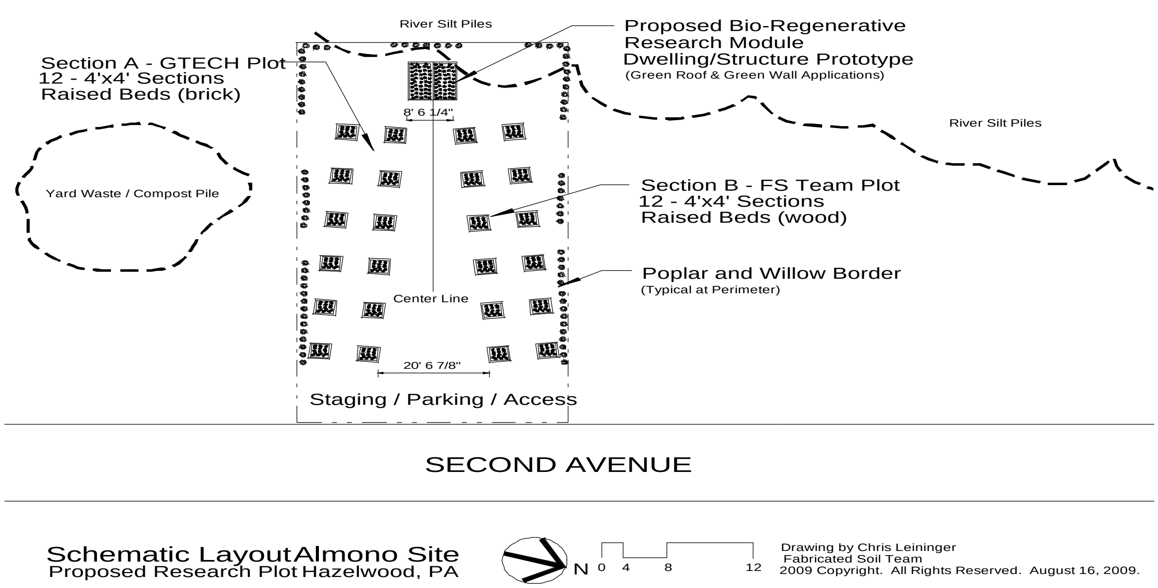
Fast-growing one-year poplar shoots for green house and cold frame installations.

Rayan Yarrington, Slippery Rock High School
Advisor: Dr. Valentine Kefeli

Two-foot, one-year-old poplar shoots (*Populus nigra)* were bent in the form of arcs and used for the construction of cold frames for plant propagation in the spring. Thick plastic film will be used for covering the cold frame. Containers for plant propagation were constructed in the form of wooden boxes with a mesh bottom. These were filled with fabricated soil. In these containers will be propagated ground cover plants and grasses for green roof construction. The conception of cold frames from poplar shoots is in progress now.



ALMONO FABRICATED SOIL PLANTING PLAN
1
C
D
2
Poplar & Willows
C
D
Poplar & Willows
ORNAMENTALS
Four O'clock
Aster
Rudbeckia
Goldenrod
Daylily
Money Plant
3
C
D
MEDICINAL
Pilea
Chamomile
ORNAMENTALS
Iris
Lily of the Valley
Hosta
Kniphofia
4
C
D
CULINARY & MEDICINAL
Catmint
Sage
Lemon Balm
GROUND COVER
Oxallis
English Ivy
Fern
Sedum
Lamb's Ears
Ajuga
5
C
D
CULINARY & MEDICINAL
Comfrey
Jerusalem Artichokes
Yarrow
CULINARY
Oregano
Horseradish
Willow
6
C
D
CULINARY
Celery
Chives
Chocolate Mint
Forsythia



River Silt Piles
Proposed Bio-Regenerative
Research Module
Dwelling/Structure Prototype
(Green Roof & Green Wall Applications)
Section A - GTECH Plot
12 - 4'x4' Sections
Raised Beds (brick)
8' 6 1/4"
River Silt Piles
Yard Waste / Compost Pile
Section B - FS Team Plot
12 - 4'x4' Sections
Raised Beds (wood)
Poplar and Willow Border
(Typical at Perimeter)
Center Line
20' 6 7/8"
Staging / Parking / Access
SECOND AVENUE
Schematic Layout Almono Site
Proposed Research Plot Hazelwood, PA
N 0 4 8 12
Drawing by Chris Leininger
Fabricated Soil Team
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