# Truth or Consequences
# Stormwater Harvesting Assessment

## Reconnaissance Report
## September 16, 2013

**by**
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**Stream Dynamics, Inc.**

## Overview

On Wednesday, September 11, 2013 Van Clothier from Stream Dynamics, Inc. met at city hall with Mayor John Mulcahy, City Manager Juan Fuentes, and Street Department supervisor Buster Smith. We discussed the damaging rainwater runoff situation and I gave a presentation on water harvesting techniques that could potentially help solve the problem. After about an hour I departed with Buster Smith for a tour of the problem areas and source areas where the water was coming from. While doing this we were eventually joined by the mayor as well as commissioner Jeff Richter.

We looked at 20 sites where flowing water was contributing to down slope flooding, and discussed potential improvements that could be made. That night it rained all night and was still raining in the morning. I returned to the source areas, and looked at flowing water at all the problematic downtown intersections, a total of 14 more sites, and was able to understand the nature of the problem and come up with a proposed solution. Each of these sites is discussed individually at the bottom of this report. Many of these are executable on public right of ways, either on T or C land or State Highway right of way.

## Executive Summary

The basic situation is that urban stormwater runoff from the upper parts of the watershed is flowing down residential streets on the hill all the way to downtown. These are not very big watersheds, and there is not a huge amount of water, however a severe problem is created because it ponds on Broadway Street and creates traffic hazards and flooding problems for downtown merchants. The configuration of the streets allows water to arrive to downtown faster than it drains off, creating deep ponding which vehicles splash through, making big waves and roostertails that exacerbate the flooding. My proposed solution has multiple parts; the first two specifically address the downtown flooding issue, and the rest deal with water quality and Green Infrastructure.

#1 The easiest thing to do is to reconfigure the intersections downtown to eliminate ponding on Broadway by draining the water more efficiently down Clancy, Daniels, Foch, Pershing, and Mims. Broadway is very flat, and these intersecting streets are steeper, but the slopes of the intersections are causing ponding on Broadway. By re-sloping these intersections, the water that arrives from upslope neighbrhoods can be drained across Broadway instead of ponding on Broadway. The flooding problem will be drastically reduced. Reshaping these intersections will not really send more water down the above mentioned streets, because this is where it eventually goes anyway; it will just send it sooner and reduce ponding on Broadway.

#2 Water harvesting in source areas. We can also make the problem smaller by slowing the rate of arrival of water to the downtown area. Several excellent example sites are located on city property. See Assessment Sites and Photos, beginning on page 5.

## Water Quality and Green Infrastructure

#3 Water harvesting in the neighborhoods south of downtown. These southward draining streets are built with deep "V" shaped cross sections so that they will act as swales to drain water out of town toward the river. There are a few opportunities to create water harvesting basins on private property and empty lots along the way to improve water quality. This area was not assessed in a detailed manner on this trip. A future site visit could look for the best opportunities to harvest water in this part of the urban watershed.

#4 Increasing the size of the wetlands near Jack Baker Park and the sewage pumping station. This would be the last chance to slow and clean urban stormwater runoff prior to putting it in the Rio Grande, and there is enough land in this vicinity to handle the volume of runoff. There is plenty of unused land in this area, and it would be a very good ecological restoration project, in addition to mitigating urban stormwater runoff. It is also a very low risk project because the slopes are very flat, the available area for a project is large, and the amount of water from the watershed that drains to here from T or C neighborhoods is quite manageable. In my opinion, this would be a valuable contribution to the ecology of the river and should get a high priority.

Funding may be available through the U.S. Fish and Wildlife Service or many other state and federal agencies that fund habitat and restoration projects. Doing a project like this would require careful planning and may need permits from the Army Corps of Engineers and the New Mexico Environment Department.

#5 Narrowing some of the streets. This will reduce the impervious acreage, and therefore reduce stormwater runoff. At the same time, it would reduce pavement and maintenance costs, and create parkways along the streets that can serve as drainage swales with water harvesting basins integrated into them. This will separate vehicle traffic from water flows. Mesquite trees grow quite well in T or C, and could be planted in the basins to shade the street. A narrower tree lined street will help reduce the heat island effect and keep town cooler in the summer. I spoke to Cyndi at La Paloma Hot Springs about this idea. She thinks it would work as long as enough street parking is retained to support small businesses.

## Suggestions for moving forward

Stream Dynamics has done a reconnaissance level assessment of the problem and come up with a preliminary design concept. If T or C is interested in continuing to work with Stream Dynamics, Inc. on this problem, I would propose doing a field design for the treatment areas that make sense to the commission and the streets department. If the project is going to actually get built, I would like to be on site with my laser level to make sure that the elevations and slopes are correct. With water flow problems, the devil is in the details. If critical elevations or slopes are not correct, the project will fail.

## Stream Dynamics, Inc. Design / Build Policy

Since successful application of watershed restoration techniques and water harvesting earthworks is intimately related to the specifics of each site, Stream Dynamics, Inc.'s policy is to follow through the entire process from assessment, through design, construction, monitoring, and maintenance. If we do not build the project, we will supervise the construction of our design. This insures fidelity to the design concept, allows us to learn from the project results, and represents a commitment to both the watershed and the landowner to adjust and repair any work until it is functioning properly within the landscape.

## Trainings and Workshops

Stream Dynamics offers trainings and workshops on water harvesting road drainage. For example, on May 6-8, 2013, Stream Dynamics taught the course Integrating Stream Restoration Principles & Transportation Maintenance to 30 people. There were classroom presentations, field exercises, and tours of project sites. The participants were mostly from the New Mexico Department of Transportation, and also included officials from various cities and Pueblos.

We would like to do a workshop/project with your staff in which we would go through the assessment, design and building process together with all your manpower and equipment.

Putting your staff through training in water harvesting will build your capacity to solve these problems in-house. The Water Harvesting Certification technical training taught by Watershed Management Group in Tucson is the only one of its type in our region. The course will be taught October 7-13 of this year.

See http://watershedmg.org/tech-trainings I took this training a few years ago, and it really opened my eyes to the importance of water harvesting, and I know your people would get a lot out of this, too. There is a wealth of practical information that you can put to use right away.

I will be teaching a course in Tucson January 16-18 titled Urban Dryland Stream Restoration Technical Training. This is sponsored by Watershed Management Group. During this 3-day training in Urban Dryland Stream Restoration, participants will gain a basic understanding of how to read and assess landscape forms and processes, design of small-scale restoration features, and hands-on implementation of those features. Emphasis will also be placed on urban wash restoration approaches and practices from backyard to larger drainage scales.

http://www.streamdynamics.us/event/urban-dryland-stream-restoration-technical-training

## Conclusion

Since T or C is a small town, and seems very receptive to trying new solutions, it wouldn't be that hard for your municipality to not only fix the stated problem of downtown flooding, but to also become the stormwater harvesting leader in our state. I think this would dovetail well with the image of the historic hot springs and downtown area: Green Streets, trees instead of flooding, downtown beautification, etc. Stream Dynamics, Inc. would be delighted to work with you all on this exciting project.

**Assessment Sites and Photos from Wednesday, September 11**

1) Detention basin at Main and Jones

Note that the outlet for this detention basin is at the very bottom of the basin. If this were blocked off and a notch cut in the top of the wall, the outlet elevation would be significantly higher and the basin would have a greatly improved capacity. The present outlet could be narrowed to serve as a weep hole to drain the basin slowly in case long term ponding becomes an issue. I believe this is on city property.

2) Second Street and Lincoln

Here we see concentrated runoff from houses, streets, and driveways coming down the hill towards downtown and bringing sediment with it. There is room for basins to the side of the street to direct water off the street and cause it to soak into the ground. Along the rim of the basins, on city property, trees could be planted to provide shade, windbreaks, beauty, fruit, habitat, etc.

3) Second Street and Juniper

Bore holes in this curb could harvest water on city property in front of Commissioner Richter's house, and anywhere else that has this general layout. Look for places where the city owns the parkway (area between the curb and the sidewalk or property line).

4) Juniper and Lincoln

It would be easy to drain this dirt road to the landscaping to the north. Just make a small hole in the low rock wall and dig out a basin that is 18" lower than the puddle amongst the mesquite and creosote. This site is on private property, and the owner may be interested in doing this to alleviate the street flooding problem because his lot is down-slope from this large puddle and has flooded in past years.

5) Complex at Garst and Main Street

This one property contributes significantly to flooding and sediment downtown. This view is from the hill above. Note a mud pit in the center of the courtyard area. This site could easily be re-graded to improve parking and driveways, retain water on site, and grow badly needed shade trees.

Showing water and sediment flowing toward downtown on September 12. Water harvesting goes in the completely opposite direction from traditional drainage designs. Note that property owner has placed stones in the drainage ditch. This is a common theme: concentrate runoff from impervious surfaces such as roofs, parking areas and roads, then armor the drainage ways. This is what creates the accelerated runoff that is flooding downtown. In this case, proper water harvesting can completely eliminate the need for stones, drainage ditch and all this water disposal infrastructure! According to my assessment of this property, it would be very easy to retain 100% of the runoff from a very large rainstorm on site, transforming a nuisance into a benefit.

6) Juniper and Joffre

Looking down Joffre, which sends all its water down Juniper and towards downtown. There is plenty of opportunity to redirect runoff from this dirt street into basins in front of each house, and the neighborhood could use a few trees. Perhaps this could be done within the street right of way. Dirt roads and driveways contribute sediment as well as water to downtown.

7) Second and Copra

Copra is a dirt street that is sending sediment to Second Street. This creates a maintenance problem for the streets department, which needs to clean up sediment after every rainstorm. Water harvesting basins could eliminate this problem. Let's take a look at exactly where the city street right-of-way is to determine if there is enough room to do this project entirely on city property. If not, perhaps a few of the neighbors would like a water harvesting amenity on their properties.

8) Second and Popular

There is no easy way to drain a dirt road that is this steep. The solution is to trap the water on the flats above the steep part. The roof of the house drains to the driveway and parking area, and then to the street. Their wasteful water practices become a maintenance and safety problem for the city. Dirt on paved streets can be particularly hazardous to bicyclists.

9A) Second Street

Runoff from a private property upslope is creating an intractable problem for the city here. The spread out flow tracks demonstrate the large amount of runoff and sediment yield. Behind the photographer's back, this runoff has nowhere to go except off a steep bank. The city has to repair this bank after every major storm. The solution is to retain runoff on site, which is a large flat area at the top of the hill. The comprehensive solution to water flow problems will require public/private cooperation.

9B) Second Street looking north near the bottom of the hill.

There is a large low lying area to the east (right side of photo) where this street could be drained and the water retained on site. This would require permission from the landowner. What the city has done is put the runoff in a grate and a culvert on the left side of the photo, accelerating its exit out of town and toward Texas. This was a fair solution within the constraint of keeping water on public property once it gets there. Most of the water is coming from private property onto the public domain, however! This seems unfair.

10) Popular Street

Sediment coming off the dirt street is creating an alluvial fan deposition on the paved street. There is plenty of unused space in the lot in front of the blue house trailer. Near the fire plug would be a good place for a water harvesting basin. This would overflow over the curb to the street with clean water. In this situation, the basin would have to be cleaned out annually to prevent it from filling with sediment. Every piece of infrastructure needs at least some maintenance. Cleaning out sediment basins is less work and a safer transportation alternative to sweeping the streets after every storm.

11) AF-AM Building on Main Street

Mr. Mayor wondering why the water from the downspouts from this building is being wasted and allowed to flow towards downtown instead of going to a water harvesting basin. The west wall of this building could sure use some shade in the summer, and the water from the roof could be used to grow the trees for free. One important concept from water harvesting is "stacking functions.' This is done by building designs that simultaneously accomplish multiple objectives. In this case they would be:

A) Elimination of stormwater leaving this site and contributing to downtown flooding.

B) Growing trees to shade the building in the summer and save on energy for cooling.

C) Creating beauty, improving property values.

D) Improving quality of life for residents and visitors.

E) Improving water quality in the Rio Grande.

12) 617 Garst

A very low concrete curb could be cut hare to allow urban stormwater runoff to irrigate these lovely pecan trees instead of contributing to downtown flooding. This would also save the homeowner on his water bill, and the city on having to maintain water delivery infrastructure.

13) 625 Garst

Where Mayor Mulcahy and Buster Smith are walking is a muddy spot that would be hard to fix on city property. The solution here is to trap the water at the top of the driveway and prevent it from arriving to the public right of way.

Same property, east side. Same situation. It would be easy to keep this water and sediment from arriving to the public domain by water harvesting basins up on the level part of the building pad. Due to space constraints, it may be impossible to fix this particular problem within the public domain.

14) Metal fence on Garst

These mulberry trees could be getting a free drink instead of sending water and sediment onto the public right of way.

15) (place holder for my numbering system and photo database)

16) Old Foch Street

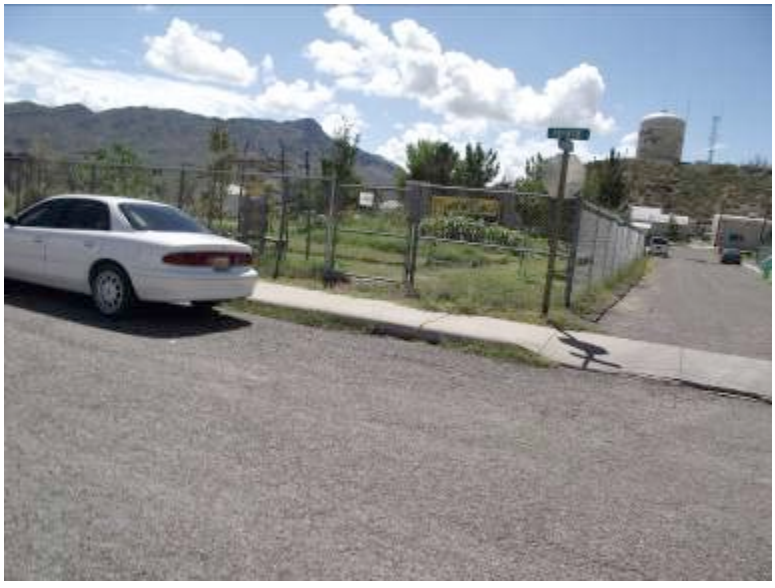
This curb could be cut to send runoff into a water harvesting basin to the left. I believe this may be on city property. In this case, a pipe would need to be installed under the sidewalk. This is a solid design concept for this site. To insure success, Stream Dynamics, Inc. would like to do a proper design with critical elevations, slopes, etc., and also be on site during construction. The devil is in the details with water flow projects, and an error in slope or elevation can cause a project to fail.

17) Filosa Park on Foch and Main


The curb on Foch Street could be cut where the mayor is standing (upper right of photo) to put more water into this detention basin. Right now, the only water it is getting is from the side street. Also, the outlet could be raised to significantly increase temporary storage capacity. This project is on city property.

18) Community Garden at 4th and Library

Curb cuts here could irrigate the row of fruit trees just inside the fence at the community garden. This is all on public land and would be a great water harvesting demonstration project.



19) Civic Center parking lot area.

This site would be good for a demonstration project on city owned land. These downspouts could conduct water under the sidewalk in a grate to arrive at water harvesting basins to grow trees for shaded parking.

Out by the street there is room to make a detention basin on city property.

20) Hanson Street Arroyo

This site is different from the others in that the sediment is coming from a non-urbanized natural area, and therefore has a more complicated solution.

This small watershed has many erosion gullies growing all over it. This has increased the amount of runoff and sediment yield. The treatment for this is to plug the gullies in such a way that the erosion is stopped, yet the overflow from this watershed still can get past the subdivision and people's houses. Stream Dynamics has treated many similar small watersheds with one rock dams, Zuni bowls and the technique known as Plug 'n Pond. If properly done, the runoff from this site would be significantly decreased, and the sediment volume and particle size would also be decreased. There will still be overflow, however. Fortunately, there is a good site on public land for a water harvesting detention and sediment clean-out basin.

This photo is looking up Hanson Street from the highway. On the left is the place to put the basin. This would have to be cleaned out on a periodic basis, but at least the sediment would not scatter across the highway during a rainstorm. This arroyo had flowed sediment across the highway the day before and had just been cleaned up by the city before our site visit.

20A) Municipal Golf Course

This site also has water and sediment arriving to it from a natural drainage area. The golf course was built spanning a desert wash that also drains a pretty large piece of country upslope. This is looking downstream at the start of the golf course. Note how wide and deep the arroyo is, and that it had been previously blocked off and culverted, and these treatments failed. The designer/builder of these treatments did not take into account the natural pattern established by the arroyo for water and sediment flow.

This view is looking downstream within the golf course. Note that the watercourse is very narrow and shallow. Large runoff events carrying a lot of sediment deposit this sediment on top of the fairways and it has to be cleaned off periodically. One solution to this is to construct a channel through the golf course that is deep and wide enough to carry most large flows. Natural arroyos have the ability to adjust their banks to accommodate the water and sediment flows that have been passed over the years. By measuring the size and shape of the arroyo upstream we can get a good template for the channel through the golf course.

**Runoff Assessment Thursday, September 12**

21) Foch Street Basins

This basin is contributing sediment to the street in the form of muddy water. This is because the outlet is so low that there is no longer any ponding effect to get the mud to settle out. This can be repaired by raising the outlet to create ponding, and also by cleaning out the portion of the basin in the vicinity of the outlet. Raising the outlet elevation will significantly increase the temporary storage capacity of this basin.

This basin on the other side of the street has filled in with sediment over the years. Also, why not cut the curb to allow water flowing in the gutter toward downtown to have a place to be detained?

21) Continued Foch Street Basins


This is Filosa Park at the corner of Foch and Main as discussed in item 17 above. After all the rains, the basin has filled to capacity - a pretty meager capacity! How about raising the outlet so we can get some real capacity here? The reason downtown floods is because water arrives there at a faster rate than it drains out.

Upslope from downtown in the source areas, we need to do everything practical to slow down the arrival of water.

Foch and Main, showing sediment in the water coming from the improperly maintained detention basin discussed above. At this low flow level, the water is turning left on Main Street. At higher flow, more of it will go straight down Foch to Broadway.

22) Garst and Juniper

Water from Lincoln and Joffre dirt streets comes down Juniper towards downtown. This needs to be intercepted above on Lincoln and Joffre as discussed in items 4 and 6 above.

23) Garst and Main

This photo is a repeat from site 5 above. Every property makes its individual contribution to the problem. Solving the problem at its source will take the cooperation of many people, but the solution is advantageous to them because it will improve their property values.

24) Clancy and Simms

Some water from Garst and Juniper comes here and could be detained in a basin along Main Street.

25) Broadway and Main

All flows turn and go down Broadway. There is lots of land here for water harvesting detention basins.

26) Broadway and Austin Area


North side of Broadway flows East toward downtown. This could be directed into a storm drain.

27) Clancy and Broadway

At this intersection, low flows on the north side of Broadway flow east toward downtown. Note ponding at center of intersection. The intersection could be altered to send all the water down Clancy and away from downtown. This will not create a new problem for Clancy Street, because the overflow from this pond goes there already.

28) Daniels and Broadway

Daniels already drains Broadway, but the intersection could be altered to drain water more efficiently and prevent ponding.

29) Foch and Broadway

Broadway flows downhill into Foch from both directions, so modifying this intersection to better transport water down Foch would do a lot to drain downtown.

30) Pershing and Broadway

Water from the east flows west on Broadway and crosses the Pershing Street intersection. By modifying the 3 dimensional shape of the intersection, this water could be directed down Pershing and eliminate this large puddle. Downside: Less fun for gonzo teenage drivers!

31) Mims and Broadway

At this intersection, the north side of Broadway flows west towards downtown. This could be directed down Mims.

32) Date and Joffre

Out of focus photo showing a detention basin that could use some improvements. We are under-utilizing the capability of the existing system here. Curb cut on Date could direct water into detention basin instead of sending it directly into the storm drain system. If you go and look at this basin, the outlet culvert is at the very bottom of the basin, so it has essentially zero capacity. The outlet could be raised easily by adding a 90 degree elbow and a section of pipe.

33) Pershing and Second

All this water is coming from residential neighborhoods and could easily be harvested instead of sending it directly to the river.

34) Pershing and 6th Street

Water from a drainage ditch is causing flooding of city streets here. I have done calculations based on Santa Fe rainfall rates (which are pretty close to T or C), and believe that most of this runoff could be eliminated if every 4th house in the upslope neighborhood had a water harvesting landscape feature.

35) Upper Pershing Street

There is plenty of land here to create beautiful water harvesting earthworks and to cause this water to slow down, spread out, and soak into the ground.

**Treatment Technologies**

**1) Pipe set in curb**

This was made by cutting out a 18" section of concrete curb and gutter, then re-pouring the concrete with a pipe set below the grade of the gutter. The pipe has a 2% slope or more. Note the wave form in the gutter to direct water into the pipe. The critical elevations in both of these examples (above and below): 1- It is essential for the basin inlet to be the lowest elevation part of the gutter. 2- the difference between the basin inlet and the bottom of the basin is your nominal pond depth. 3- the bank of the pond is at the same or higher elevation as the curb. This means that this treatment never contributes to flooding of the nearby property. This type of treatment works well where there is a parkway, or sliver of land behind the curb that is at the same elevation as the curb. Note that there is no overflow. These are "oxbow" ponds. Water can flow into them, but the only way it flows out is by soaking into the soil. The first flush of stormwater, which has the most pollution in it, goes into the basin where it is bio-remediated by the soil microorganisms instead of going directly into the river.

**2) Bore hole in curb**

In Tucson, Arizona there are several contractors who have concrete bore drills mounted on a truck. This works well if you have a soft asphalt gutter and a concrete curb. The drill is able to cut a bit into the asphalt gutter to insure base flow enters the basin.

### 3) Poured Concrete diversion

For steep streets it is necessary to make sure the water harvesting diversion is steep enough and deep enough to redirect fast flowing water. In this case, the concrete curb and gutter have been removed with a concrete cutting saw and jack hammer, and a new diversion gutter has been poured and carefully sculpted to direct the water toward a water harvesting system. Remember - you can't merely redirect the water to someplace else - you have to have a planned overflow.

### 4) Cut Concrete diversion

Removing old concrete is a lot of hard work. Then you have to make a form, buy and pour concrete and tool it as it cures. This takes a lot of time, about 6 man hours. Where practical, you can just cut out the curb and then grind down the gutter to make your diversion. This can be done in less than two hours, uses no materials and creates less waste.

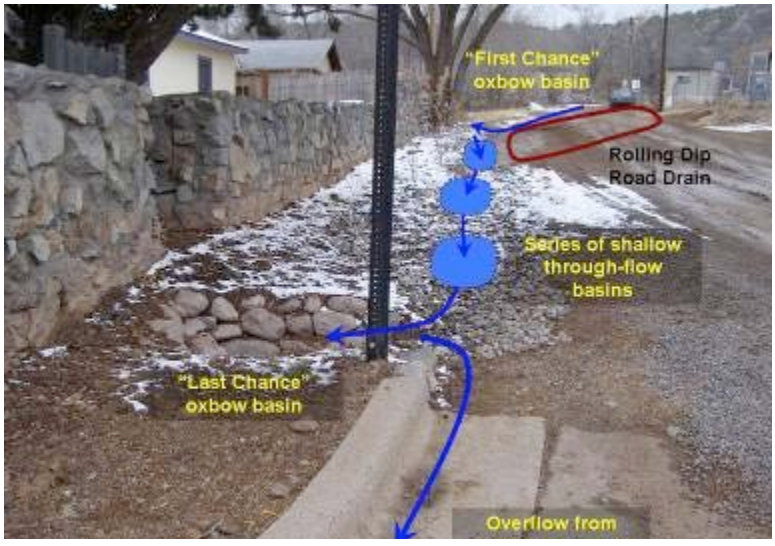
**5) Streetside oxbow basin**

Before: Storm water runs off dirt street and into this yard, which is below grade. Property owner had tried to block flow with hay bales and bags of concrete.

Elegant design can simultaneously solve several problems. In this case, my client's property was getting flooded, so she was blocking the flow with hay bales and trying to keep the runoff on the street.

After: Cinder block wall built 4 feet inside property line and integrated into existing wall to create a private space for storage and a public space for oxbow water harvesting basin. Landform and path to new gate is now shaped uphill towards wall. To capture first flow, inlet of basin is 3" below high point in outlet channel. Planting shelf is two inches above this outlet elevation, and planted with native shrubs to beautify the public right of way.

A newly built wall creates a space for an oxbow basin to catch sediment from this dirt street, then overflow to a series of shallow basins along the side of the street within the public right of way. The first basin needs to be cleaned out with a shovel 2-3 times per year because it will lose capacity as it fills in with sediment from the dirt street. The material is applied to the berm in the street to maintain its height.




This system prevents sediment from getting on the paved street from the dirt street above. This is a common problem. Cleanout basins as part of a water harvesting system, if properly maintained, will keep the streets free of sediment during and after major rainstorms.

**6) Oxbow diversion from drainage ditch**

This is a hand dug diversion that intercepts water from a street side drainage ditch. When the ditch flows, the first flush of water is diverted into the basin. Since the banks of the basin are higher than the banks of the ditch, once the basin is full, water continues to flow past it in the ditch. During the entire runoff event the basin is kept topped off as it soaks water into the ground.

Aldo Leopold High School Youth Conservation Corps digging the basin in 2006.

This site at State and Virginia Streets in Silver City. site is called Silva Creek Botanical Gardens. Since the water harvesting feature was built, volunteers from the Native Plant Society have planted 125 different native plant species. All are growing on harvested rainwater!

**7) Street runoff going over steep bank**


This small side street used to drain off a steep bank and the city periodically would dump a load of dirt to prevent this from eroding the bank. This resulted in ponding at the end of this street.


The street was reshaped, creating a series of basins that eventually overflowed to a rock rundown off the bank.

The street is now properly drained and the water is going to landscaping vegetation. The roots of the many grasses, wildflowers and young trees open up pathways in the soil and greatly increase percolation. The overflow has only flowed once in four years.

**8) Large curb cut to large oxbow basin on city property**

This five acre urban sub-watershed in Santa Fe used to drain straight to the Arroyo Chamisos.

Now it first has to fill in a large porous basin that has been planted with trees. The water is cleaned as it goes sub-surface into the aquifer.

In my opinion, T or C needs to do a project that would accomplish this at the downstream end of town before stormwater enters the Rio Grande. Since the water table is so high there, this would result in the expansion of the existing wetlands.

**9) Rolling Dip Road Drain**

This is a very important road drainage system for all dirt roads. It is very easy to build and reduces maintenance. The same thing can be used for paved roads. This is a bit more work because you first have to remove the asphalt, then reshape the street, then replace the asphalt.

This steep driveway was trapping all of the runoff from the house and parking area above in a roadside ditch that drains to the county road at the bottom of the hill. Previously, large runoff events would remove the driveway surfacing and clog the culvert in the ditch along the county road.

Reconfigured with a "Rolling Dip" road drain, a short section of the downhill-trending road runs uphill. Water, as you know, does not flow uphill. It is directed to the side and into a water harvesting basin. Note also that the driveway has cut through a ridge. The original drainage design transferred water from one sub- watershed into another. The corrected drainage design keeps water in its originating sub-watershed. By reading the landscape we can get clues as to how to fix drainage problems.

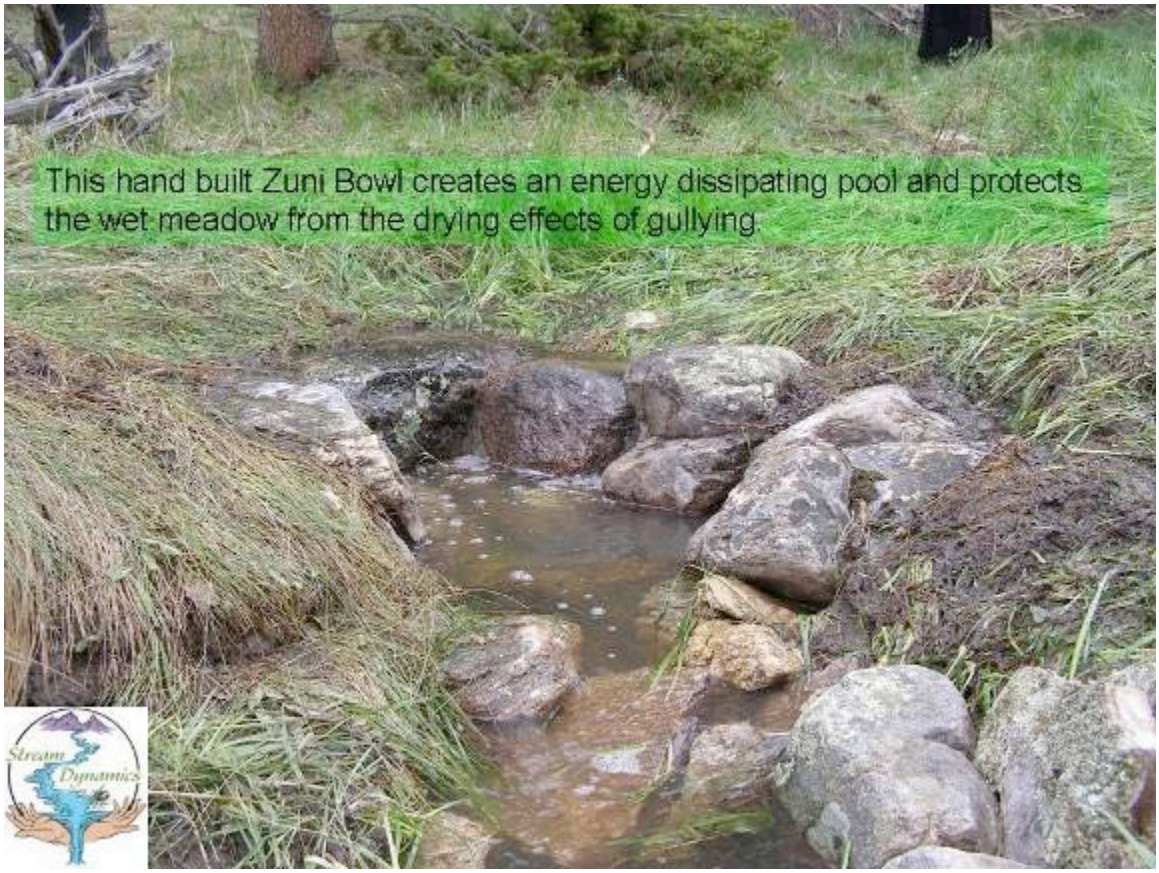
10) One-Rock Dam

Photo 1: day of construction - note the footprints of the workers. This is a structure designed to stabilize small degraded arroyos and cause them to start a regenerative process of growing vegetation. This reduces sediment and flooding problems as the vegetation holds on to the sediment in the bed and banks of the arroyo, creates roughness, and causes the water to slow down, spread out, and soak into the ground more.

Second photo: after one runoff event in this two square mile drainage in southeast Arizona near the Mexican border.

Water harvesting by slightly detaining flows has caused a flush of grass to grow in the arroyo bottom. This reduces sediment yield and the grass roots increase percolation - reducing runoff.

11) Zuni Bowl




This is the type of structure necessary to stop the headcuts in the Hanson Street Arroyo.