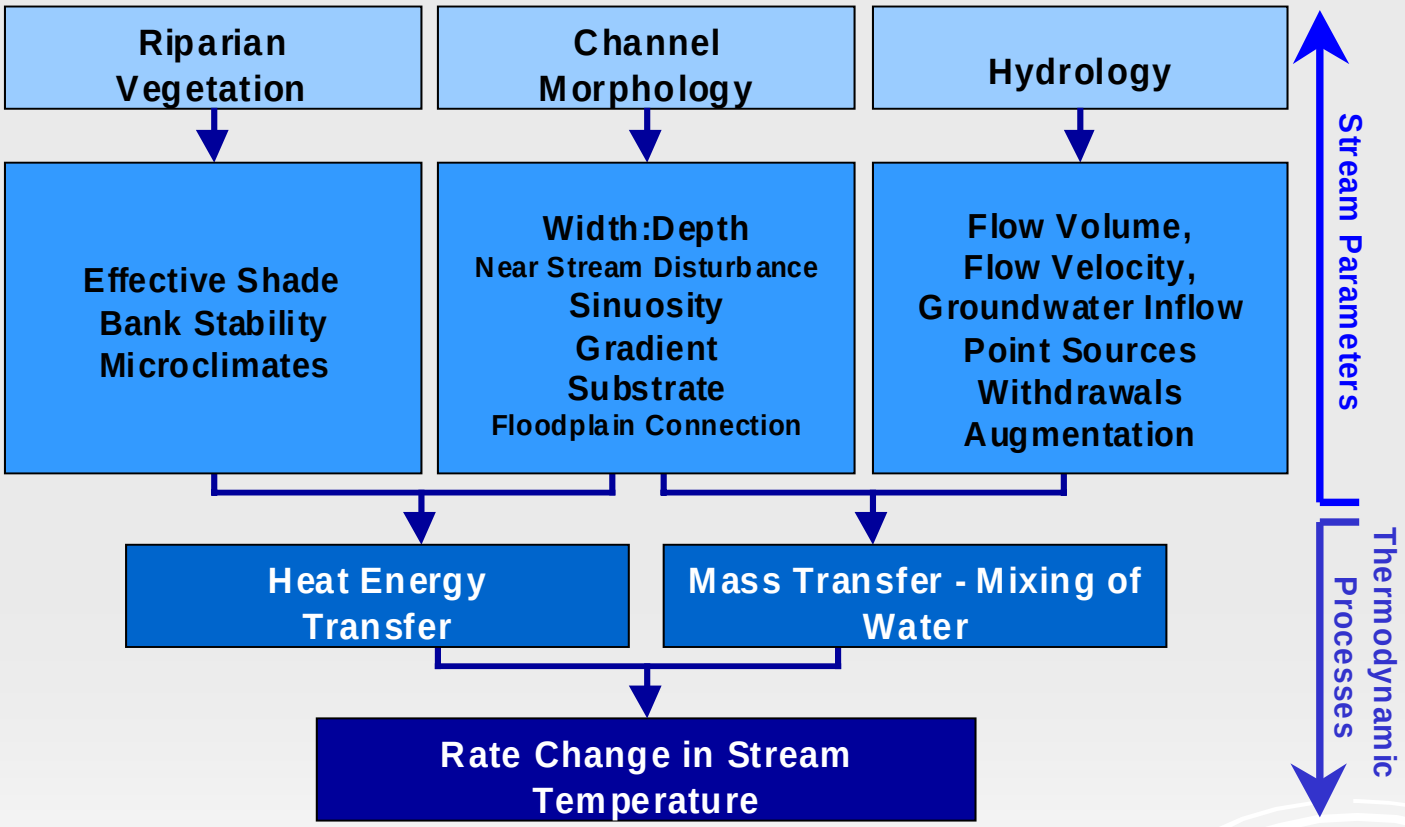
Potential Natural Shade for Temperature TMDLs

- by Mark Shumar, State Technical Services Office, Idaho Dept. of Environmental Quality

Natural Stream Temperature

- Air Temperature
- Direct Solar Radiation
- Ground Water Temperature
- Hydrology/Morphology
- Floodplain Connectivity

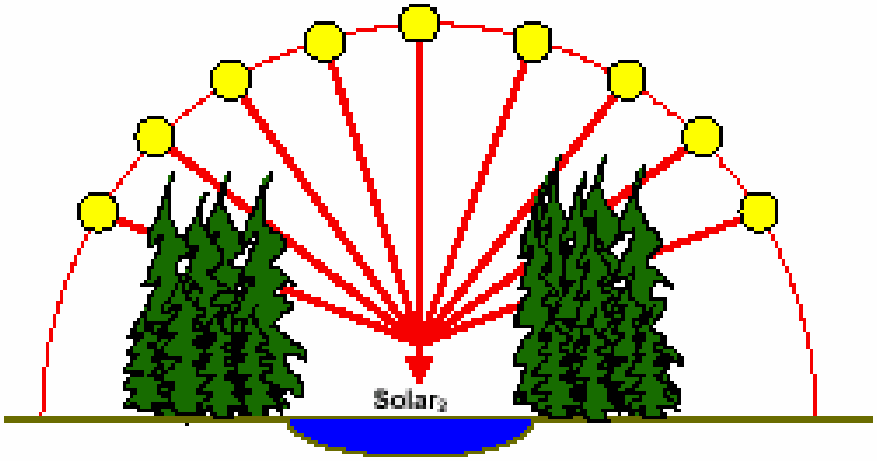
Stream Temperature Conceptual Model Flow Chart



Effective Shade

Effective Shade Defined

$Solar_1$ – Potential daily direct beam solar radiation load adjusted for julian day, solar altitude, solar azimuth and site elevation.



$$\text{Effective Shade} = \frac{(Solar_1 - Solar_2)}{Solar_1}$$

Where,

$Solar_1$: Potential Daily Direct Beam Solar Radiation Load

$Solar_2$: Daily Direct Beam Solar Radiation Load Received at the Stream Surface

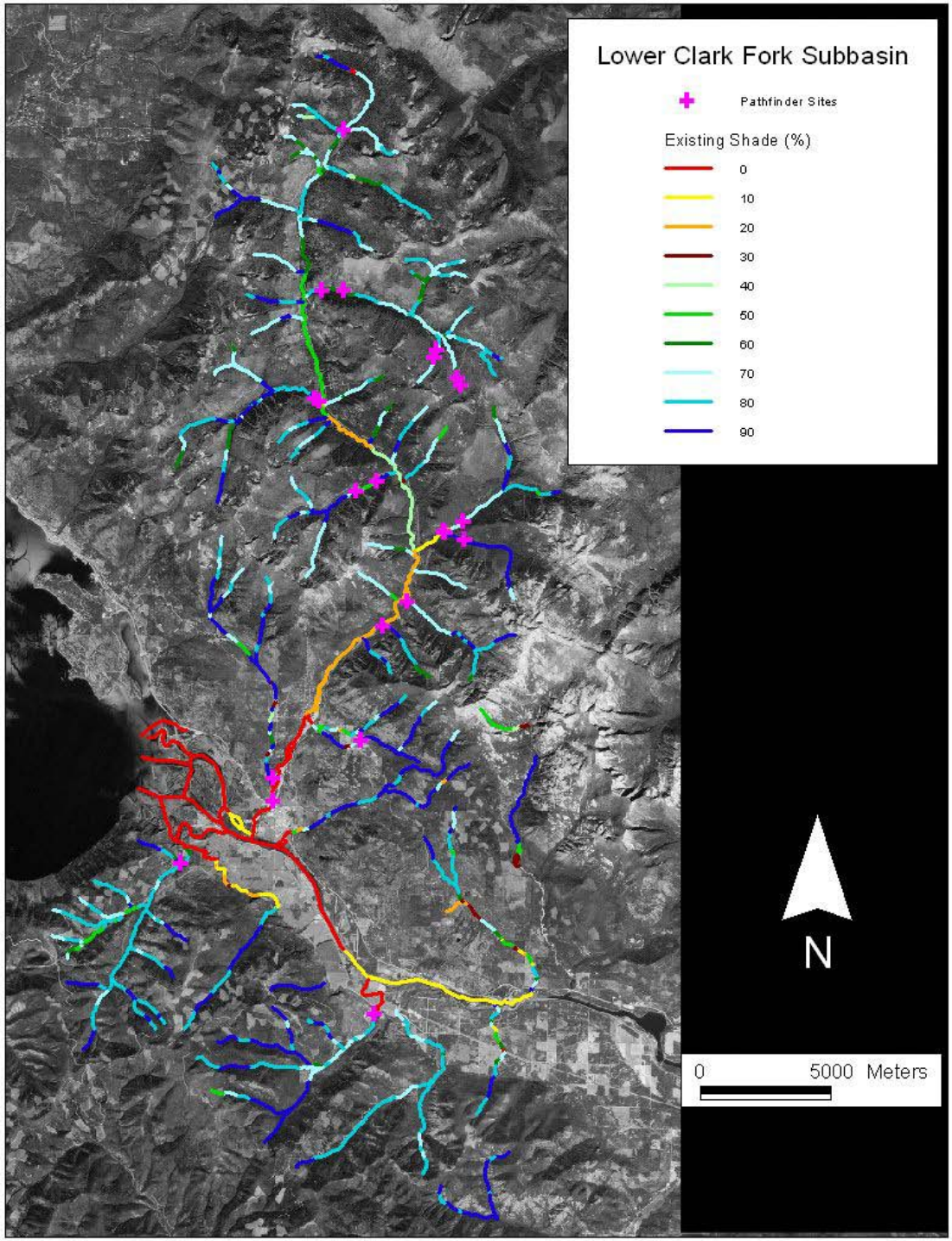
Potential Natural Vegetation

- Provides the optimal effective shade (along with topography)
- Produces natural stream temperatures (assuming no point sources)
- Equivalent to natural background conditions in Idaho WQS

Temperature TMDL

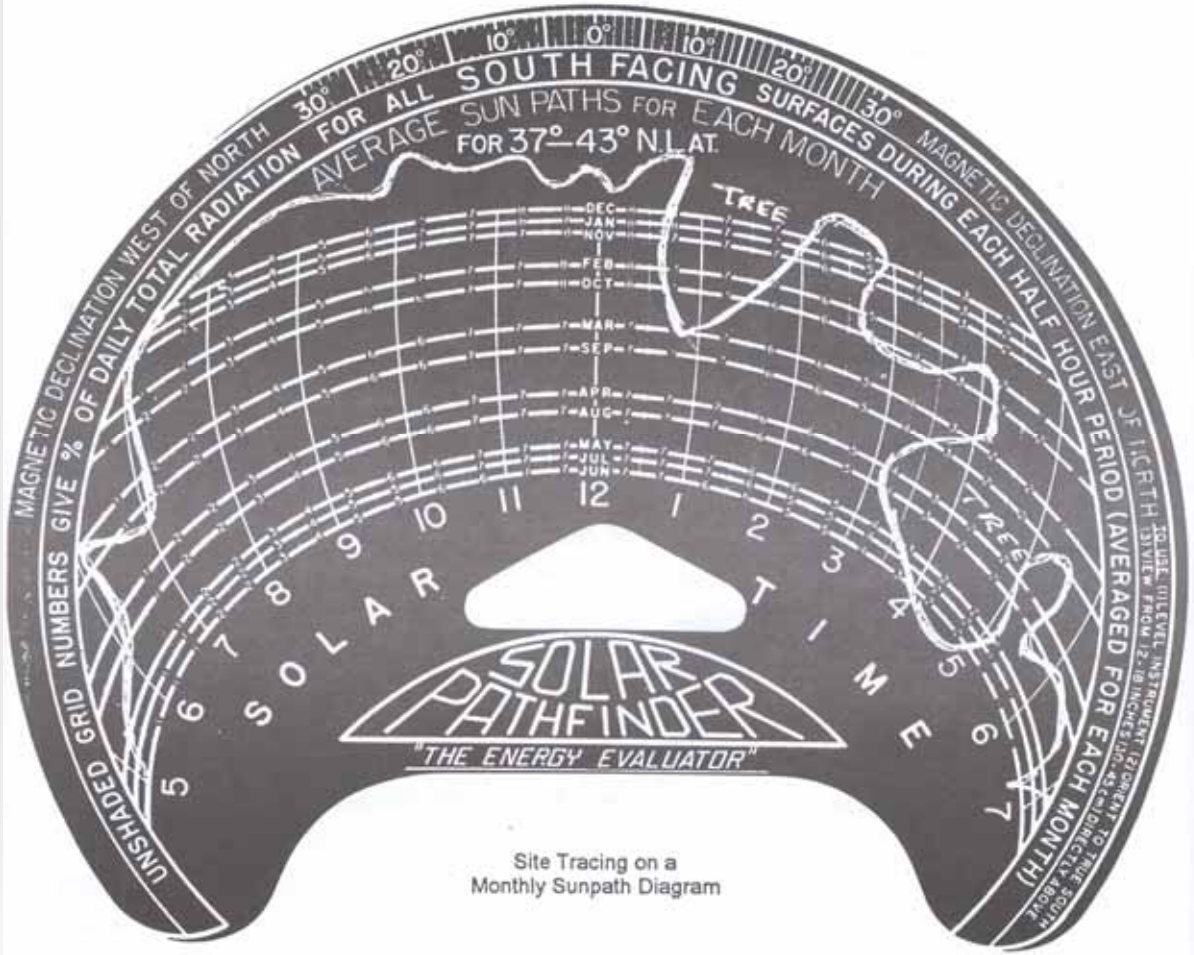
- Loading Capacity = Solar Load under PNV
- Existing Load = Solar Load under existing effective shade
- Load Reduction = PNV Load – Existing Load

Existing Effective Shade Aerial Photo Interpretation


Lower Clark Fork Subbasin
Pathfinder Sites
Existing Shade (%)
0
10
20
30
40
50
60
70
80
90
N
0
5000 Meters

Existing Effective Shade Field Verification

Monthly Sunpath Example



Site Tracing on a
Monthly Sunpath Diagram

aerial class	pathfinder actual	pathfinder class	delta	
70	67.9	60	10	
90	90.9	90	0	
80	56.9	50	30	
40	54.1	50	-10	
90	91.9	90	0	
80	86.9	80	0	
70	90.8	90	-20	
80	87.6	80	0	
0	7.1	0	0	
10	25.7	20	-10	
90	78.5	70	20	
10	50.3	50	-40	
90	73.3	70	20	
62	66	62	0	average

Potential or Target Shade

Shade Calculator (ODEQ)
Computer Model

Potential Effective Shade

Geometric Relationship that Influence Shade Production

Solar Altitude and **Solar Azimuth** are two basic measurements of the sun's position. When a stream's orientation, geographic position, riparian condition and solar position are known, shading characteristics can be simulated.

Solar Altitude measures the vertical component of the sun's position
Solar Azimuth measures the horizontal component of the sun's position

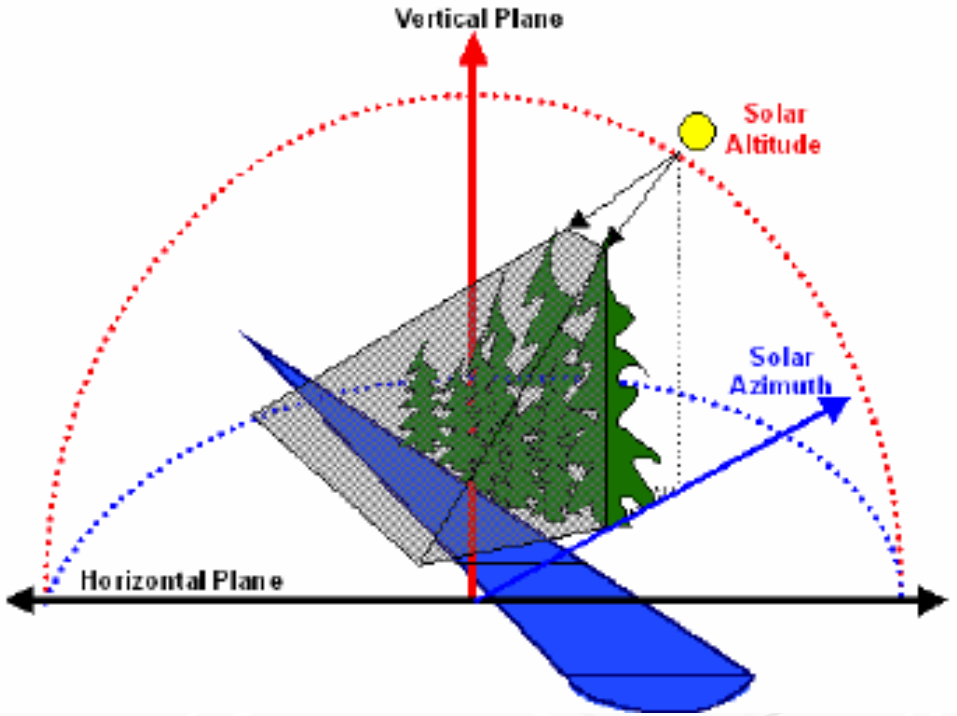


Figure 10. Effective Shade Curve – Application in Ponderosa Pine/Common Chokecherry Habitat Type

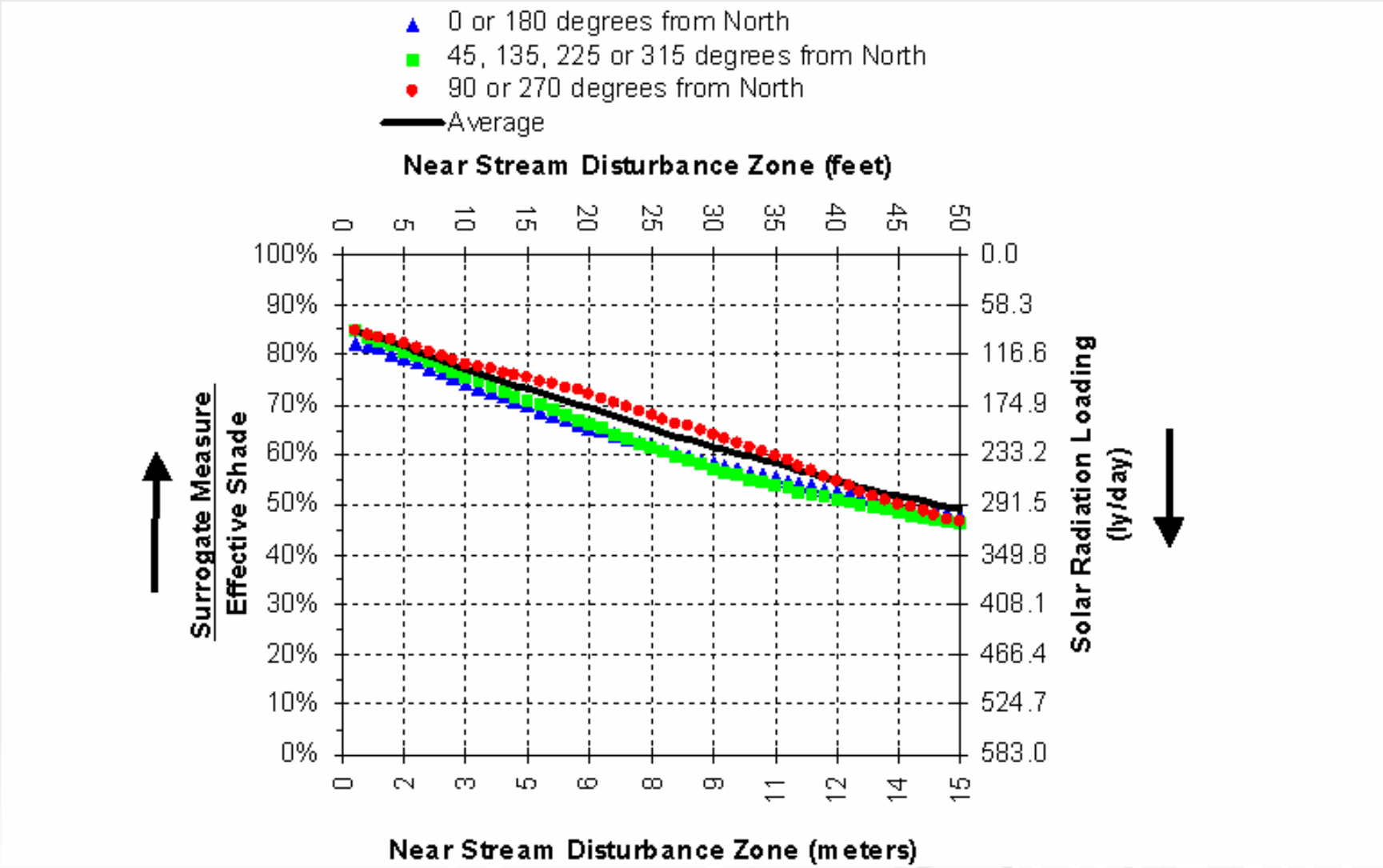
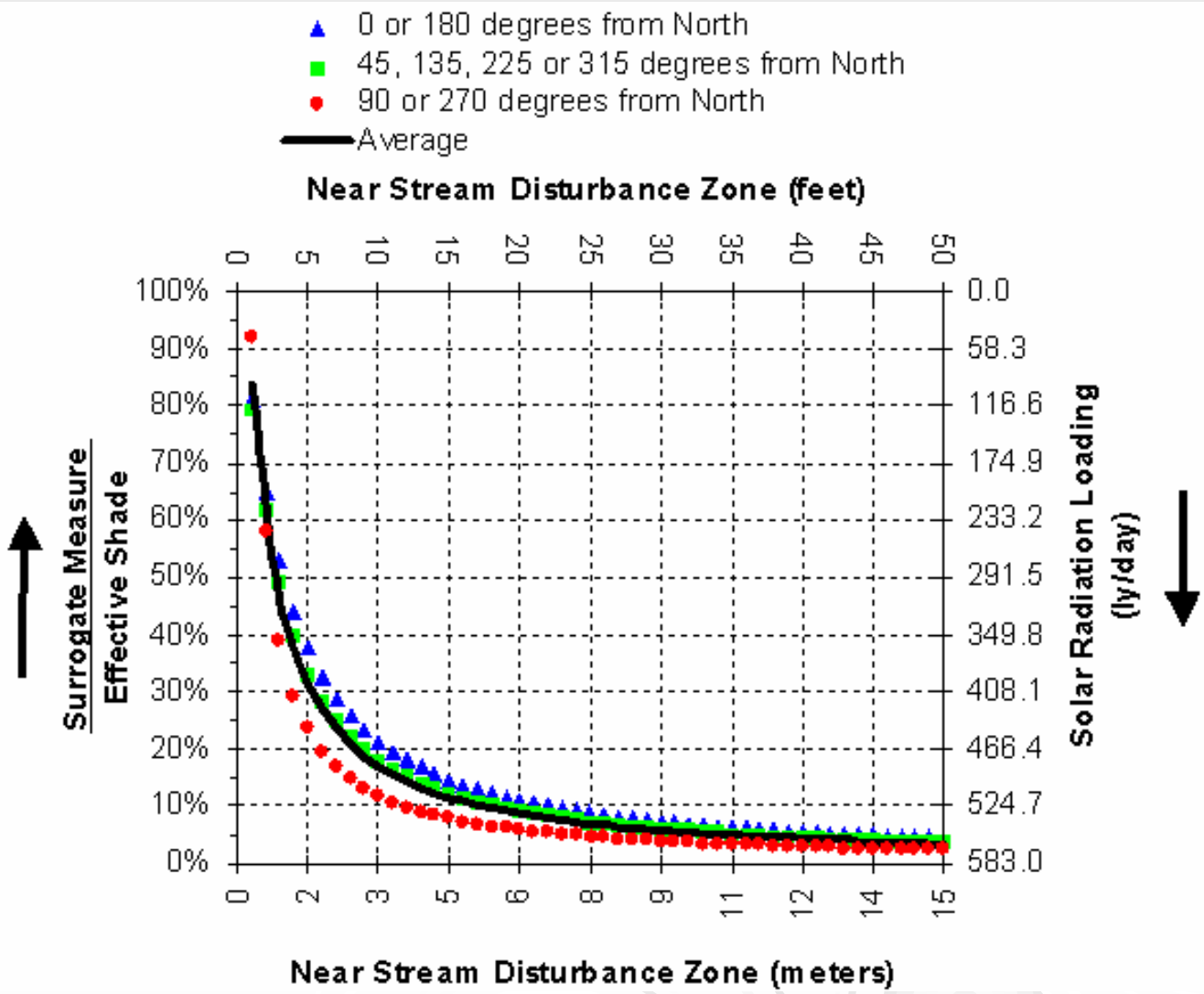


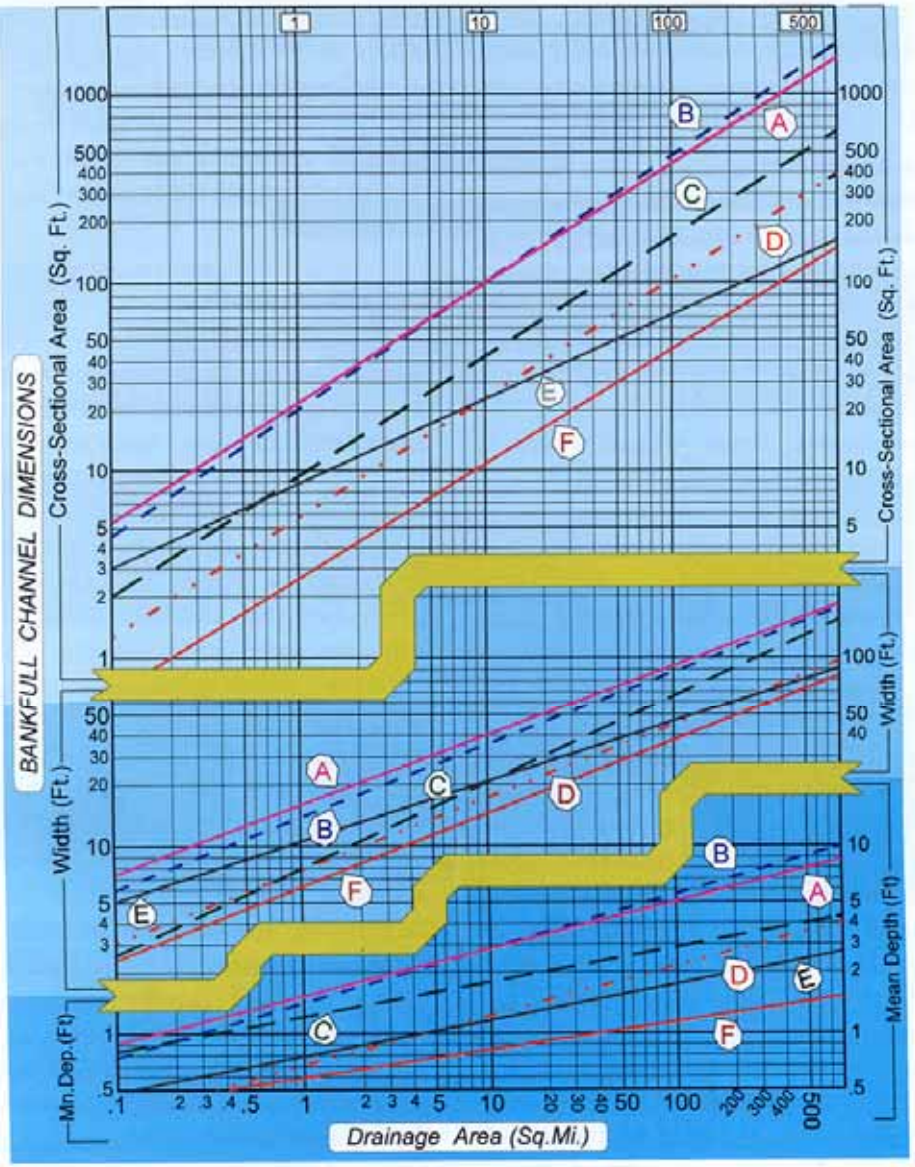
Figure 8. Effective Shade Curve – Application in Meadow Habitat Type – Tufted Hairgrass



Natural Channel Widths

Drainage Area Relationships

Existing Bankfull Widths



A: San Francisco Bay region at 30" annual precipitation.*

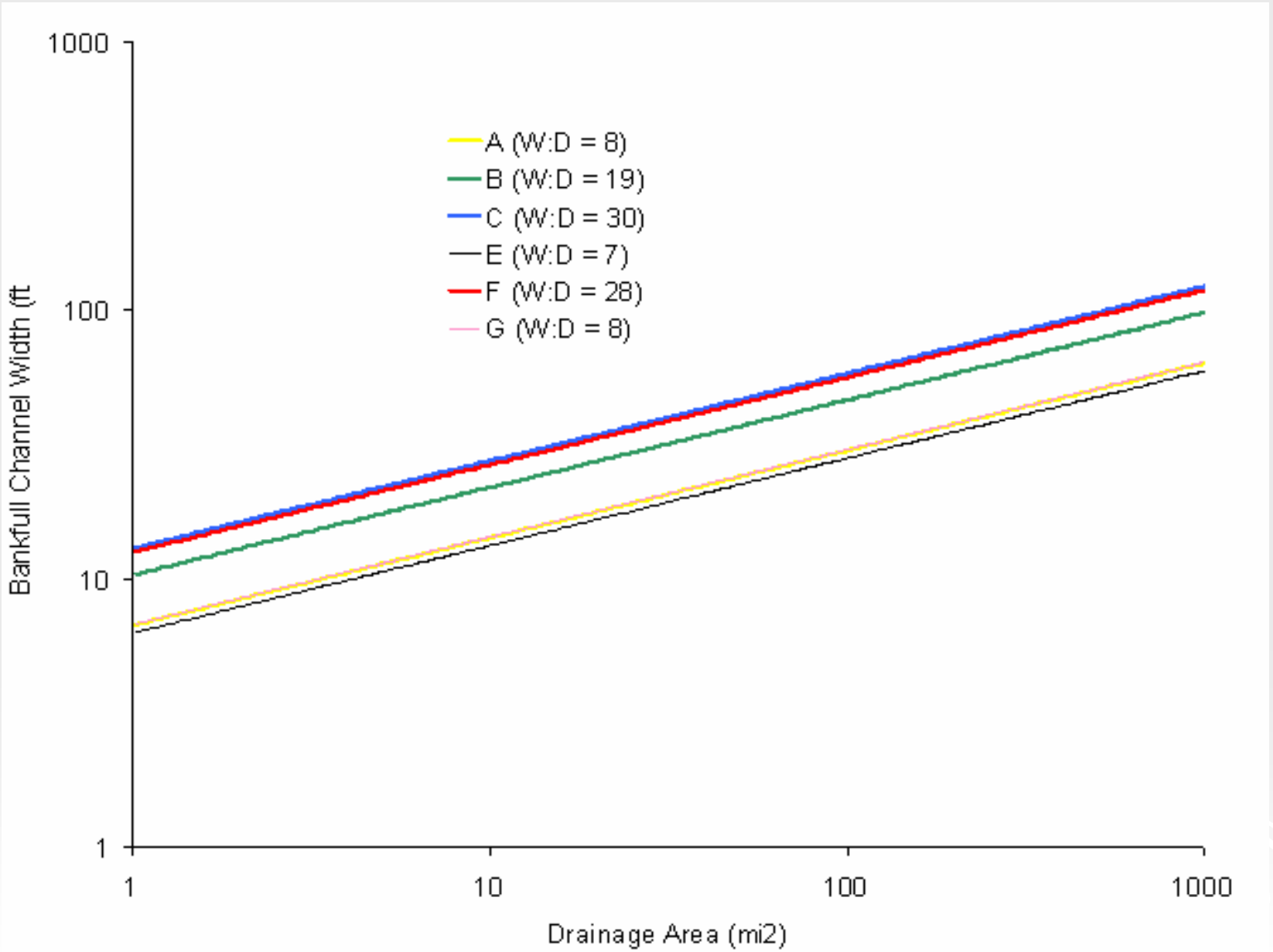
B: Eastern United States.*

C: Upper Green River, Wyoming.* Dunne and Leopold, 1978.*

D: Upper Salmon River, Idaho.* (Emmett, 1975)

E: Colorado.*

F: Zuni Mountains, New Mexico.* Jackson, 1994.*


1000
100
10
1
Bankfull Channel Width (ft
A (W:D = 8)
B (W:D = 19)
C (W:D = 30)
E (W:D = 7)
F (W:D = 28)
G (W:D = 8)
1
10
100
1000
Drainage Area (mi2)

LCF Natural Stream Widths

- Existing bankfull widths in Upper Trestle Creek are 35% greater than bankfull width estimated by drainage area.
- A 35% increase (rounded to nearest whole meter) was applied to all natural bankfull widths estimated by drainage area for the LCR subbasin. (e.g. 2m + 35% = 2.7 = 3m)
- Thus, natural bankfull widths used in the loading analysis are ~ 35% greater than widths estimated by drainage area.

Table 1. Effective Shade Targets for the Forested Tributaries Vegetation Type.

Effective Shade Curves	Stream Width (m)													
	2	4	5	8	10	12	14	18	19	21	24	28	40	54
VRU 8	95	92	89	85	81	75	72	65	63	58	56	49	40	31
VRU 10	90	89	80	73	68	62	54	45	46	42	39	35	36	20
Mattole River	92	92	92	91	90	89	87	84	83	82	78	75	64	52
Willamette Basin	94	88	86	81	77	73	64	55	54	52	49	44	38	30
Target Class (%)	**90**	**90**	**80**	**80**	**80**	**70**	**70**	**60**	**60**	**50**	**50**	**50**	**40**	**30**

Table 2. Effective Shade Targets for the Forest/Shrub Mix Vegetation Type.

	Stream Width (m)			
Effective Shade Curves	7	8	11	40
Alvord Lake	62	64	51	-
Walla Walla	86	85	78	25
Mattole River	91	89	86	31
Willamette	67	65	53	23
Target Class (%)	**70**	**70**	**60**	**20**

Solar Load Calculations

Segment Length (meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)
999	0.8	5.5 x (1 - 0.8)	0.9	5.5 x (1 - 0.9)	Potential - Existing

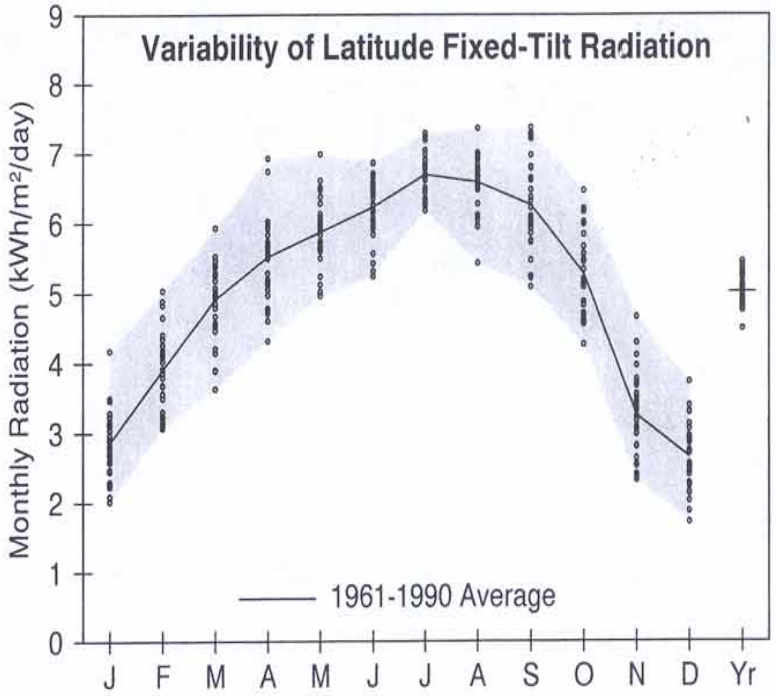
Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)
999 x 2	Area x Above	2	Area x Above	Potential - Existing

Pocatello, ID

WBAN NO. 24156

LATITUDE: 42.92° N
LONGITUDE: 112.60° W
ELEVATION: 1365 meters
MEAN PRESSURE: 864 millibars

STATION TYPE: Secondary



Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.7	2.6	3.8	5.1	6.2	7.0	7.3	6.3	5.0	3.5	2.0	1.5	4.3
	Min/Max	1.4/2.1	2.3/3.0	3.0/4.3	4.2/6.2	5.2/7.3	5.8/7.8	6.7/8.0	5.3/7.0	4.2/5.7	3.0/4.0	1.6/2.4	1.2/1.8	4.0/4.6
Latitude -15	Average	2.6	3.6	4.7	5.6	6.3	6.8	7.3	6.8	6.1	4.9	2.9	2.3	5.0
	Min/Max	1.9/3.6	2.9/4.6	3.6/5.7	4.5/7.0	5.3/7.5	5.7/7.6	6.7/7.9	5.7/7.6	5.0/7.2	4.0/5.9	2.2/4.1	1.6/3.2	4.5/5.4
Latitude	Average	2.9	3.9	4.9	5.5	5.9	6.2	6.7	6.6	6.2	5.3	3.2	2.6	5.0
	Min/Max	2.0/4.2	3.1/5.0	3.6/5.9	4.3/6.9	4.9/7.0	5.2/6.9	6.2/7.3	5.4/7.3	5.1/7.4	4.3/6.4	2.3/4.6	1.7/3.7	4.5/5.4
Latitude +15	Average	3.0	4.0	4.8	5.1	5.2	5.4	5.8	6.0	6.0	5.3	3.4	2.8	4.7
	Min/Max	2.1/4.5	3.1/5.2	3.5/5.9	4.0/6.4	4.4/6.2	4.5/5.9	5.4/6.3	4.9/6.7	4.8/7.1	4.3/6.6	2.3/4.9	1.8/4.0	4.2/5.2
90	Average	2.9	3.6	3.8	3.4	3.0	2.8	3.1	3.7	4.4	4.5	3.1	2.7	3.4
	Min/Max	1.9/4.3	2.6/4.6	2.7/4.6	2.7/4.3	2.7/3.5	2.5/3.0	2.9/3.3	3.1/4.1	3.5/5.2	3.5/5.6	2.0/4.5	1.7/3.8	3.0/3.8

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m²/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m²/day)	Potential Load minus Existing load (kWh/m²/day)	Gordon Creek
530	0.7	1.65	0.9	0.55	-1.10	
450	0.4	3.3	0.9	0.55	-2.75	
1730	0.8	1.1	0.9	0.55	-0.55	
155	0.7	1.65	0.9	0.55	-1.10	tributary
200	0.8	1.1	0.9	0.55	-0.55	tributary
Segment Length (meters)	Segment Area (m²)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
530	530.00	874.50	1	291.50	-583.00	
450	1350.00	4455.00	3	742.50	-3712.50	
1730	6920.00	7612.00	4	3806.00	-3806.00	
155	155.00	255.75	1	85.25	-170.50	tributary
200	600.00	660.00	3	330.00	-330.00	tributary
Total	**9,555.00**	**13,857.25**		**5,255.25**	**-8,602.00**	**-62**

% Reduction

Segment Length (~miles)	Existing Shade (fraction)	Existing Summer Load (kWh/m²/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m²/day)	Potential Load minus Existing load (kWh/m²/day)	Lightning Creek
0.15	0.9	0.55	0.9	0.55	0.00	
0.15	0.8	1.1	0.9	0.55	-0.55	
0.6	0.9	0.55	0.9	0.55	0.00	
0.1	0.7	1.65	0.8	1.10	-0.55	
1.8	0.7	1.65	0.8	1.10	-0.55	pathfinder = 73.3%
0.25	0.7	1.65	0.7	1.65	0.00	
0.35	0.6	2.2	0.7	1.65	-0.55	
0.4	0.7	1.65	0.7	1.65	0.00	ab Moose
0.25	0.6	2.2	0.7	1.65	-0.55	
0.45	0.7	1.65	0.7	1.65	0.00	
0.6	0.8	1.1	0.7	1.65	0.55	ab Quartz
0.6	0.7	1.65	0.6	2.20	0.55	
0.9	0.6	2.2	0.6	2.20	0.00	ab Rattle
3.7	0.5	2.75	0.6	2.20	-0.55	pathfinder = 50.3%
1.45	0.2	4.4	0.5	2.75	-1.65	
3	0.4	3.3	0.5	2.75	-0.55	ab EF
5.3	0.2	4.4	0.5	2.75	-1.65	pathfinder = 25.7%
3.5	0	5.5	0.3	3.85	-1.65	pathfinder = 7.1%

Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
241.4	724	398	3	398	0	
241.4	724	797	3	398	-398	
965.6	2897	1593	3	1593	0	
160.9	805	1328	5	885	-443	
2896.8	14484	23899	5	15933	-7966	ab Gem
402.3	4426	7302	11	7302	0	
563.3	6196	13631	11	10223	-3408	
643.7	7081	11684	11	11684	0	ab Moose
402.3	5633	12392	14	9294	-3098	
724.2	10139	16729	14	16729	0	
965.6	13518	14870	14	22306	7435	ab Quartz
965.6	15450	25492	16	33989	8497	
1448.4	23175	50984	16	50984	0	ab Rattle
5954.6	113137	311126	19	248901	-62225	ab Wellington
2333.5	56005	246423	24	154014	-92409	
4828.0	115873	382380	24	318650	-63730	ab EF
8529.5	238827	1050837	28	656773	-394064	ab Cascade
5632.7	304166	1672913	54	1171039	-501874	Cascade to mouth
Total	**933,259**	**3,844,779**		**2,731,097**	**-1,113,682**	**-29**

% Reduction

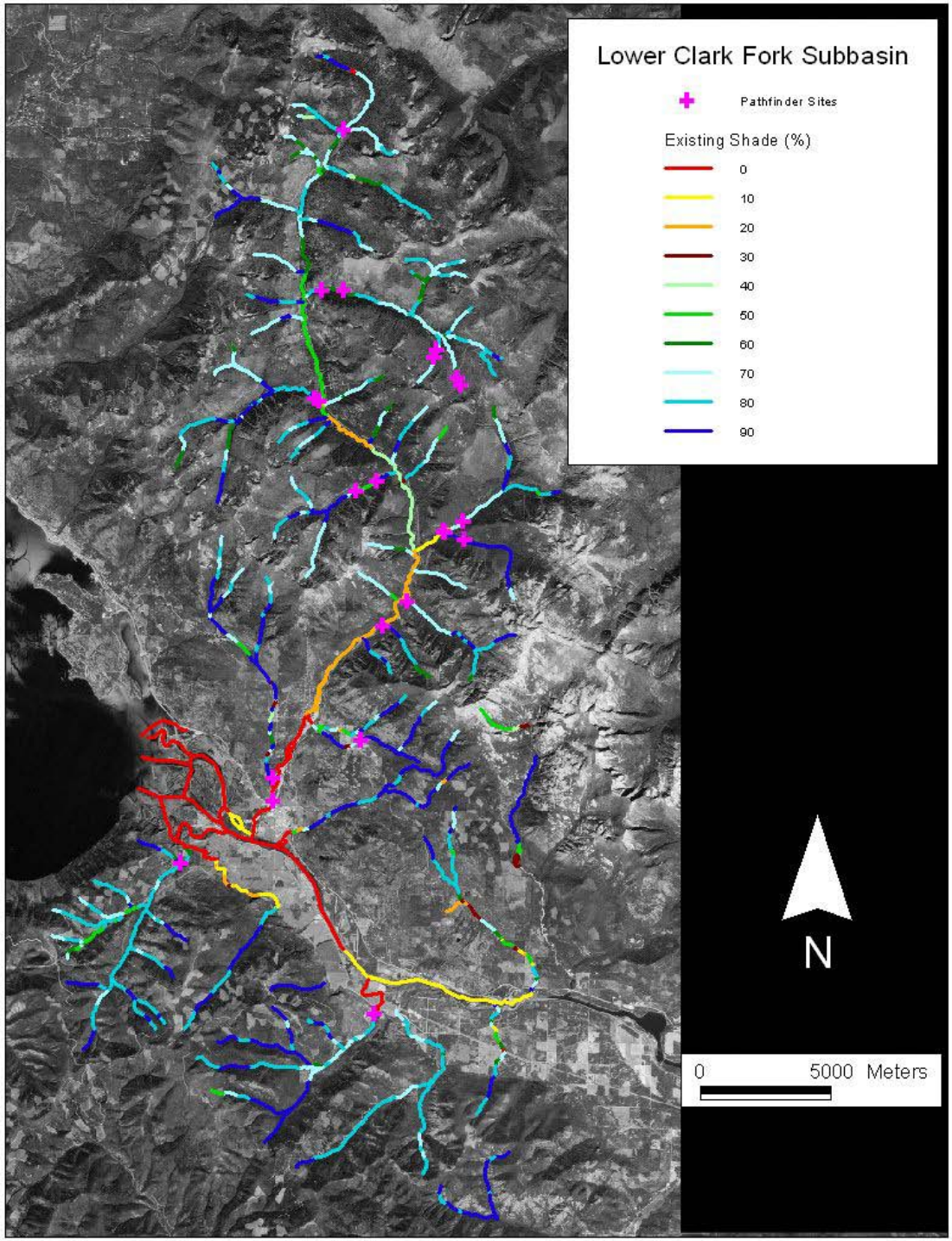

Lower Clark Fork Subbasin
Pathfinder Sites
Existing Shade (%)
0
10
20
30
40
50
60
70
80
90
N
0
5000 Meters

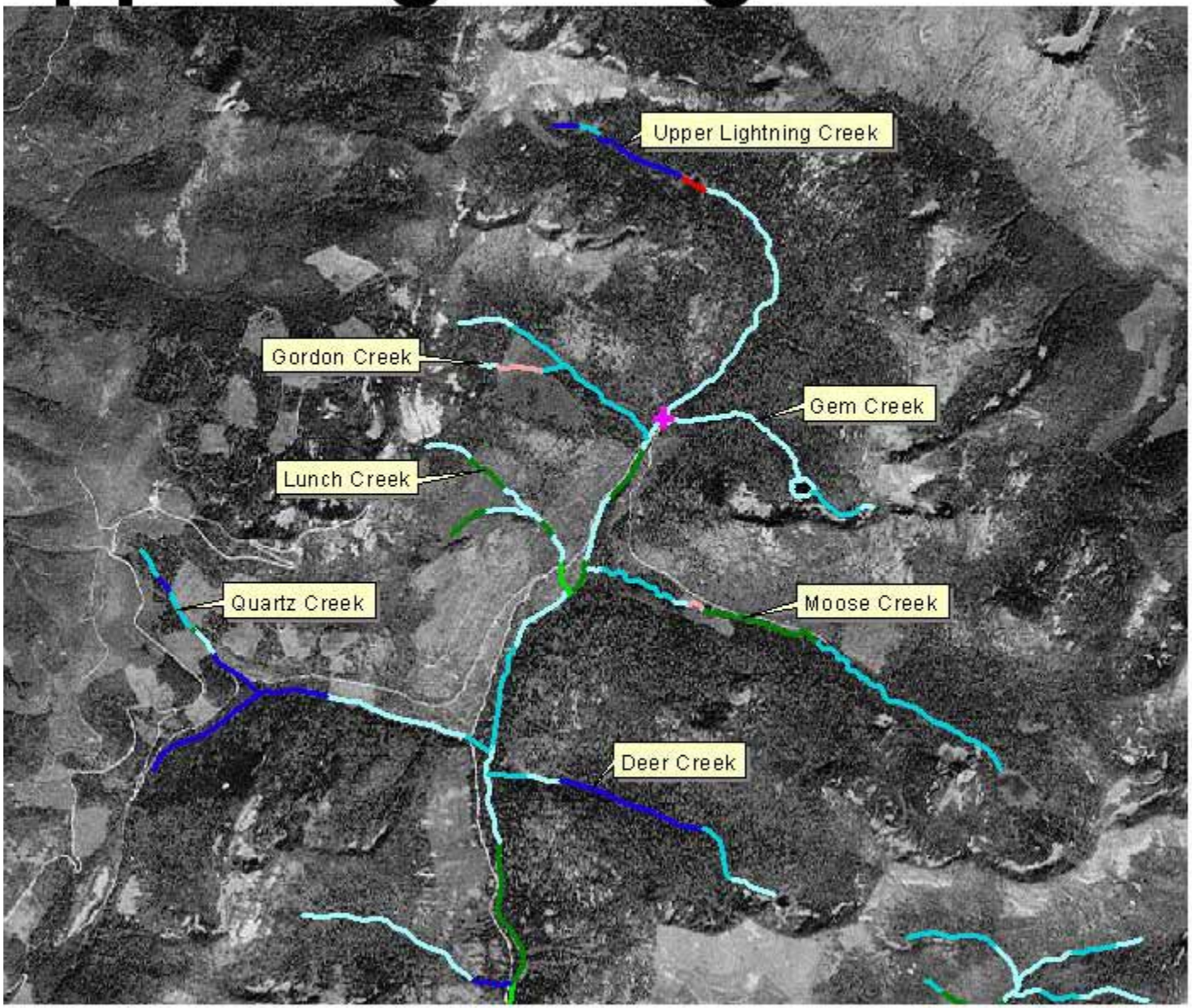
Table 31. Excess Solar Load and Percent Reduction to Achieve Loading Capacity for the Lower Clark Fork River and Associated Tributaries.

Water Body	Excess Load (kWh/day)	Percent Reduction
Lower Clark Fork River	1,279,300	8%
Derr Creek	174,416	28%
Twin Creek	94,936	39%
Gold Creek	60,657	55%
Mosquito Creek	39,548	39%
West Johnson Creek	29,629	59%
Dry Creek	22,729	28%
Unnamed Tributary	16,684	42%
WF Blue Creek (ID only)	13,200	18%
Johnson Creek	8,294	8%

Table 32. Excess Solar Load and Percent Reduction to Achieve Loading Capacity for Lightning Creek and Associated Tributaries.

Water Body	Excess Load (kWh/day)	Percent Reduction
Lightning Creek	1,113,682	29%
East Fork drainage	76,772	32%
Rattle Creek	55,743	49%
Mud, Steep, Silvertip, Trapper, etc.	30,649	62%
Spring Creek	30,635	30%
Cascade Creek	28,438	50%
Unnamed tributary	20,152	69%
Fall, Sheep & Bear Creeks	13,970	54%
Moose Creek	12,730	54%
Wellington Creek	12,683	20%
Morris Creek	11,729	32%
Porcupine Creek	9,807	19%
Gordon Creek	8,602	62%
Lunch Creek	7,158	73%
Gem Creek	5,830	66%
Quartz Creek	5,352	27%
Regal Creek	4,183	40%
Deer Creek	3,790	42%

Jpper Lightning Creek



Lower Clark Fork Subbasin

Pathfinder Sites

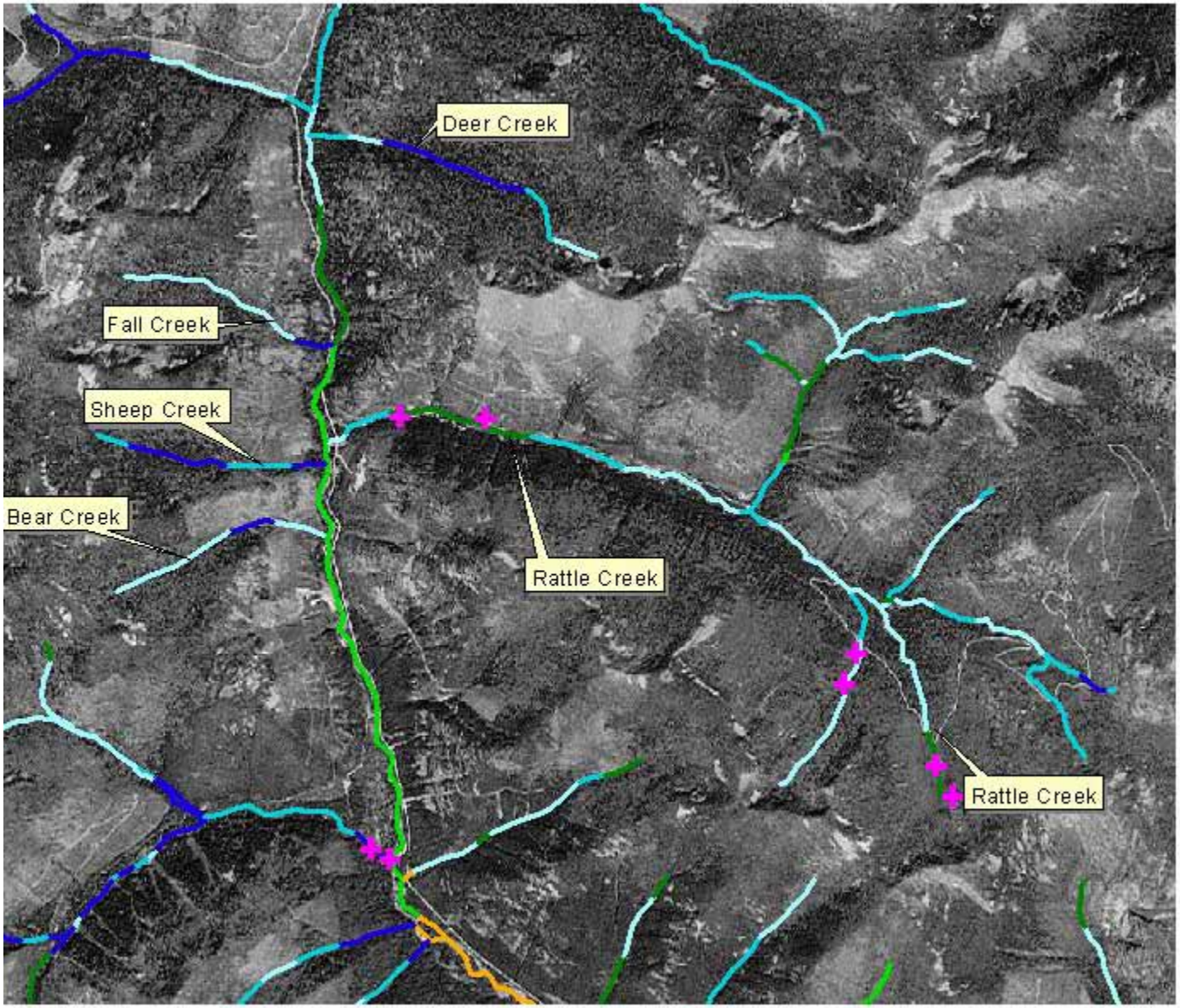
Existing Shade (%)

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90

2 0 2 4 Miles

N
W E
S

Rattle Creek Area



Lower Clark Fork Subbasin

Pathfinder Sites

Existing Shade (%)

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90

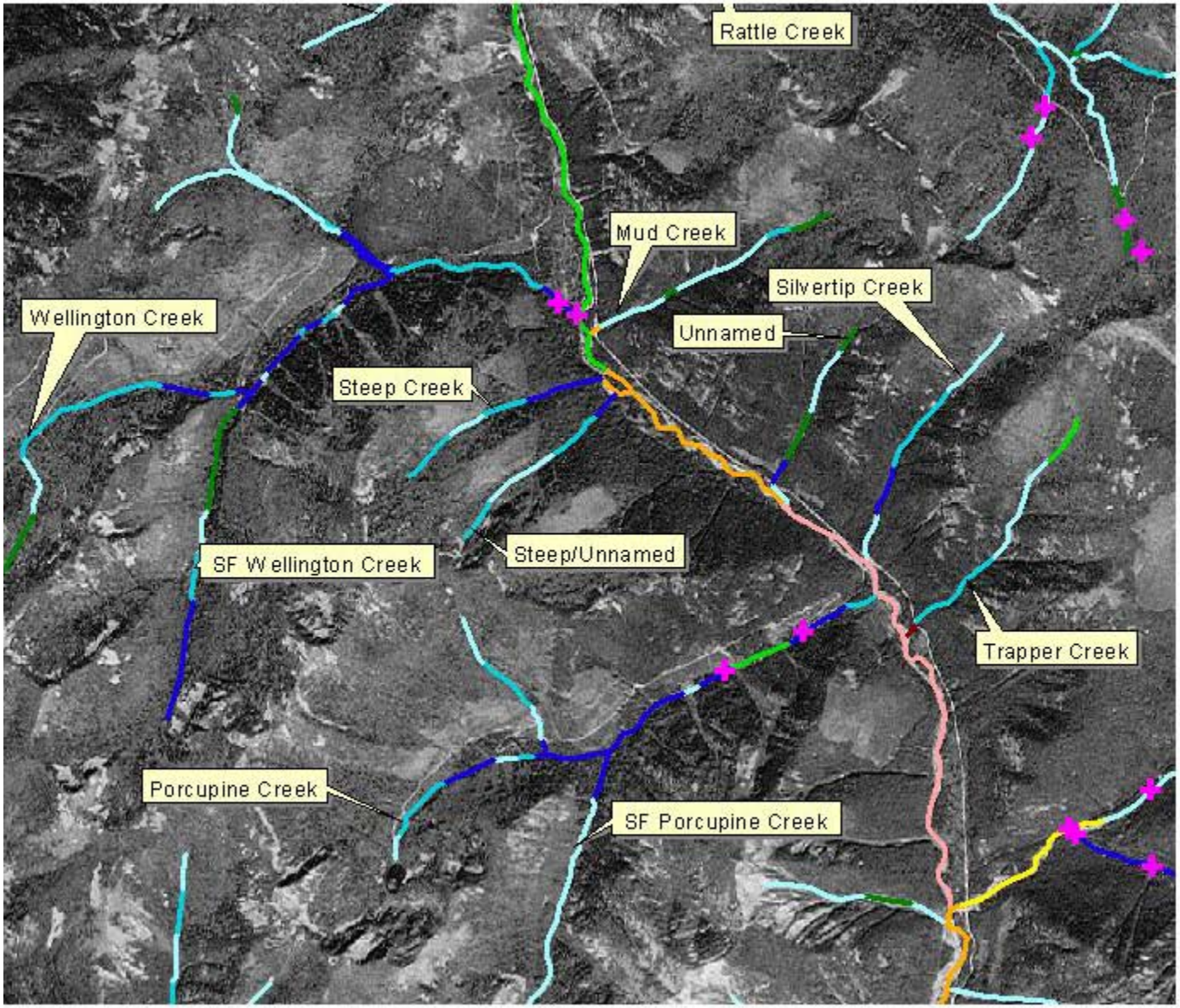
2 0 2 4 Miles

N

W E

S

Wellington/Porcupine Area



Lower Clark Fork Subbasin

Pathfinder Sites

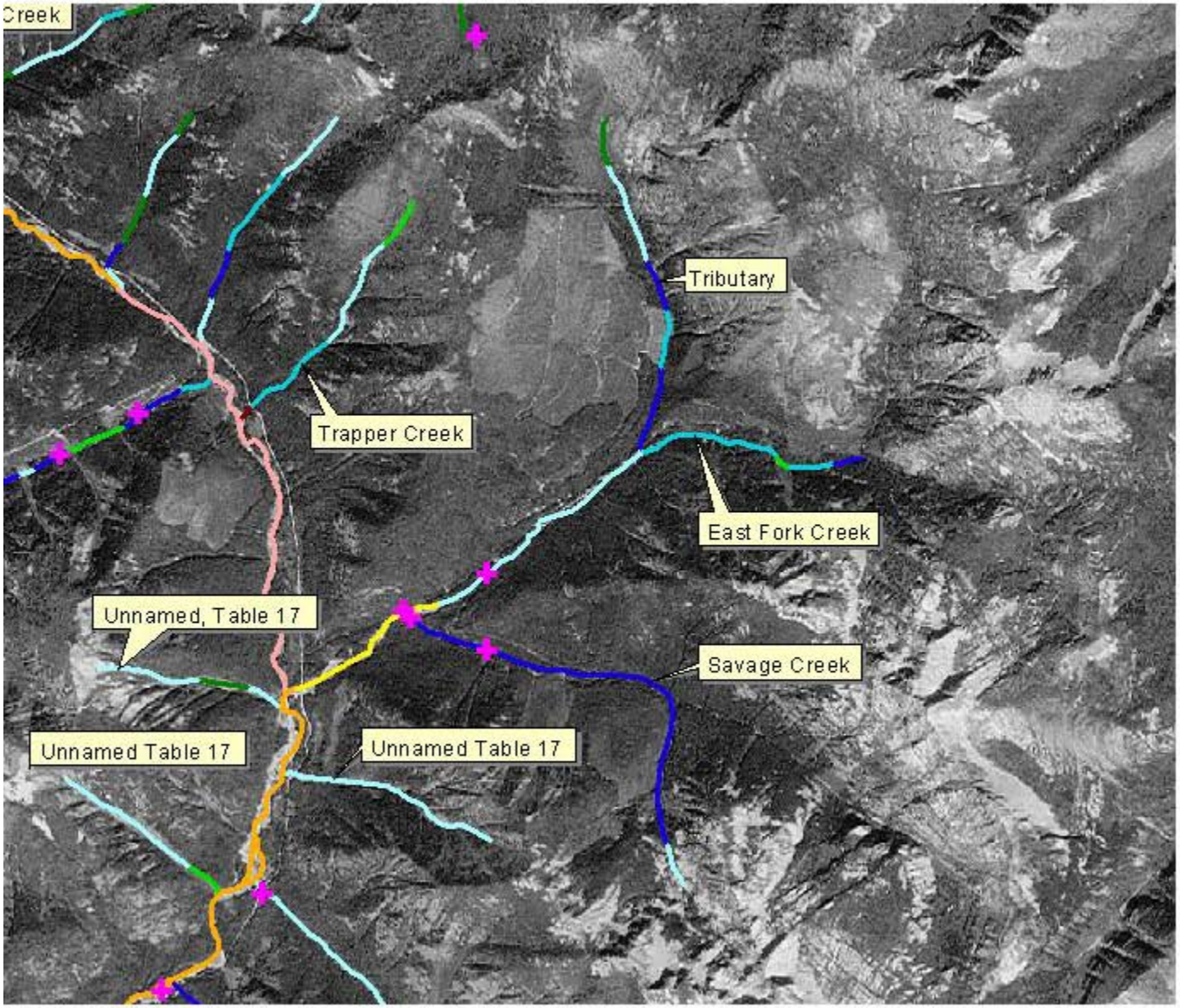
Existing Shade (%)

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90

2 0 2 4 Miles

N
W E
S

East Fork Creek Area



Lower Clark Fork Subbasin

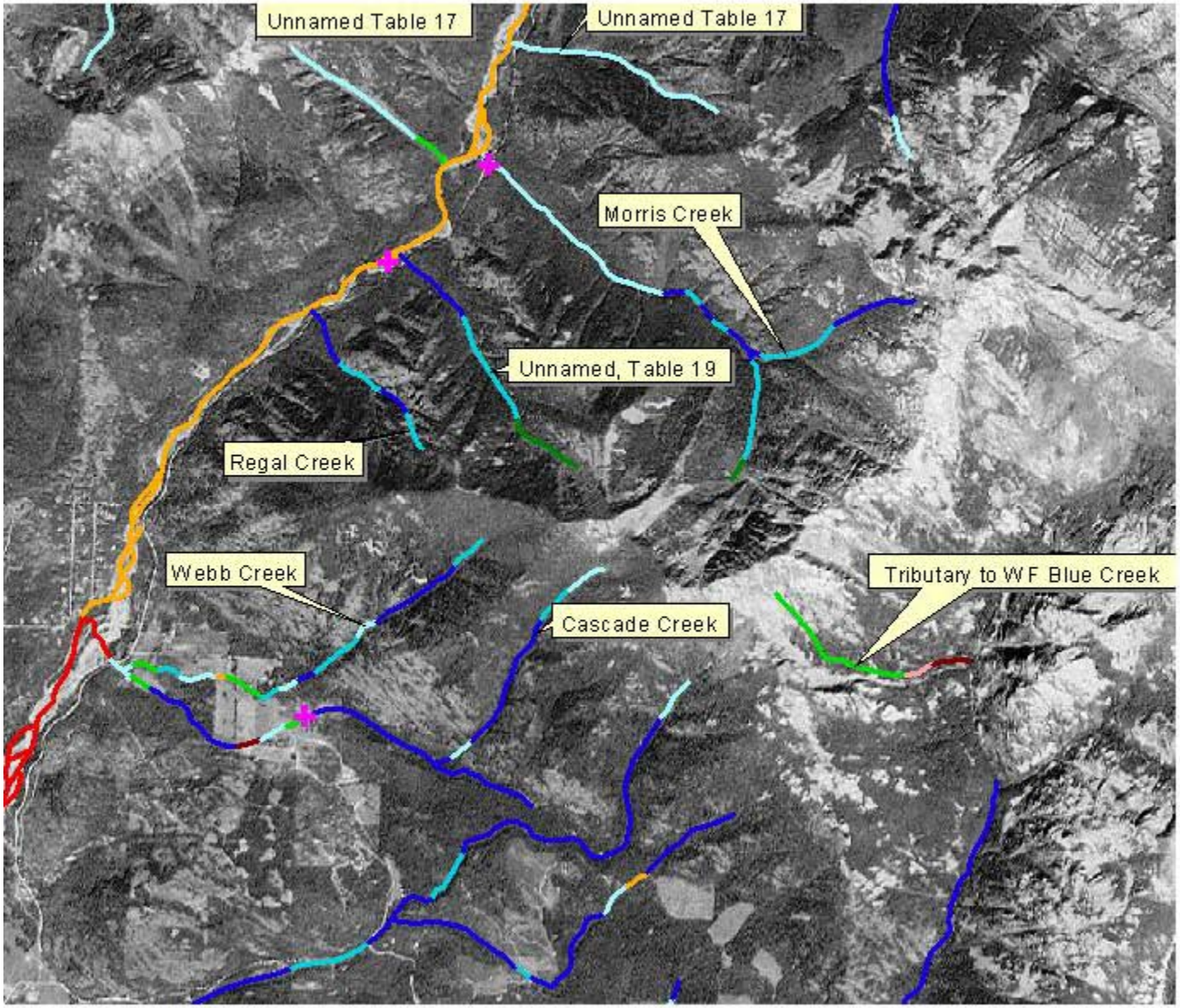
Pathfinder Sites

Existing Shade (%)

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90

N
W
E
S

Morris/Cascade Area



Lower Clark Fork Subbasir

Pathfinder Sites

Existing Shade (%)

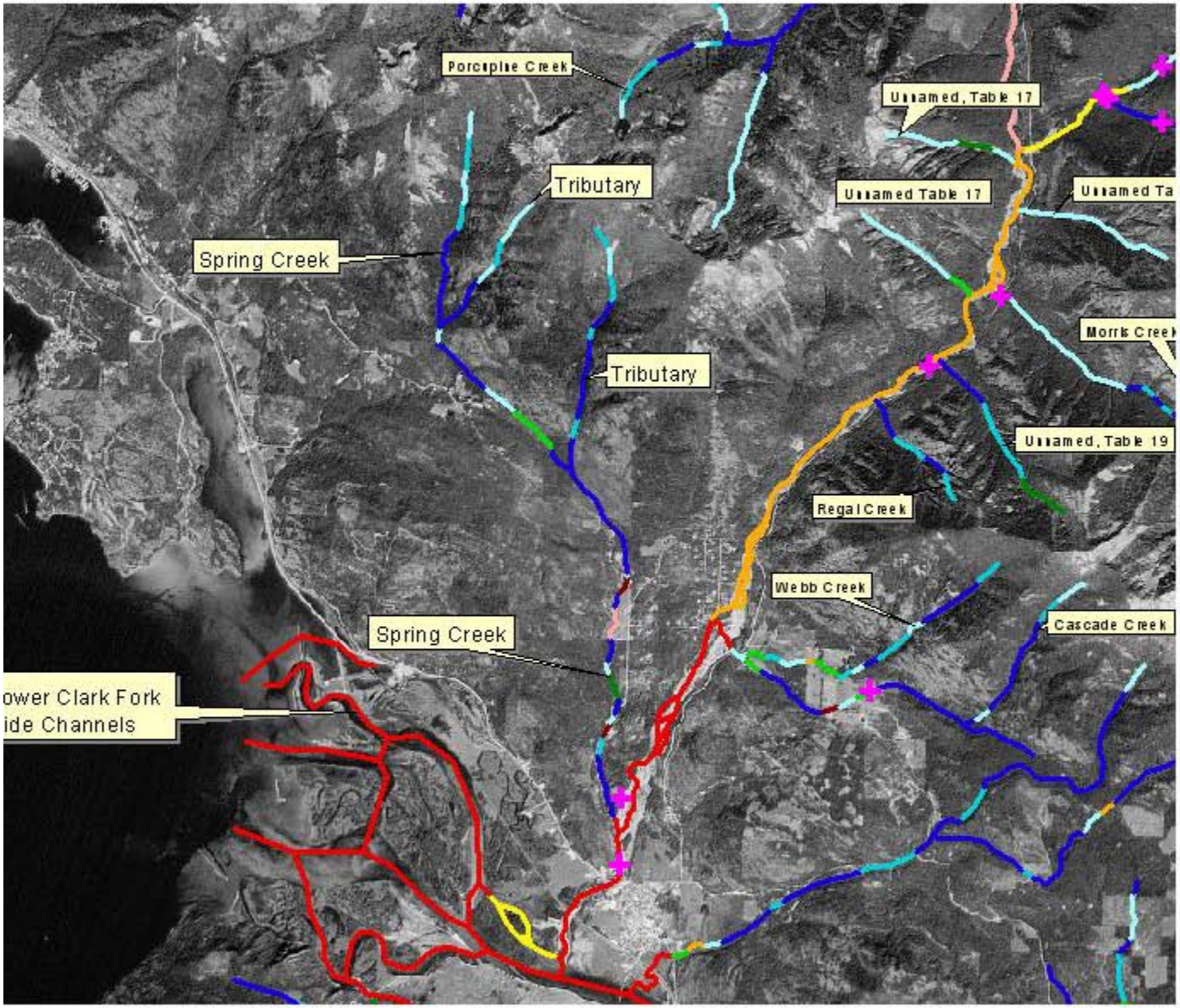
- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90

N

W E

S

Spring Creek Area



Lower Clark Fork Subbasin

Pathfinder Sites

Existing Shade (%)

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90

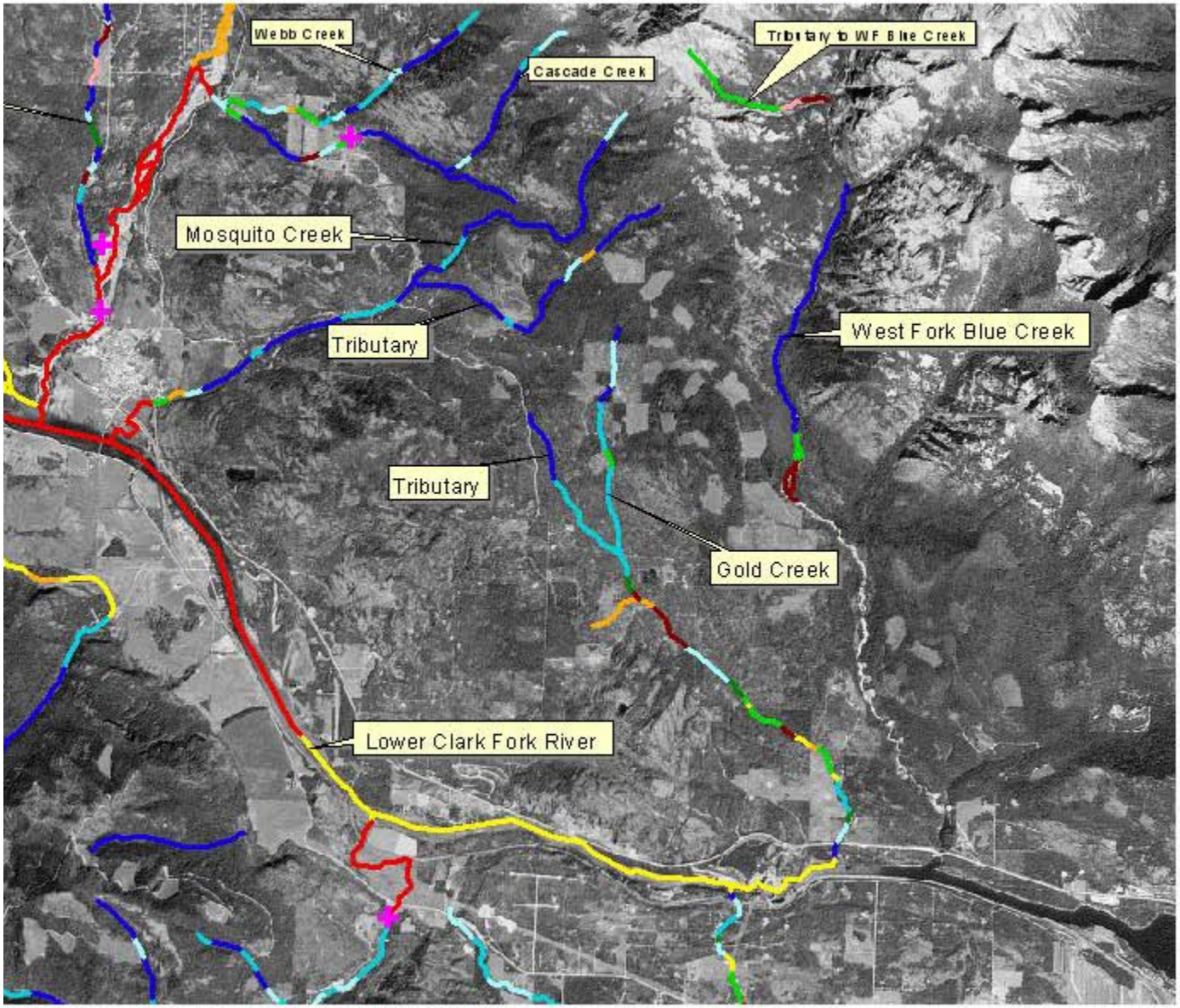
3 0 3 6 Miles

N

W E

S

Mosquito/Gold Area



Lower Clark Fork Subbasin

Pathfinder Sites

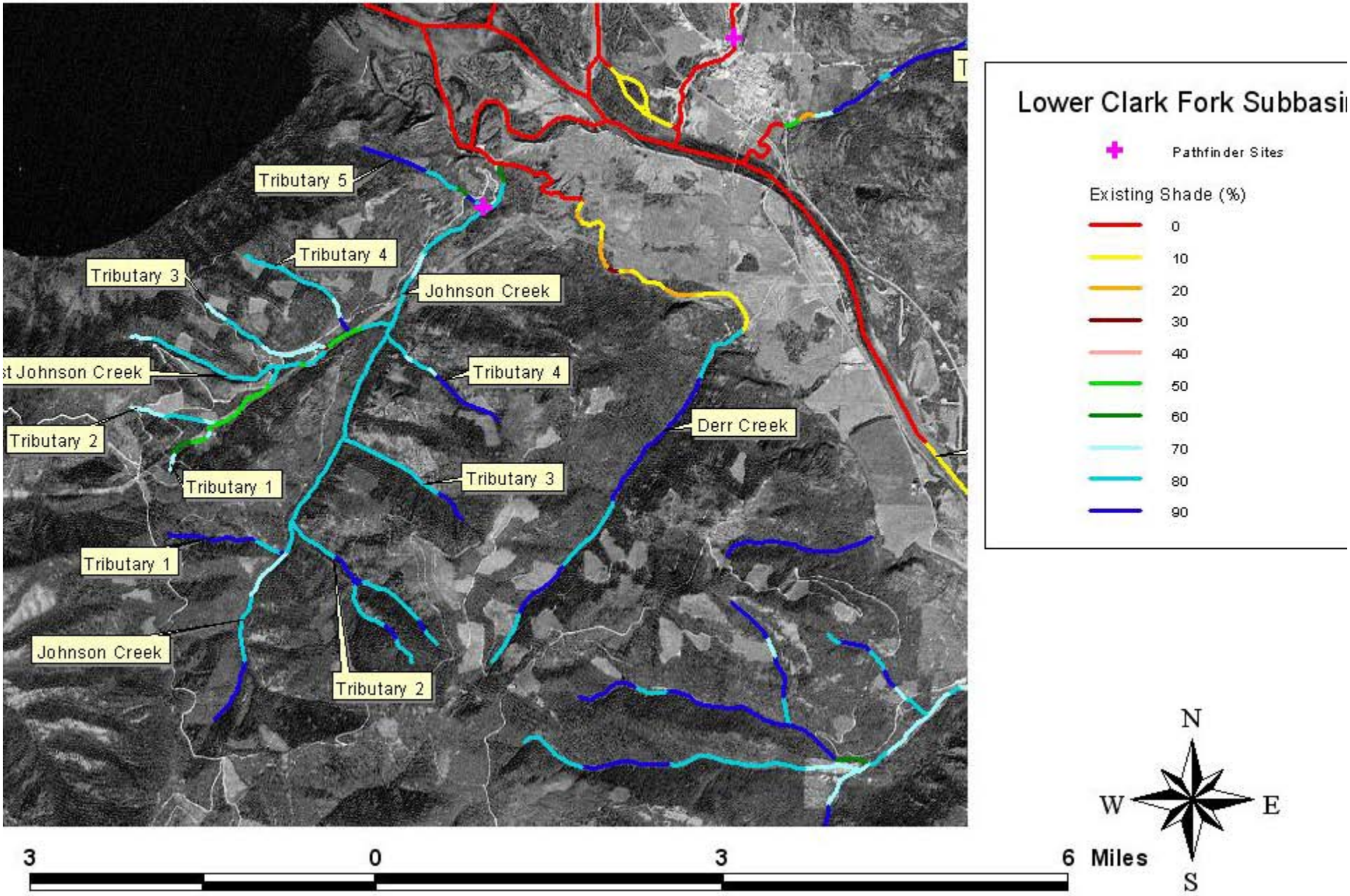
Existing Shade (%)

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90

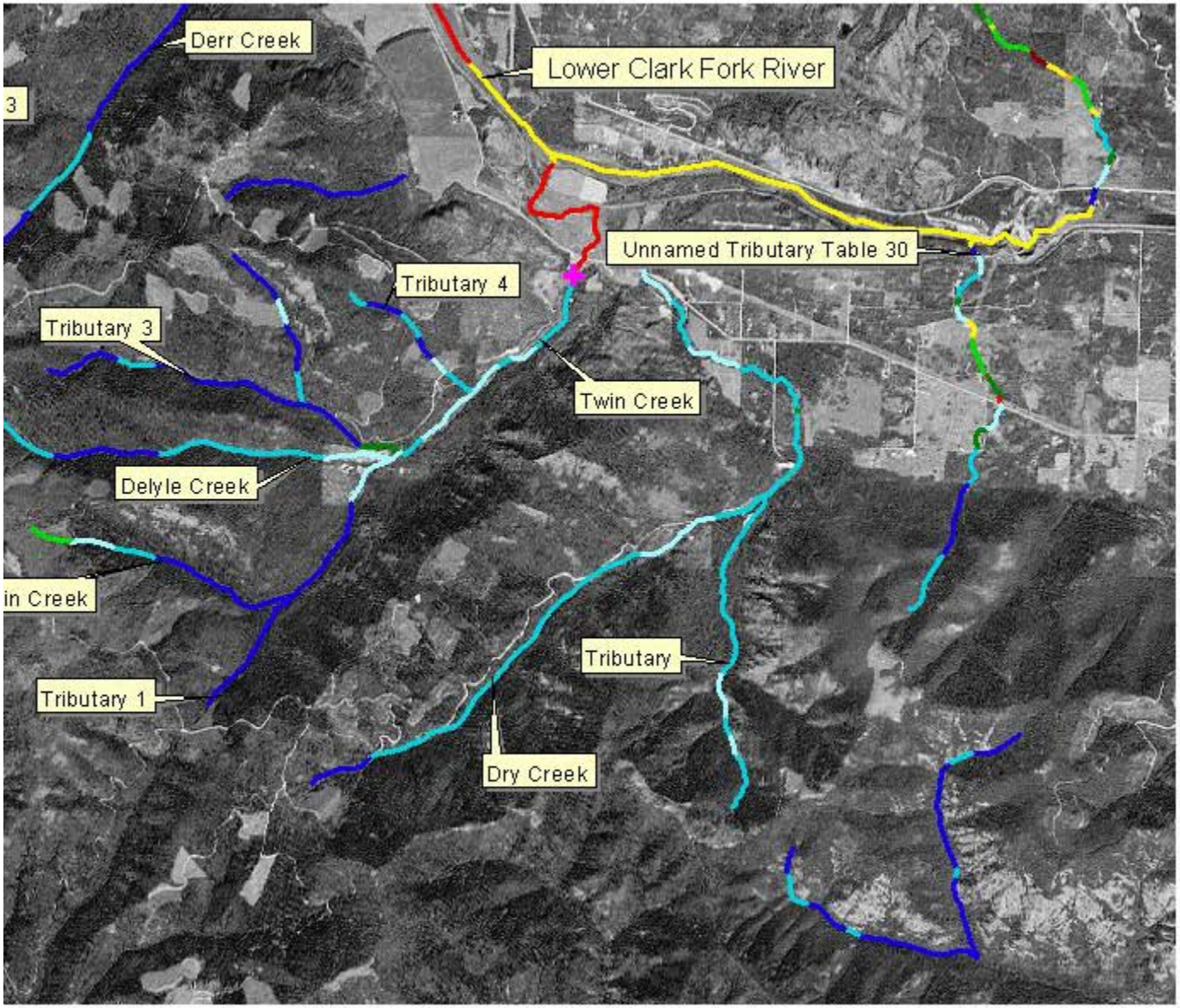
3 0 3 6 Miles

N
W E
S

Johnson/Derr Area



Twin/Dry Area



Lower Clark Fork Subbasin

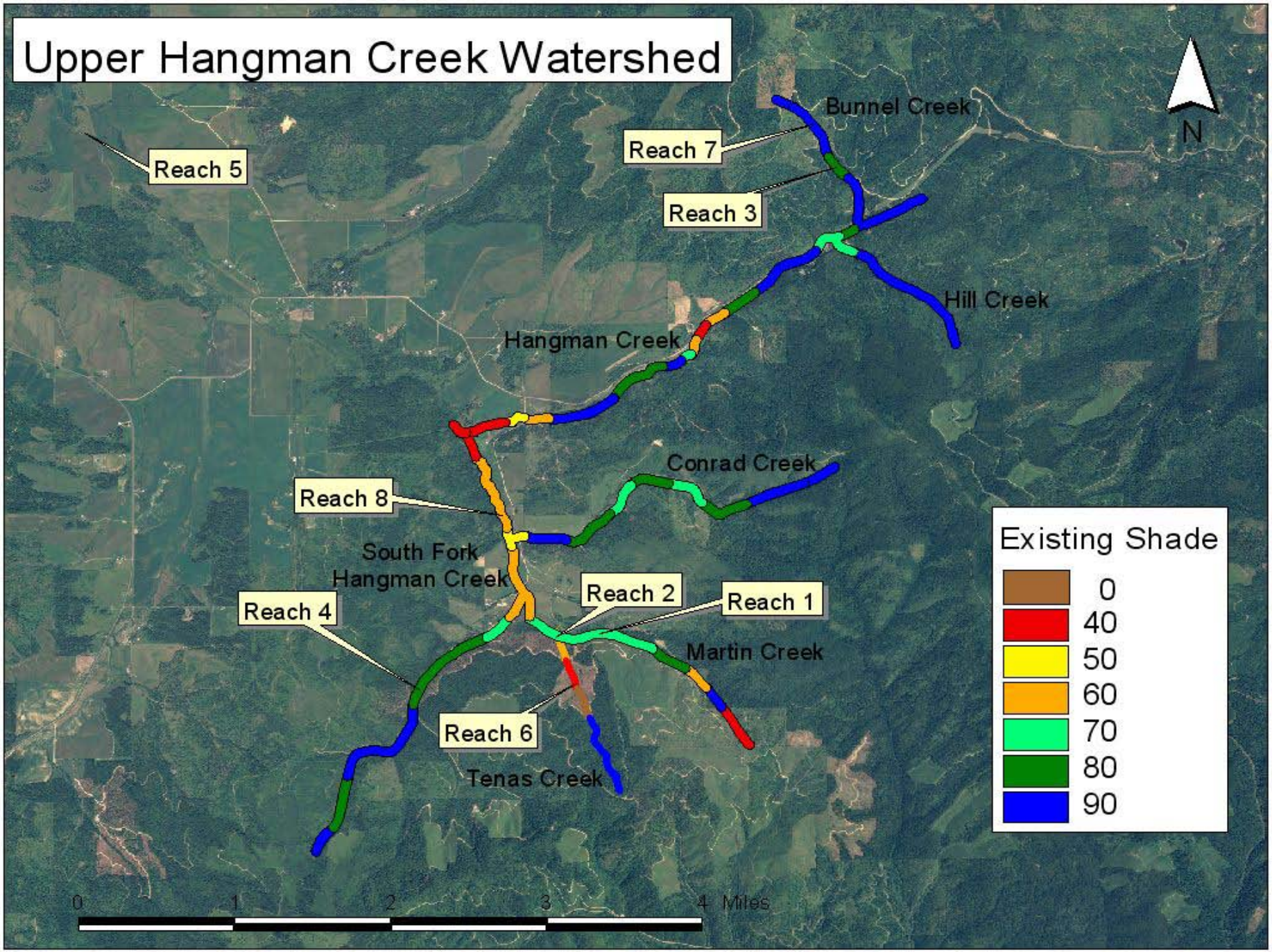
Pathfinder Sites

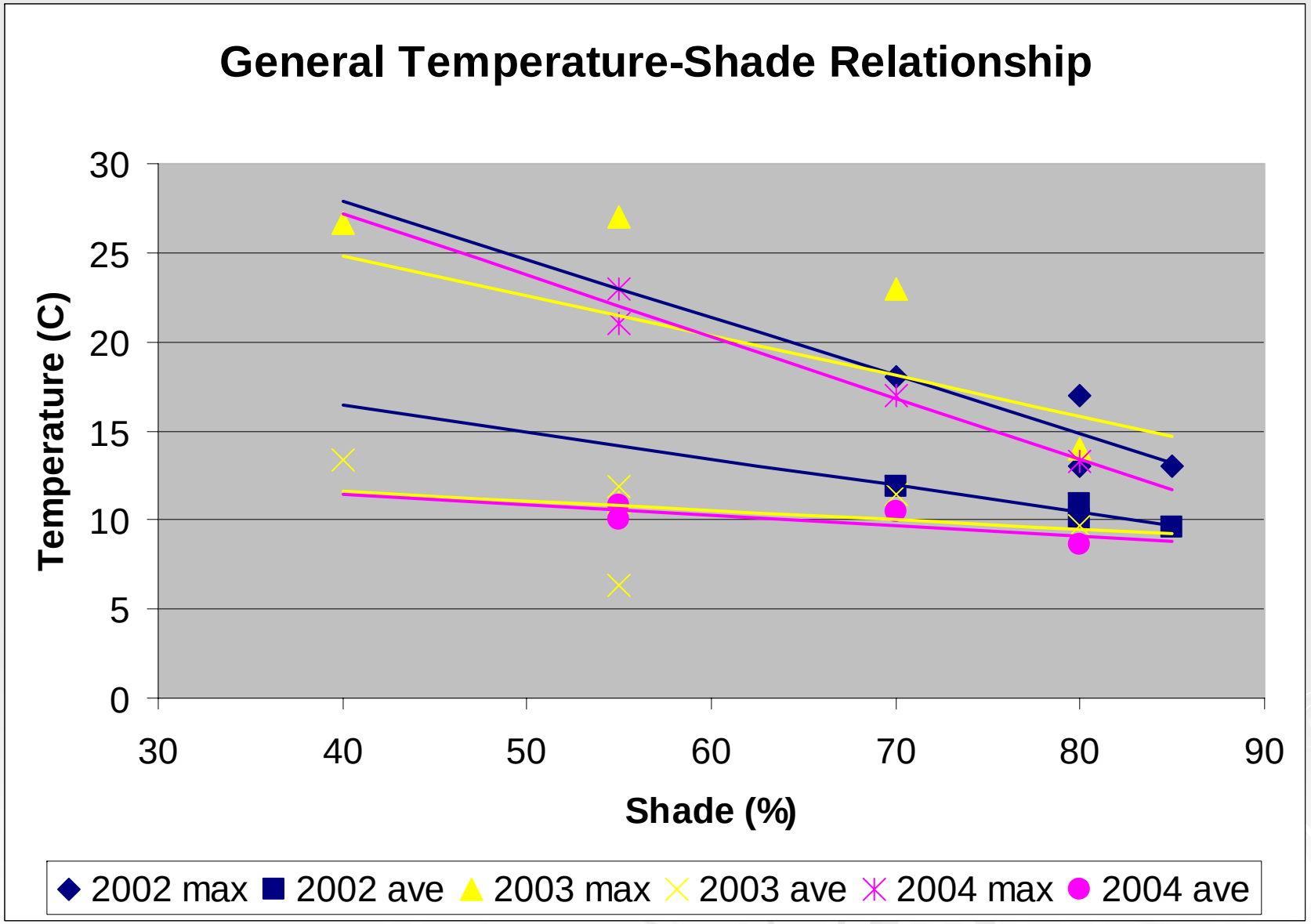
Existing Shade (%)

0
10
20
30
40
50
60
70
80
90

N
W
E
S

3 0 3 6 Miles


Upper Hangman Creek Watershed
N
Bunnel Creek
Reach 7
Reach 5
Reach 3
Hill Creek
Hangman Creek
Conrad Creek
Reach 8
South Fork
Hangman Creek
Reach 2
Reach 1
Reach 4
Martin Creek
Reach 6
Tenas Creek
Existing Shade
0
40
50
60
70
80
90
0
1
2
3
4 Miles


General Temperature-Shade Relationship
Temperature (C)
30
25
20
15
10
5
0
30
40
50
60
70
80
90
Shade (%)
2002 max
2002 ave
2003 max
2003 ave
2004 max
2004 ave