We have:

$$f(t+\delta t,x)=f(t,x)+u\delta t\frac{f(t,x-1)-f(t,x)}{\delta x}$$

As usual, let $C\equiv\frac{u\delta t}{\delta x}$. Now put in a sine wave: $f(t=0,x)=\exp\left(ikx/\delta x\right)$. Plug this in to get $f(\delta t)$:

$$f(\delta t,x)=\exp\left(ikx/\delta x\right)+C\left[\exp\left(ik(x-\delta x)/\delta x\right)-\exp\left(ikx/\delta x\right)\right]$$

factor out the exponential and we have:

$$f(\delta t,x)=\exp\left(ikx/\delta x\right)\left[1+C\exp(-ik)-C\right]$$

We become unstable when the magnitude of the term in square brackets becomes larger than unity. To find the critical k, we need to fine the value of C when that magnitude becomes equal to 1. Split the complex exponential up into sin/cos, so we have:

$$1+C\cos(k)-C-iC\sin(k)$$

which has magnitude

$$(1+C\cos(k)-C)^2+C^2\sin^2(k)$$

$$1+C^2\cos^2(k)+C^2+2C\cos(k)-2C-2C^2\cos(k)+C^2\sin^2(k)$$

This equals 1 for the marginally stable k, which cancels the first one. So we are left with:

$$C^2\cos^2(k)+C^2+2C\cos(k)-2C-2C^2\cos(k)+C^2\sin^2(k)=0$$

Replace $\sin^2(k)$ with $1-\cos^2(k)$:

$$C^2\cos^2(k)+C^2+2C\cos(k)-2C-2C^2\cos(k)+C^2-C^2\cos^2(k)=0$$

Cancel and group like terms together:

$$2C^2+2C\cos(k)-2C-2C^2\cos(k)=0$$

Cancel out a $2C$ and group terms with and wihtout a $\cos(k)$:

$$\cos(k)(1-C)+(C-1)=0$$

$$\cos(k)(1-C)=1-C$$

$$\cos(k)=1$$

Since $\cos(k)$ is always less than or equal to one, there is *no* non-zero value of k for which $C>1$ is stable. Rather, either all scales are stable, or all scales are unstable.